DETECTION OF ENVIRONMENTAL AND URBAN CHANGE USING REMOTE SENSING AND GIS

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ABSTRACT

DETECTION OF ENVIRONMENTAL AND URBAN CHANGE USING REMOTE SENSING AND GIS

This thesis is an example of how land use changes could be detected via high resolution remotely sensed data in GIS environment. In order to perform "change detection" IKONOS satellite images, belonging to 2001 and 2004, have been used. An automated Graphical User Interface (GUI) has been created for detection of environment. Different image enhancement techniques and a fuzzy inference system have been combined in the GUI. The detection results are classified according to some basic levels such as 20, 50 % and 70 %. Additionally, four different change detection algorithms have been applied, which are pixel-based, object based, feature based. These algorithms have been examined according to change detection levels with different image enhancement techniques.

In this context, the primary objective of this thesis is to detect environmental changes regularly using RS and GIS in order to obtain up-to-date information about the urban areas.

The secondary objective of the thesis is to compare the existing techniques with the newly developed GUI for change detection of environmental changes and to discuss the improvement in the overall results using information obtained with different detection techniques.

The hypothesis of this thesis is to develop a new GIS based change detection system. Thus, it would be realized in the GIS environment efficiently and overlaid the results with digitized data in the same environment.

Keywords: Remote Sensing, GIS, change detection, urban data, Izmir

ÖZET

KENTSEL VE ÇEVRESEL DEĞİŞİMİN UZAKTAN ALGILAMA VE COĞRAFİ BİLGİ SİSTEMLERİ İLE SAPTANMASI

Bu tez arazi kullanım değişikliklerinin yüksek çözünürlüklü uydu görüntüleri yardımı ile Coğrafi Bilgi Sistemi (CBS) çerçevesinde nasıl saptandıklarına bir örnektir. Bunu yapabilmek için 2001 ve 2004 yıllarına ait IKONOS uydu görüntüsü kullanılmaktadır. Değişimi saptayabilmek için otomatik bir kullanıcı arayüzü yaratılmıştır. Değişik resim geliştirme teknikleri ile bulanık mantık sistemleri arayüze entegre edilmiştir. Değişim sonuçları % 20,50 ve 70 olarak sınıflanmış ve dört farklı yöntem kullanılmıştır; bunlar, pixel, obje ve karakter tabanlı yöntemlerdir. Bu yöntemler farklı değişim yüzdeleri ile denenmiş ve sonuçları yazılmıştır.

Bu bağlamda, tezin temel amacı uzaktan algılama ve coğrafi bilgi sistemi kullanarak çevresel değişimlerin düzenli aralıklarla takibini sağlamak ve de güncel veri tabanı yaratmaktır.

İkinci amaç ise mevcut değişim belirleme teknikleri ile yeni yaratılan arayüzün karşılaştırılarak, sonuçlar üzerindeki gelişimlerin tartışılmasıdır.

Sonuç olarak tezin amacı yeni bir CBS tabanlı değişim saptama sistemi geliştirmektir. Böylece, sonuçlar CBS ortamına etkin bir şekilde aktarrılıp, mevcut sayısal haritalar ile aynı ortamda çakıştırılabilecektir.

Anahtar Kelimeler: Uzaktan Algılama, CBS, alan değişimi, şehir verisi, Izmir

To my family

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LIST OF ABBREVIATIONS

GIS	Geographical Information Sysyem
RS	Remote Sensing
GUI	Graphical Unser Interface
IT	Information Technologies

CHAPTER 1

INTRODUCTION

1.1. Background

A first step towards dealing with important environmental issues is to produce relevant and up-to-date spatial information which may provide a better understanding of the problems and form the basis for the identification of suitable strategies for sustainable development. At this point, Remote Sensing (RS) technology provides data from which updated land cover information can be extracted efficiently and cheaply. Thus, land use change detection has become a major application of remote sensing data. *"The essence of such monitoring is to measure changes over time (e.g. a polygon changes from a category to another) and space (e.g. an island migrates from one location to another)"* (Muchoney and Haack 1994, 10).

On the other hand, Geographical Information Systems (GIS) have developed since the 1960s for land use applications and military purposes. These systems evolved to display and manipulate both vector and raster data and the main characteristic of GIS were to integrate graphical and non-graphical data in order to make spatial analysis and queries.

However, although up to recent years these two technologies (RS and GIS) have been used independently from each other or only in one direction (either GIS benefited from RS or vice versa), with the improvements in computer technology, many researchers have used GIS and RS techniques to enhance each other's operations (Thomson and Hardin 2000).

Although there have been many applications in integration of RS and GIS technologies, in this thesis, integration method will be used for land cover/use change detection analysis of the case area. This thesis deals with the extraction environmental changes in urban areas using very high resolution IKONOS satellite images. In the 21st centruy, accurate information is needed about these environmental changes for updating GIS and their databases. The updated GIS-based information is used for important applications such as city planning, industrial planning, transportation planning, and disaster management as so on.

This thesis is important to see the difference where the land use change is legal or illegal for local governments. Hurskainen and Pellikka (2004) have defined that illegal housing settlements are settlements whereby persons, or squatters, assert land rights to or occupy for exploitation land which is not registered in their names, or government land, or land legally owned by other individuals.

Especially to monitor illegal housing determination is a very difficult task for local governments. Additionally, there were not legal effective regulations to control for them. Local governments also did not want to impose any restrictive policies on illegal housing because they have become important voter in every local and national election. However, "New Criminal Law", 5237 numbered, accepted in 2004, has restricted objects for illegal housing. It has been added as Appendix at the end of the thesis. According to the heading 184, illegal housing is definitely recognized as a problem which has to be solved by local governments.

Urban growth is an important global environmental issue that affects both developed and less developed countries. Rural-urban migration is the major driving force behind urbanization. Urban areas are dynamic environments in terms of their land-use, so regular and up-to-date information on urban change, especially growth, is required. In particular, this information is needed for strategic planning purposes, environmental impact assessment, and for the appropriate allocation of services and infrastructure within cities. Effective planning policy and appropriate resource management can only be accomplished through informed decisions, but even basic information on urban extent and change is often outdated, inaccurate or simply does not exist (Grey, et al. 2003). The cities growing spatially with industrialization cause to create their own sub-regions; this increased the in-migration to urban areas. Because of the overlapping of fast urbanization and inadequate planning policies, illegal housing became an alternative to planned housing.

The problem of illegal housing and uncontrolled urban development has always been on the agenda for Turkey for the last 50 years and many different solutions have been proposed from different points of view. However, the problem still remains unsolved and consequently increasing the number of people has settled, especially after the 1980s, in those areas of cities where transportation and land acquisition is easy (Keleş 1996).

The main characteristic of such settlements is that they are usually located within or near the ecologically valuable areas where drinking water is available, transportation cost is minimum and cost of services of infrastructure is low. An important aspect of illegal settlements which supports and makes the problem greater is that there are many institutions responsible plan, manage and protect these areas and these institutions act independently from each other.

As a result, it can be concluded that this confusion in authority open channels for the construction of illegal houses. The problem of authority has three dimensions: the fist is the lack of cooperation between institutions; that is, there are central and local governments both of which are responsible for the same area. The confusion in determination of the spatial boundaries of their authority causes dilemmas for intervention to the problem of illegal settlements. These institutions gather data independently from each other and try to intervene, again, independently from each other.

Secondly, many political parties have used their powers to regularize these settlements in exchange of votes in elections. Therefore, especially in the 1980s, “reconstruction amnesties” have been on the agenda for Turkey and most of the governments allowed such settlements, their numbers and size have increased.

Lastly, there is “time” problem. The institutions can not intervene in these areas in time, because they grow so rapidly and the existing technologies are not sufficient to allow them to make such interventions in time. The land use maps and other data about such areas are not updated regularly. Therefore, new methods should be used to monitor such changes.

In Turkey, especially the local governments want to detect environmental changes on time. Therefore, they bought different satellite images, or software such as Google Earth. However, because of lack of personnel and knowledge, these images are used to be observed as visually. There are many projects such as in İstanbul, Kocaeli and so on. “Milli Emlak Genel Müdürlüğü” tries to control illegal settlements via Google Earth and the internet. Additionally, they have a plan for establishing an automation system in 81 provinces and 860 districts in Turkey (Journal of Zaman, 2006). Another example is Kocaeli KUTAS project applied by Greater Municipality of Kocaeli. They have bought IKONOS images belonging to January 2006, then will digitize as-is maps, lastly perform field survey. They are planning to buy new satellite images every six months. It is called as “imar takip projesi” (Kocaeli Gazetesi 2006). The other example is Greater Municipality of İzmir, 2005 IKONOS image has been bought in order to monitor the city; however, it has not been started, yet. There are many reasons for this, firstly Municipality has a limited financial for buying images, so, they have only 2005 image. Additionally, there is not enough knowledge and specialized staff to do it. These examples show us that to detect environmental change will be an unavoidable process for both the local governments and the federal government in the near future.

Moreover, in Turkey the Prime Ministry State Planning Organization has started to state with the Eighth Five-Year Development Plan 2001-2005 and continues with the Ninth Development Plan 2007-2013 that "*A database management system based on geographic information system related to housing and urbanization will be created*"(Tarhan 2002, Devlet Planlama Teşkilatı 2006). The existing studies and the federal government decisions show that, the local governments have to be used information technologies (RS and GIS) for urbanization.

RS & GIS based change detection application has some problems in Turkey. Some of them are based on data variation used in local and central governments. Another reason is bureaucratic problems. Why this thesis is needed by the local governments is categorized as follows.

Each municipality has not enough financial support to buy software and data. Therefore, a GIS-based Graphical User Interface (GUI) has been created. In this way, environmental change detection could have been performed just using MapInfo software. There is no need to be used different software for image processing, RS and GIS parts.

There is a specialized staff problem in the local and the federal governments. Existing staff has limited or no background knowledge about complex image processing algorithms, RS and GIS software usage. The defaults occurred as the case result and will be mentioned in the chapter 5, could be helpful for these staff.

There may be data loss or mistakes while converting data from RS to GIS software. Thus, performing the same process again is loss of time. Moreover, if the case area is huge, some mistaken points could be overlooked. That may cause the result of the change detection. In the thesis, the created GUI runs into MapInfo software, therefore, the losses will be minimized.

There is a coordinate disharmony problem between the raster and vector data. Additionally, the maps have the same projection but different datum, also cause the coordinate disharmony. Thus, GIS-based data coordinates usage is a solution in the thesis.

The thesis contains the detection of environmental changes and overlay them into GIS environment. This makes performing different analysis and queries possible. In order to do this, remotely sensed data have analyzed with different image processing algorithms, then detected changes, transferred difference pixel coordinates and overlaid with digital data.

The case area is in İzmir, specifically Limontepe, Cennetçeşme, Salih Omurtak and Yüzbaşı Şerafettin Districts shown in Figure 1. The red circle in the figure 1 shows the specific location of the case area. It is located in southern part of İzmir and approximately covering 30 km^2. The case area is in Konak because; Konak is the biggest district in terms of settlement density and also the center of İzmir. On the other hand, archive satellite images obtained from firms effected the site selection. For example, a cloudy image cannot be used for change detection process. This area has the clearest scene among available the archive images of the other districts.

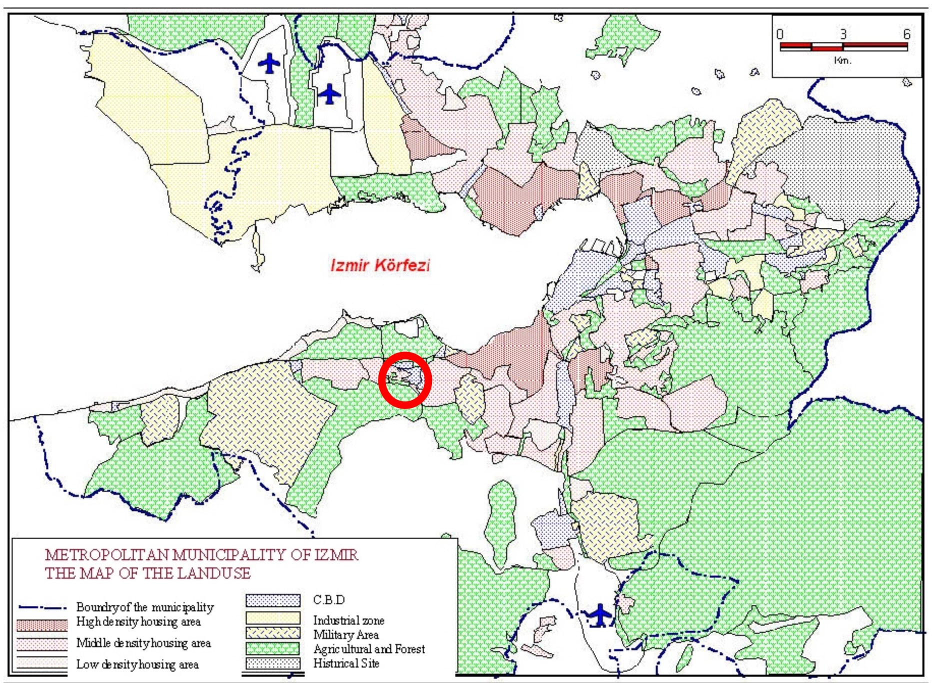


Figure 1.1. The case area of the study.

Because of very high resolution, panchromatic scene (PAN) (1 meter) will be used for the detection of differences between two dates. After detecting features, multi spectral scene will help to increase and calibrate the detection accuracy. Next, specific object detection process will be performed than; a pixel based study will be planned if required.

In order to perform these steps; ERDAS will be used as remote sensing; MapInfo will also used as GIS software. Additionally, graphical user interfaces (GUI) will be created with Delphi and MapBasic. Firstly, change detection process requires remote sensing based studies. However, sometimes atmospheric effects or weather conditions (cloud effect etc.) can be misleading. Therefore, a field survey will be done after change detection to control the results and to get the highest accuracy rate for the study.

1.2. The Research Objectives and Hypothesis

The primary objective of this thesis is to detect environmental changes regularly using RS and GIS in order to obtain up-to-date information about the urban areas. The primary objective can be subdivided into following tasks:

a. implementation of existing methods;
b. studying limitations and advantages of these existing methods,
c. development of a new automated graphical user interface (GUI) for detecting environmental changes, and
d. transferring them into GIS environment in order to update urban information.

The secondary objective of the thesis is to compare the existing techniques with the newly developed GUI for change detection of environmental changes and to discuss the improvement in the overall results using information obtained with different detection techniques.

At the end of the study it will be hoped to reach the following conclusions:

- Informing local governments periodically,
- Getting an effective local government management,
- Obtaining urban growth change detection via legal jurisdiction
- Getting perception a healthy urban life.

The hypothesis of this thesis is to develop a new GIS based change detection system. Thus, it would be realized in the GIS environment efficiently and overlaid the results with digitized data in the same environment.

1.3. Thesis Organization

The organization of this thesis is as follows:

Chapter 1 introduces background of the thesis, additionally; the hypothesis and research objectives have been defined.

Chapter 2 describes urban planning and information technologies integration. RS and GIS relationship with urban planning will be discussed separately. Additionally, RS and GIS integration for change detection analysis is another discussion point for this chapter.

Chapter 3 examines "the change detection" concept. The techniques and application examples in the World are discussed. In this chapter, traditional change detection methods will be performed the case area. The results obtained using the traditional methods are presented.

Chapter 4 implements the thesis methodology, algorithms and fuzzy inference relations. The methodology contains four different methods such as pixel by pixel, total bands difference, equal matrix and not equal matrix. Algorithms are composed of spectral, spatial and radiometric image enhancement algorithms. Fuzzy inference describes the relationship of the application.

Chapter 5 presents the detection of environmental changes on the case area. This chapter contains characteristics, components and system realization of the thesis. Additionally, the system realization part is divided according to the methods such as high percentage case, middle percentage case and low percentage case. After the comparison of the change detection performed by different percentage and methods, transferring to GIS part is mentioned.

Chapter 6 represents briefly summarize the research work and concludes. The recommendations and need of future work for the improvement of efficiency and reliability of the used methods are suggested.

Finally, appendix contains the heading 184 of the "New Criminal Law" of Turkey, 5237 numbered, accepted in 2004.

CHAPTER 2

CHANGE DETECTION

"Urban areas represent a complex association of population concentrations, intensive economic activities, and diverse lifestyles. They are a microcosm of human activity, and frequently experience rapid changes that need to be monitored and understood" (Lindgren 1974, 233). Today changes made on cities are more extensive and take place more rapidly than ever before. Not only the city centers but also the urban fringes are under pressure because of their environmental significance such as forestry areas, water resources etc.

Avery (1997) has defined "urban planning" as the orderly regulation of the physical facilities of a city to meet the changing economic and social needs of a community, including the development plans for future industrial expansion. So it can easily be recognized that the information about current and accurate land use in urban areas is very important for the management and planning of these areas.

Therefore, urban planners need a reliable mechanism to detect and monitor urban land use changes in time. Remote sensing provides a variable source of data from which update land cover information can be extracted efficiently. "*Remotely sensed data can be used as a tool to detect, monitor and evaluate changes in ecosystems to develop management strategies for ecosystem resources*." (Mouat, Mahin and Lancaster 1993, 39).

Land use change detection is a very important application or remote sensing data. Therefore this chapter provides an overview of the available methods for change detection of urban areas. The combination of knowledge of from different areas of study such as: remote sensing, GIS, urban planning, artificial intelligence, is required to solve different issues raised by the process of change detection. This overview presents theoretical background and different challenges inspiring this research.

2.1. Theoretical Background

Since it is dealed with image based change detection, it is necessary to understand the concepts of a digital image and those affecting the process of change detection.

Resolution is an important concept of digital images to define their characteristics. They can be defined by four types of resolutions called as spatial, spectral, radiometric and temporal (Lillesand, et al. 2004). They control the ability to interpret the image data.

The spatial resolution describes the smallest visible ground unit discernible on an image (Solway Firth Coastal Information System 2007).

The spectral resolution is that the ability to distinguish two spectral features closes to one another; the smallest difference in wavelength between two such distinguished features (Cassini-UVIS Mission to Saturn and Titan 2007).

The radiometric resolution defines the actual information content in an image. Every time an image is obtained on film or by a sensor, its sensitivity to the magnitude of the electromagnetic energy determines the radiometric resolution. The radiometric resolution of an image describes its ability to discriminate very slight differences in energy. The finer the radiometric resolution of a sensor the more sensitive it is to detecting small differences in reflected or emitted energy (Canada Centre of Remote Sensing 2007).

The temporal resolution is defined as a measure of how frequently the remote sensing sensor will pass over the exact same location. It is also called a revisit time. The lower this value becomes the more often an image of the same spot can be acquired by the same device (GIS Glossary 2007).

Table 2.1 shows the some selected satellites and their characteristics. In order to make change detection process at building scale, high resolution satellite images are required. Because of this, IKONOS is chosen as an image resource. As shown in Table, it has 1 meter resolution for PAN (panchromatic) and 4 meters resolutions for MS (Multi Spectral). The images belong to 2001 and 2004 years. The IKONOS satellite has been in use since 1999, therefore achieve images are only available for the selected study area was taken in 2001 and 2004

.

Table 2.1. Satellites characteristics
(Source: Nik İnşaat Ticaret Limited Şirketi 2007)

Satellite	Operator	Launch and date	Sensor	Spatial res. (m)	Radiometric Res. (bit)	Temporal Res. (day)
IKONOS-2	Space Imaging	1999	SAR PAN MULTI	18 1 4	3 11 11	3.5-5
Landsat1/2/3	NASA-EOSAT	1972/75/78 1978/82/83	MS	80	8	18
Landsat4/5	Space Imaging	1982/84, 1987/-	TM TM TM	30 30 120	8 8 8	16 16 16
Landsat7	NASA	1999	PAN ETM ETM	15 30 60	8 8 8	16 16 16
Orbview 3	Orbimage	2003	PAN MULTI	1 4	8 8	>3 >33
Radarsat1	CSA	1995	SAR	8-100		3-35 (24)
Radarsat2	CSA-MDA	2003	SAR	3-100		3-35 (24)
Spot 1/2/3	CNES/SPOT	1986/90/93 -/-/96	HRV-PAN PAN	10 20	8 8	1-4(26) 1-4(26)
Spot 4	CNES/SPOT	1998	HRV-PAN HRVIR HRVIR VEGETATION	10 20 20 1000	8 8 8 4/8	1-4(26) 1-4(26) 1-4(26) 1
Spot 5	CNES/SPOT	2002	HRS-PAN HRG-PAN HRG HRG VEGETATION	10 2,5-5 10 20 1000	8 8 8 8 4/8	1-4(26) 1-4(26) 1-4(26) 1-4(26) 1
Quickbird 2	Digital Globe	2001	PAN MULTI	0,61-0,73 2,5-2,9	11 11	3.5 3.5

2.2. Change Detection Techniques

Satellites provide us with the digital images of the same geographic areas within a pre-defined interval. This makes possible monitoring and detecting urban and environmental changes among different times.

Tardie and Congalton (2005) have defined "Change Detection" as a technique used in remote sensing to determine the changes in a particular object of a study between two or more time periods. According to them, this process provides quantitative analysis of the spatial distribution in the area of interest; because of this, change detection is a useful and an important process for urban and environmental monitoring.

Time series of remote sensing data can be created to monitor changes in landscapes at local to regional scales. Classic land-cover change detection techniques are based on the comparison of sequential land cover maps derived from remote sensing data or other sources for the same area. For every sampling unit of the maps, the land cover categories at the two dates are compared. Therefore, the images should be interpreted well. A sound understanding provides us with the right parameters in order to get a reliable change detection process. These parameters are related the satellite resolutions such as temporal, spectral, spatial and radiometric resolutions. The comparison of successive maps fails to detect subtle changes within broad land-cover classes. Thus, rather than detecting changes on the basis of land-cover categories, change detection is better performed on the basis of the continuous variables defining these categories, whether these are reflectance values measured by a satellite sensor or biophysical attributes derived by model inversion.

Commonly used change detection techniques are as follows (Gupta 2007)

- Image differencing,
- Image ratioing,
- Image regression,
- Vegatation index differencing
- Change vector analysis
- Principal components analysis,
- Multidate classification,
- Post-classification comparison and visual interpretation.

2.2.1. Image Differencing

Image differencing method is based on the arithmetic operation of subtraction. The change image is obtained by subtracting the brightness values of each pixel pair in the same bands of the images taken at different dates. The required value in the change image is calculated as (Fung and LeDrew 1988, Morain and Baros 1996):

$$P_{ij(change)} = P_{ij(1)} - P_{ij(2)} + C$$

where

$P_{ij(change)}$: Brightness value of the pixel in the i^{th} row, j^{th} column in the change image,

$P_{ij(1)}$: Brightness value of the pixel in the i^{th} row, j^{th} column in the first date image,

$P_{ij(2)}$: Brightness value of the pixel in the i^{th} row, j^{th} column in the second date image,

C : The constant to make all the resultant values to have a (+) sign because the subtraction result ranges between (-255) and (255).

2.2.2. Image Ratioing

Image ratioing is quite similar to image differencing. It is also an arithmetic operation in which every pixel pair is ratioed instead of subtraction. The mathematical formula of image rationing is as follows (Singh 1989):

$$P_{ij(change)} = P_{ij(1)} / P_{ij(2)}$$

where

$P_{ij(change)}$: Brightness value of the pixel in the i^{th} row, j^{th} column in the change image,

$P_{ij(1)}$: Brightness value of the pixel in the i^{th} row, j^{th} column in the first date image,

$P_{ij(2)}$: Brightness value of the pixel in the i^{th} row, j^{th} column in the second date image.

In the resultant image, unchanged pixels have a value equal to or very close to 1. Similar to differencing, a thresholding is necessary to separate the changed and unchanged areas.

2.2.3. Image Regression

In image regression method, pixels of the time 1 are assumed to be a linear function of the pixels of time 2. Therefore, the brightness values of time 1 can be regressed against the brightness values of time 2 using a least squares regression (Mouat, et al. 1993). Gupta (2007) has considered the image regression is differences in mean and variance between pixel values from two dates.

$$P_{ij(change)} = P^{\wedge}_{ij(2)} - P_{ij(1)}$$

where

$P_{ij(change)}$: Brightness value of the pixel in the i^{th} row, j^{th} column in the change image,

$P_{ij(1)}$: Brightness value of the pixel in the i^{th} row, j^{th} column in the first date image,

$P^{\wedge}_{ij(2)}$: The predicted value of the pixel in the i^{th} row, j^{th} column obtained through regression line for the second date.

A thresholding technique is applied to the resultant image to detect areas of change.

2.2.4. Vegetation Index Differencing

In this technique, the change image is obtained by taking the differences of the vegetation indices computed for multiple dates of images with using this technique. The normalized difference vegetation index (NDVI) is computed for each image as (Mouat, et al. 1993, Wilsona and Sader 2002):

$$NDVI = \left((NIR - RED)/(NIR + RED)\right)$$

where

NTR is the near-infrared band response and

RED is the red band response for a given pixel.

The difference between the vegetation indices computed separately for each image gives a measure of the vegetation change in the area.

2.2.5. Vector Analysis

"With the vector analysis method any number of input bands may be employed from each acquisition date. Once the corresponding input bands from each acquisition are geometrically registered and radiometrically normalized, CVA may be implemented. The CVA algorithm produces two `channels' of output change information: (1) change vector direction; and (2) multispectral change magnitude (computation and representation of these change vector components is described in greater detail below). Changed areas may then be described in these terms, as well as by other attributes such as geographic location and area. In addition, the capability to display some or all of the change information output from CVA in the context of a background image has been found to be useful" (Johnson and Kasischke 1998, 413)

2.2.6. Principal Components Analysis

"Principal Component Analysis (PCA) is a procedure which transforms the data such that new orthonormal axes are aligned with the directions of maximum variability in the data. Essentially, a set of correlated variables are transformed into a set of uncorrelated variables (principal components) which are ordered by decreasing variability"(Gomez, et al. 2007, 1014).

For two multispectral images, the method is to compute their difference and apply PCA to a matrix of values taken from all the bands of the difference image. Then by reconstructing the difference image using only the first PCA component it is assumed that the result will exhibit the most significant global changes.

Applying PCA to all the bands of multispectral images the data representation problem is automatically solved, this is an advantage of this method. However the threshold, to separate significant changes from insignificant, still remains to be estimated (Gomez, et al. 2007).

2.2.7. Post-Classification Comparison

The post classification approach contains the analysis of differences between two independent categorization products. *Application approaches include either visually imaged interpretation (pattern recognition) or computer data categorization (spectral analysis) or a combination of both. Subsequent to multitemporal categorization, a comparison of multi-temporal categories is performed typically using vector or raster format GIS-based analysis* (García-Aguirre, et al. 2005, 82).

2.2.8. Multidate Classification

Multidate classification method is applied to a multidate image composite having the same bands from the images of the same sensor taken at two different dates. The classification is performed using all the available bands or only the selected ones from the images of both dates similar to traditional classification in which different land use classes are expected to have different statistics, the classes showing the "from-to change" information are expected to have significantly different statistics “from no change” classes (Singh 1989).

2.2.9. Visual Interpretation

Visual interpretation is a traditional approach used before the invention of digital imagery, and is still used very widely. The advantage of it is that the human eye is very good at identifying different cover types based on tone, texture, shape, and relation of one area to another. The method is a low tech approach and does not require sophisticated equipment, making it quite accessible to a wider variety of users. However, the delineations and quality control are significantly labor intensive, and preferable only when manual interpretation is key to correct classification, or where massive data volumes require sifting for a few obvious changes, or finally when the same areas need to be analyzed frequently over short time intervals. Additionally, change detection between land cover classes may vary with different personnel since the interpretations involve subjective judgment (Center for Coastal Physical Oceanography 2007).

2.2.10. Fuzzy Inference

"Fuzzy logic provides a mathematical formalism for combining evidence from various sources to estimate the significance of the detected changes." (Deer and Eklund 2002). Fuzzy logic is able to be applied on a pixel basis to generate a compound image which shows the type and degree of change for each pixel. It can also be used to combine groups of pixels into a single change, or to combine measurements such as size shape and color of a changed region into a single decision about whether or not the change has occurred.

Some fuzzy classification algorithms using a fuzzy set membership offers promise of improvement in the accuracy of post classification comparisons. This technique can be used to implement decision making process for detected changed pixels. These rules are based on the information such as mean, standard deviation of the spectral values corresponding to the object of interest in the case area data. However, this process of change detection is not generalized (Dear and Eklund 2002, Nedeljkovic 2004).

2.3. The Comparison the Existing Change Detection Methods

In this section, the selected existing methods are classified as:

- image to GIS change detection
- image to image change detection

The post-classification method is used for image to GIS change detection, additionally; image differencing methods is presented as image to image change detection methods. The results obtained these two methods are mentioned in this section. The post-classification method is selected as change detection method, because, it provides initial information about the location and size of features such as buildings and roads. The image differencing method is selected because; it is computationally efficient, reliable and accurate method for change detection.

The post classification method performs multispectral classification on image, and then compares the results in classification. The disadvantage of this method is that errors in classification have compounding effects (GIS Development 2006). Figure 2.1 and 2.2 show the supervised classification results from the case area. The classification errors cause spurious difference areas. In the figure 2.3, the supervised classification change detection result is implemented. The difference percentage has been 50 %. In GIS environment, each type of objects saves as a layer. Thus, the results obtained from the post-classification and GIS data can be compared as the feature layers. Figure 2.4 and 2.5 present the ERDAS image differencing process results. The images, firstly, are overlaid than, differenced each other. The difference, bigger than 50 %, has been shown in the Figure 2.6. In the following chapters, the comparison of these results and thesis's GUI will be discussed.

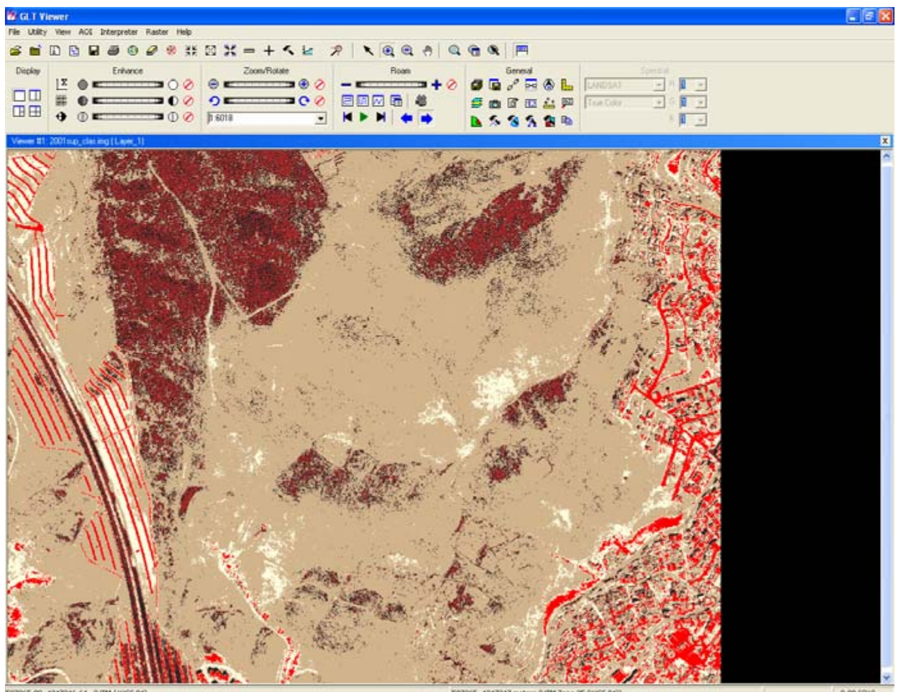


Figure 2.1. 2001 pan image supervised classification result

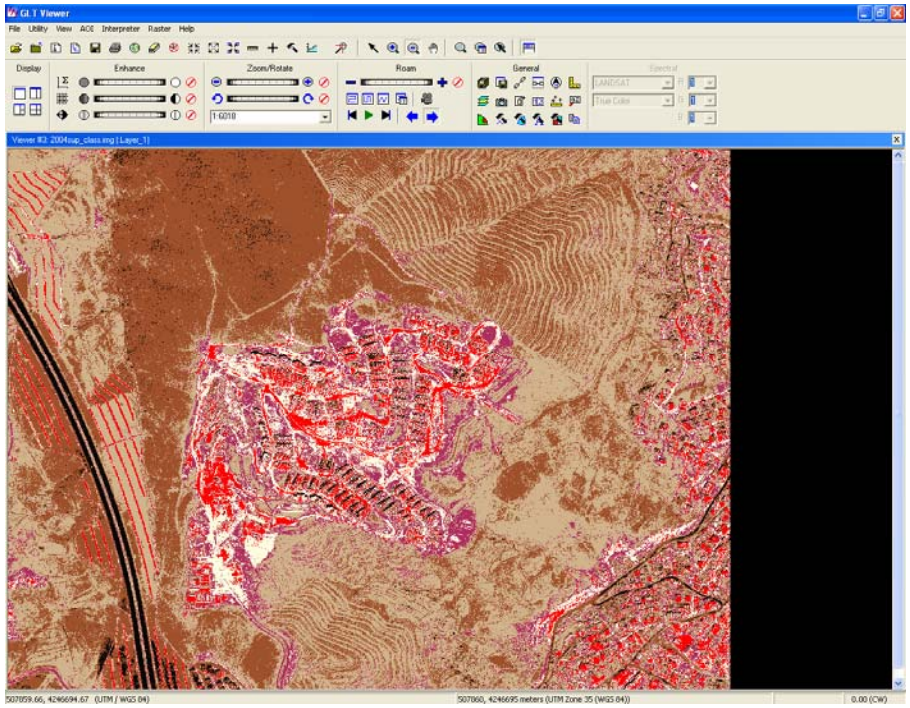


Figure 2.2. 2004 pan image supervised classification result

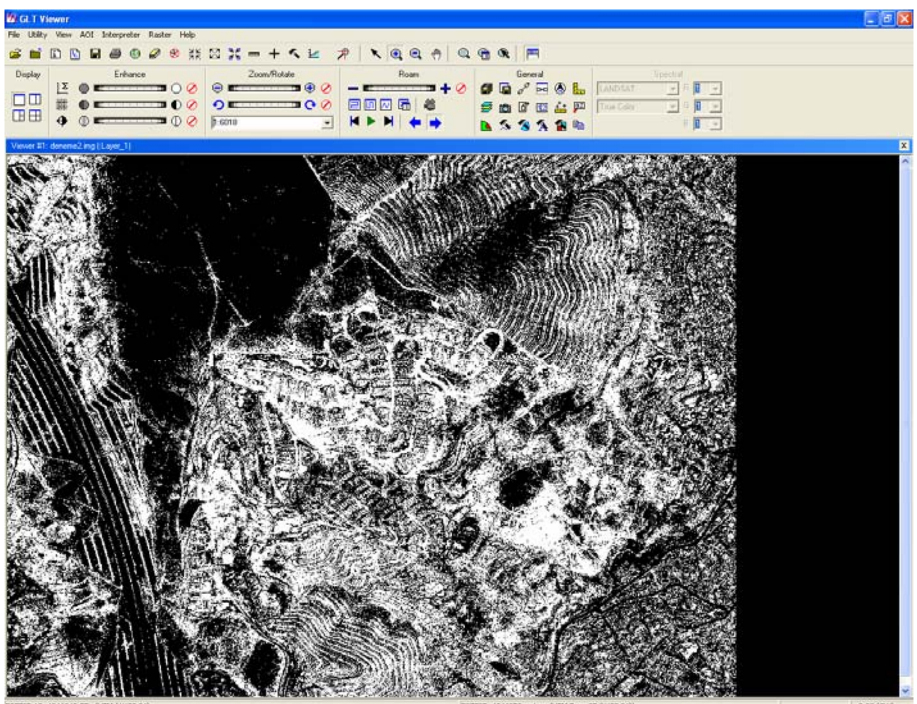


Figure 2.3. The result of supervised change detection

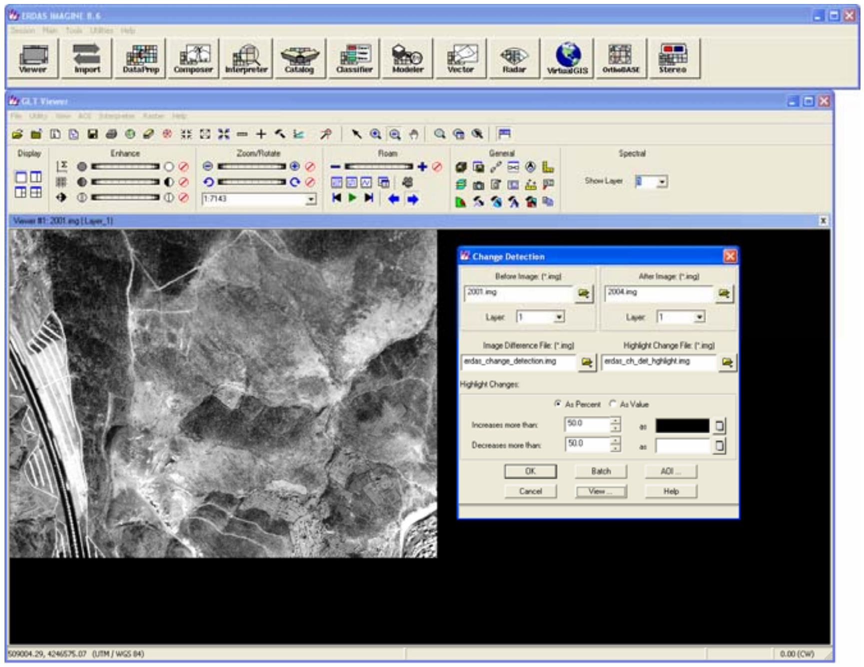


Figure 2.4. Change detection process in ERDAS

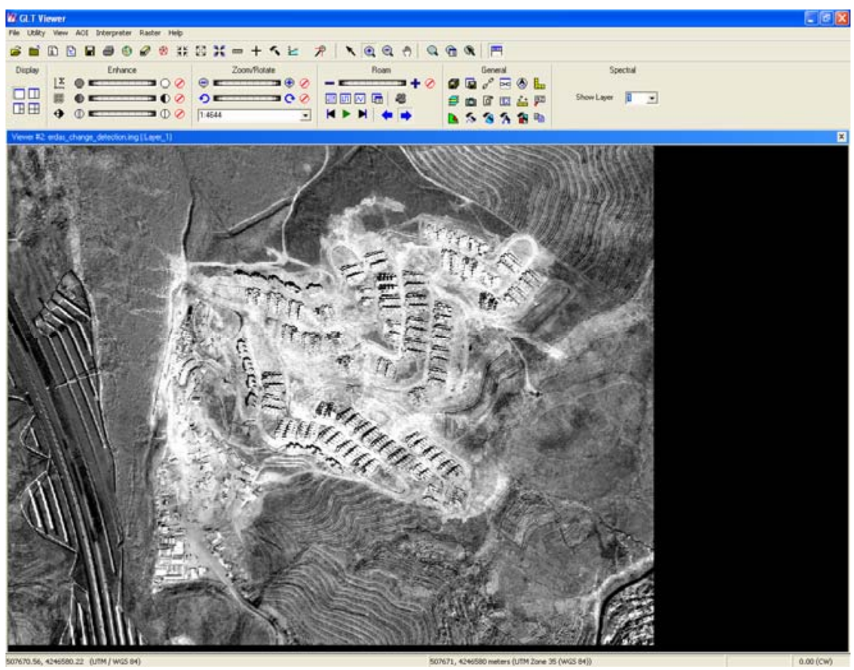


Figure 2.5. The result of overlay 2001 and 2004 PAN images

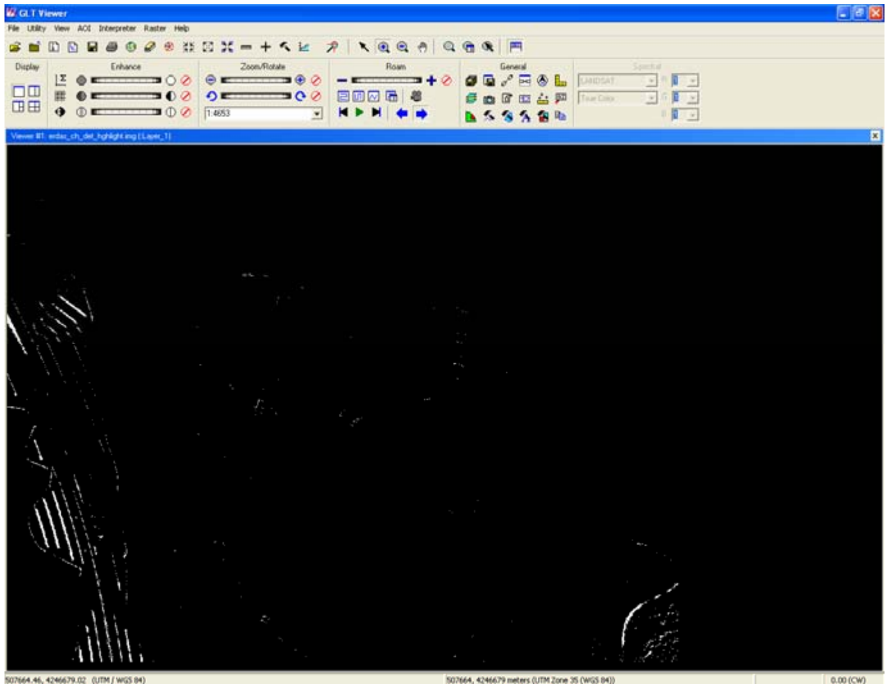


Figure 2.6. The result of 50 % change detection process

2.4. Limitations of the Existing Change Detection Methods

Two of most common use change detection methods, image differencing and supervised classification, have limitations for detection the changes. The supervised classification method is inaccurate for detection presence of heterogeneous objects with similar spectral response. This causes to misclassify the features or objects. Thus, the change detection process concludes as being unreliable. The image differencing method does not recognize the detecting changes according to the type of objects. It is only defines the overall change pixels in the image. If there are heterogeneous types of objects in urban areas, these methods are not suitable for change detection. In order to improve the result, some image enhancement algorithms should be processed and/or the image differencing method should be used with feature extraction tools.

As mentioned before, when satellite images are overlay, there has always geometric distortion. Because of this, any misregistration or misclassification causes errors in the detected change. The case area in this thesis is an example of the heterogeneous areas. There have both illegal and legal settlement areas, the legal part of the building shapes and size have well defined; on the other hand, the illegal part has not. Because of this, in order to detect changes, resolution is very important issue for detecting small size and not well defined settlement areas. IKONOS has 1 m/pixel resolution for PAN images; therefore, the GUI applications are based on the PAN images in the thesis.

CHAPTER 3

LITERATURE REVIEW

3.1. Linking Remote Sensing and Urban Planning

Remote sensing technology have been using since 1950's. Aerial photographs have been in widespread use for a half-century and satellite images for a quarter century. These images have been used for different studies in planning and land development (Liverman, et al. 1998). Planning discipline requires different professions study together such as social scientist and information technologists. As planning concerns both *human* and *spatial* information, it requires interdisciplinary studies. Thus, planning is concerned not only with "why things happen" but also "where things happen" and the relation between these. However, these two different questions sometimes cause conceptual conflictions. Their jargons, epistemological approaches and theories are different. The important point is how different sciences could work together. This question may be answered as:

- According to some remote sensing experts the answer is social utility. Remote sensing is expensive, and government spending on its more justifiable if it improves understanding of the social system by being incorporated into social science research.
- According to social scientists, one important reason for using remotely sensed data is to gather information on the context that shapes social phenomena.

Remote sensing provides an additional means of gathering contextual data, particularly in describing the biophysical context within which people live and work. Remotely sensed data provide alternative representations of reality. On the contrary maps, remotely sensed data presents reality, i.e., the satellites get images what represents on the Earth. In addition, remote sensing has the potential to supplement georeferenced social data by characterizing numerous aspects of the context, ranging from land cover to soil moisture, or to weather.

Remote sensing can provide measures for a number of dependent variables associated with human activity, particularly regarding the environmental consequences of various social, economic and demographic processes. Besides, models that combine remote observation with ground-based social data have the potential to improve understanding of the determinants of various land-use changes.

Remote sensing can provide a variety of additional indicators for analysis (related to cities, towns, districts, provinces or countries), including land cover, moisture measures, locations of major roads and hydrographic features. Gathering such measures from the ground might be possible, but often is prohibitively expensive because of the need to collect large amounts of small-scale data for aggregation. Remote sensing can sometimes provide highly aggregated data for lower cost.

Remote sensing might also help with the census undercounting problem. One source of a census undercounting is the failure to recognize a physical structure that is a dwelling unit. Moreover, remotely sensed data have been used for measuring other socially significant variables, especially in urban and suburban context. Additionally, it is clearly that remote sensing is well suited to provide comparable data for different geographic regions or at different periods.

Remotely sensed data are composed of individual pixels that can be combined to allow working at any scale or level of analysis coarser than the pixel size. Besides, time-series data can be helpful when planners attempt to trace relationships of cause and effect but cannot perform experimental methods. Remote platforms sometimes provide time-series data of good comparability on variables of interest to planners. They concerned with the effects of context on behavior or with processes of human-environment interaction.

3.2. RS and GIS Integration for Change Detection Analysis

The relation between the remotely sensed data and GIS data has always been in one direction. For example, the information obtained from remotely sensed data has been used to update the base map and its database in an area.

While remote sensing data has been regarded as an important input for GIS data, the opposite side has always been neglected and GIS thematic overlays have not been used widely, many researchers have suggested to use RS and GIS data to enhance each other's result (Thomson and Hardin 2000).

Kam (1995) has mentioned that GIS stored land information gives only a static model of the real world for a particular time period and must be regularly updated. For this purpose, satellite data are superior because they possess a higher temporal resolution which has the potential for monitoring the dynamic changes within a GIS. Thus, an urban information system, combined with up-to-date remotely sensed data, can greatly improve the efficiency of change detection, map compilation and revision.

When remotely sensed data is used alone in urban applications, we face some problems especially in the classification process. Because, sometimes pixels showing the same reflectivity can be put into the same class although they actually belong to different classes. Kam (1995) has also remarked that conventional image processing techniques based solely on spectral observation are often not sufficiently accurate for urban studies. To overcome these problems, researchers have used ancillary data stored in GIS to improve the accuracy of classification results.

On the other hand, RS and GIS have different structures used to acquire access and store the data. Because of this, the integration of remote sensing tools and technology with the spatial analysis orientation of GIS is a complex tax. RS is restricted to methods that employ electromagnetic energy such as light, heat and radio waves. A GIS is an information system for spatial data that are referenced by geographic coordinates. It is designed to acquire, store, retrieve, manipulate, analyze and display these data according to user-defined specifications.

3.3. Change Detection Applications in the World

Teeffelen, et al. (2001) have mentioned that new possibilities of combining high spatial resolution IKONOS images with contextual image analysis techniques, in other words urban monitoring. SPARK method (Spatial Re-classification Kernel) presented in the study. The aim is to use local, spatial, patterns captured by adjacent image pixels to improve the identification of city quarters. According to SPARK, at first, apply a supervised classification algorithm to the image using a maximum likelihood classifier, then, define SPARK decision rules of local, spatial patterns typical of the various city quarters, and at the end, reclassify the image resulting from the first step using the SAPRK decision rules. Reclassify the categories based on these new decision rules.

Iasillo and Albanese (2001) have examined the urban monitoring with high resolution remote sending data. IKONOS image was chosen as high resolution satellite image. The first application was land use identification. Visual interpretation has been selected as methodology for feature extraction.

Spitzer, et al. (2001) have argued that change detection with 1 m resolution satellite and aerial images. The study's algortihm was based on two approaches: principal component analysis and bayesian decision on "change" vs. "nochange". Additionally, IKONOS image was used for satellite image data.

Hall and Hay (2003) have discussed that a multiscale object specific approach to digital change detection. To detect changes at different scales within the landscape, three fundamental components are required: (i) multi scale data source, (ii) a change detection framework and (iii) feature detectors that can detect relevant changes at specific scales. A number of computational techniques currently exist that allow for multiscale representations, for example; quadtrees, pyramids, Fourier transform and scale space. The authors suggested a three level categorization system that differentiates these methods by introducing the notion of pixel, feature and object level image processing. They also noticed the object is the most advanced level of processing. Their methods used for data analysis is explained as:

- radiometric normalization
- object-specific multiscale data set generation using object-specific analysis (OSA) and object-specific up-scaling (OSU).
- Feature detection using marker controlled segmentation (MSC) and
- Change detection.

Ridd and Liu (1998) have shown that a comparison of four algorithms for change detection in an urban environment. Image differencing (pixel-by-pixel), image regression, chi square transformations were used for this study. The objective is:

- The ability to differentiate change form no-change.
- The ability to detect different kinds of change.

Chi square transformation method can be shown as:

$$Y = (X - M)^T \sum^{-1} (X - M)$$

Where

Y is the digital value of the pixel in the change image

X is the vector of the difference of the six digital values between the two dates for each pixel.

M is the vector of the mean residuals of each band for the entire image.

T is the transverse of the matrix

$\sum^{-1}$ is the inverse covariance matrix of the six bands.

Balzerek (2004) has shown that applicability of ikonos-satellite scenes monitoring, classification and evaluation of urbanization process in Africa. The study was based on pixels such as “mixed-pixels” and “pore pixels”. Image classification was used as change detection method.

Jung (2004) has stressed that detecting building changes from multi temporal aerial stereopairs. His goal is to detect changes in an aerial scene by comparing grey scale stereopairs taken several years apart to update a geographic database. Three models were used for the study. The first one is the detection of single class objects using a comparison algorithm before a classification step. The second model is to detect changes for an entire scene simultaneously. Thirdly, it is aimed to compare images using a given similarity measure without any information on the objects belonging to the scene before and after comparison.

Kosugi, et al. (2004) have argued that urban change detection related to earthquakes using an adaptive nonlinear mapping of high-resolution images. Principal Component Analysis, image ratio and vegetation index methods were used for the study.

Hathout (2002) has argued that the use of GIS for monitoring and predicting urban growth in East and West St Paul, Winnipeg, Manitoba, Canada. The objective is that to investigate the impact of urban growth on the agricultural land. 1/20.000 was study scale. Markov probability chain analysis was used for predicting the changes for a group of features. It is based on the transitional probability of changes within and between classes.

Miller, Pikaz and Averbuch (2005) have studied that objects based change detection in a pair of gray-level images. Its algorithm is an object-based approach. This includes:

- The blob extraction algorithm, based on connectivity analysis along gray level.
- Each blob from one image is searched for a corresponding blob in the other image.

The advantages are:

- The bound detection of the change object is accurate.
- The input images can contain several “objects of change” with in a considerable difference in their sizes.
- The detection of change is robust and insensitive to noise as long as the change is a connected component.
- The worst case time complexity of the algorithm is almost linear in the image size.

Authors had used statistical based approach, surface modeling and contrast invariant. Statistical based approach has two components:

- The amount of source light incident on the scene.
- The amount of light reflected by objects in the scene.

Surface modeling is a model the gray level distribution such that the surface of the errors is negligible. Contrast invariant is a technique that sets a new representation of an image, which is contrast independent.

Stossel and Dockstader (2004) have discussed that a model-based change detection process called MOSAIC (Multimodality Operational Site Analysis and Intelligent Change-detection.) MOSAIC was developed in order to satisfy four objectives.

- To reduce imagery and geospatial analyst workloads.
- To improve the performance of traditional change detection systems.
- To minimize false alarms.
- To filter the detected changes.

Advantages are:

- By combining 3D-volumetric models, MOSAIC is capable of accurate, reliable detections independent of acquision geometry and nearly eliminates false detections due to perspective differences, obstructions and shadows.

- MOSAIC allows the analyst to specify important events and regions of interest.
- It has the ability to include non-literal features such as political boundaries and underground structures.

Vector product format was used to process change detection.

Bruzzone and Serpico (1997) have stressed that detection of changes in remotely-sensed images by the selective use of multi-spectral information. Image differencing was used for this study.

Hazel (2001) has discussed that object-level change detection in spectral imagery. Object level change detection (OLCD) was used for this study. OLCD needs higher spatial scale and less registration accuracy.

Hurskainen and Pellikka (2004) have defined that *illegal housing settlements* are settlements whereby persons, or *squatters*, assert land rights to or occupy for exploitation land which is not registered in their names, or government land, or land legally owned by other individuals. They have performed a study for Se-Kenya. Their methodology is based on post-classification comparison change detection. They used MOSAIC and e-Cognition softwares for change detection.

Watanabe, et al. (2004) have written that detecting changes of buildings from aerial images using shadow and shading model. Extracting buildings from images and comparing the extracted buildings were the methods used for the study.

Park, et al. (1998) have discussed that urban expansion and change detection analysis using Russian 2m resolution DD-5, IRS-1C and Landsat TM data. Change vector analysis, image ratio and vegetation index were the methods used for change detection process.

Şirinyıldız (2004) has shown that change detection by ikonos imagery. Vector data mask was used for detection process.

Xue, et al. (2004) have stressed that urban change detection based on self-organizing feature map neural network (SOFM). SOFM has two layers: input and output. In addition vector quantification algorithm was used for change detection.

Li and Narayanan (2003) have studied that a shape based approach to change detection of lakes using time series remote sensing images. This approach based on SVM (support vector machines). It has shown superior performance in real-world applications. This approach can be divided into transform-based, region based and contour based.

Dekker (2004) has stressed that object based updating of land use maps of urban areas using satellite remote sensing. Different satellite images were used for the study, such as Landsat 5 TM (30 m), ERS 1 (30 m) and Ikonos (4 m). Also, different change detection techniques were used. At result, object based classification was preferred to pixel-based classification because it is more accurate.

McDermid, et al. (2005) have argued that object oriented analysis for change detection. In order to enable sound multidate comparisons, both images were subject to geometric and radiometric correction. 100m provincial DEM was resampled to 30m and used for orthorectification. According to the authors, object-oriented approaches offer a better alternative for many standard image processing tasks. A preliminary analysis of change detection over a fast-changing forested scene in the foothills of Alberta showed that an object-oriented approach to labeling various categories of anthropogenic change worked better overall than a pixel-based technique relying on less sophisticated spatial operators.

Walter (2004) has performed an object based classification of remote sensing data for change detection. The approach classifies not single pixels but groups of pixels that represent already existing objects in a GIS database. It is based on a supervised maximum likelihood classification. At first, remote sensing data are classified with a supervised maximum likelihood classification into different land use classes. Secondly, the classified remote sensing data have to be matched with the existing GIS objects in order to find those objects where a change occurred, or which were collected wrongly.

Murakami, et al. (1999) have represented that change detection of buildings using an airbone laser scanner. DSM (digital surfacing model) was used by detecting changes of buildings. The difficulty of detecting building changes from aerial or other optical images arises from the fact that the changes to be detected in a GIS database are not those of the optical surface characteristics of buildings.

Cho and Ntoulas (2002) have mentioned that effective change detection using sampling. According to this approach, they first sample a small number of data items from each data source and download more data items from the sources with more changed samples. The advantage of this method is that the frequency-based policy is proven to be optimal when they can estimate the change frequencies of data items accurately. On the contrary, it is very difficult to estimate the change frequency of a data item accurately. Additionally, they need to keep track of change history of every data item in order to estimate the change frequencies.

Haverkamp and Poulsen (2003) have discussed that change detection using IKONOS imagery. Principal Component Analysis (PCA) was used for this study. Their automated change detection process distinguishes objects that have undergone particular changes in multi spectral space between two sets of data imaged at different times. They have concentrated on urban changes, identifying and ignoring changes in vegetation coverage. Therefore the study includes new roads, repaved roads, and disturbed soil related to construction activities, and new buildings and building additions. The change detection process itself begins with a pixel-by-pixel comparison followed by change region analysis, verification, and labeling.

Quéré, et al. (1997) have argued that change detection from remotely sensed multi-temporal images using morphological operators. Image differencing was used for this study. In order to detect:

- It consists in generating as many images as there are object classes in the difference image.
- It consists in simply isolating objects classes by a substraction of two consecutive images generated.

Benz, et al. (2004) have presented that multi-resolution, object-oriented fuzzy analysis of remote sensing data for GIS ready information. The objectives are:

- To use signal processing for real world objects.
- Usage of polygons for suitable interface to GIS
- Fuzzy systems

Advantages of object-oriented analysis are meaningful statistic and texture calculation, an increased uncorrelated feature space using shape and topological features and the close relation between real world objects and image objects. E-cognition was the first general object-oriented image analysis software.

Jensen (1997) has represented that classification of urban land cover based on expert systems, object models and texture. This study was based on texture-based classification.

Zhang, Wang and Shi (2004) have argued that detection of buildings from Landsat-7 ETM + and SPOT panchromatic data in Beijing China. The methods are:

- Image fusion
- Multi-spectral analysis
- High-pass filters and post-processing.

Tupin and Roux (2003) have mentioned that detection of building outlines based on the fusion of SAR and optical features. The objective is how SAR and optical images could be simultaneously used for building detection process. The method is:

- Application of the Canny-Deriche edge detector
- Thinning of the edges
- Polygonal approximation of the edges to obtain a vectorial representation.

It was based on the detection of specific features. As a result, the big building detection is difficult because the SAR primitives are disconnected and correspond to a small part of the building.

Canty and Niemeyer (2003) have examined that pixel based and object oriented change detection analysis using high resolution imagery. E-cognition was used for this study's analysis. Both pixel and object based analysis were performed; however, pixel based change detection process have a lot of false signals.

Gitelson and Henebry (2002) have presented consequences of institutional change: land-cover dynamics in Kazakhistan 1960-2000. Principal Component Analysis and Change Vector Analysis were used for this study.

Ngai, et al. (1994) have represented that model based feature classification and change detection. Feature classification subsystem and Fourier translation were used for the study. The main targets are:

- Spatial extent,
- Changes in image pixel intensity and image texture
- Changes in DEM
- Changes in scattering behavior
- Presence of shadows

Yagoub (2004) has presented monitoring of urban growth of a desert city through remote sensing, Al-Ain, UAE, between 1976 and 2000. Principal Component Analysis, visual interpretation and image classification methods used for detection process.

Mascle and Seltz (2004) have represented that automatic change detection by evidential fusion of change indices. They used "mono index analysis" and "multi-index analysis" in their studies.

Bitelli, et al. (2004) have discussed image change detection on urban area because of earthquake. It presents results in information extraction from Medium Resolution to Very High Resolution satellite imagery both for rapid damage assessment purpose and damage information extraction, using classical and object-oriented approaches. In pixel-based approaches, images are processed as they are, and the registration is the very first result to acquire. In object-based change detection algorithms, imagery is firstly divided in meaningful regions, to simulate the abstraction done by a human interpreter.

Lunetta, et al. (2004) have represented that impacts of imagery temporal frequency on land cover change detection monitoring. This study compared change detection results for temporal frequencies corresponding to 3-, 7-, 10-year time intervals via Landsat 5 Thematic Mapper. The objective was to determine the minimal or optimal temporal imagery data requirements to adequately document the amount and type of land cover conversion over a 13-year period. Change detection was performed using an identical change vector analysis technique for all imagery dates.

Niemayer and Canty (2003) have shown that pixel based and object based change detection analysis using high resolution imagery. According to their results, due to different sensor and solar conditions at both acquisition times the objects are mismatched and form different shadows. Thus, a pixel-based change detection analysis may bring out a lot of false signals. Pizel based techniques are suitable for change-/no change- analysis of medium resolution imagery while object oriented approaches seem to expand the possibilities to detect and interpret changes using high resolution satellite imagery.

Im and Jensen (2005) have studied that a change detection model based on neighborhood correlation image analysis (NCI) and decision tree classification. It is based on the fact that the same geographic area (e.g., a 3_3 pixel window) on two dates of imagery will tend to be highly correlated if little change has occurred, and uncorrelated when change occurs. Larger neighborhood sizes were useful for removing this noise but introduced some inaccurate change information (such as removing some linear feature changes). NCI that contains three unique types of information: correlation, slope, and intercept; that can be related to the change information.

Yuan, et al. (2005) have argued that land cover classification and change analysis of the Twin Cities (Minnesota) metropolitan area by multitemporal Landsat remote sensing. They have developed a methodology to map and monitor land cover change using multitemporal Landsat Thematic Mapper (TM) data in the seven-county Twin Cities Metropolitan Area of Minnesota for 1986, 1991, 1998, and 2002. The results quantify the land cover change patterns in the metropolitan area and demonstrate the potential of multitemporal Landsat data to provide an accurate, economical means to map and analyze changes in land cover over time that can be used as inputs to land management and policy decisions.

Lacroix, et al. (2006) have stressed that detecting urbanization changes using SPOT5. An automatic system to estimate the urbanization changes on the Belgian territory, using SPOT5 images and the National Geographic Institute vectorial database is proposed. The images and the vectorial data are first co-registered. Then, the vectorial database is projected and dilated to produce a mask representing the old status of the database. On the other hand, a fusion of two classification processes on the images enables to extract the built-up area and the communication network, providing a mask representing the actual state of the urbanization in the zone. The comparison between the two masks gives coarse information of the changes. The system has then been tested and evaluated on 10 zones selected on SPOT5 5 and 2.5 m resolution images in order to include sub-urban and rural areas. The results were compared to the results of visibility tests performed by an experimented photo-interpreter.

Xiao, et al. (2006) have argued that Evaluating urban expansion and land use change in Shijiazhuang, China, by using GIS and remote sensing. The study explores the temporal and spatial characteristics of urban expansion from 1934 to 2001, and land use/cover change from 1987 to 2001. The objectives of the study are:

- to explore the temporal and spatial characteristics of urban expansion in last 70 years;
- to detect and evaluate the land use and land cover change due to urbanization between 1987 and 2001, and output land cover maps; and
- to analyze the main factors governing urbanization and land use and land cover change.

Johson and Fullwood (2004) have mentioned that multi-sensor fusion for classification and change detection in remote sensed imagery. The study was based on feature based correspondence of regions in the two input images. Images were processed from pixel data to be stored in a vector database. Single image classification was used for this study.

3.4. Evaluation of the Existing Change Detection Examples

As a result of literature survey, it is clearly seen there are 3 classification techniques for using change detection especially at urban scale. These are pixel-based, feature-based and object-based classification techniques. Feature-based studies have been accepted as optimum technique in order to get the high accuracy. The differences among those can be explained as written below.

The pixel-based methods consist of a series of decision rules applied in a GIS environment: a technique that is limited to its ability to incorporate spatial information (McDermic, et al. 2004). Pixel-based classification algorithms are widely used in land use studies, but the limitations are clear and widely accepted. The idea of a pixel belonging to a certain class is that it has to be close to the spectral feature space of that class. The pixel-based approach with very high resolution is not justifiable for classifying complex environments, such as urban areas (Hurskainen and Pellikka, 2004).

- Pixels do not sample the urban environment at the spatial scale of the features to be mapped, and buildings are represented by groups of pixels which should be treated as individual objects instead.
- A building reflects a wide range of spectral signatures as the pixels will represent facets of the roof. This is especially true in the context of illegal housing, where roofs are constructed from diverse materials with variable texture and color.

The basic idea of object-based classification is to classify not single pixels but groups of pixels that represent already existing objects in a GIS databases. Each object is described by an n-dimensional feature vector and classified to the most likely class based on a supervised maximum likelihood classification (Walter 2004).

Feature-based classification is performed on each changed object to determine if a changed object is a feature of interest or a false change. False changes can be caused by differing observation geometries or seasonal changes in the image background. The classification process is based on attribute models which in turn are based upon attributes of feature signatures in representative images (Ngai, et al. 1994).

On the other hand, the most common methods using for change detection process are image differencing, image rationing, principal component analysis and change vector analysis. The existing studies show that to select GIS or RS software may not be enough to detect the changes. There is no special graphical user interface (GUI) created by the study owners. At this point, this study differs from the others because; it is expected to be created a GUI for change detection process.

This thesis contains all of the techniques explained above, at different levels. For example, feature-based classification will be used to detect land changes. The object-based classification will be used to detect the illegal building changes. The pixel-based classification will be used to adjust the results and increase the accuracy of the study. After classification, different change detection process mentioned above will be used to get the results. Technique which gets the highest accuracy for detection illegal housing, that process will be the optimum way of to do this study. After detecting the changes, a database management system about them will be set, thus local governments use it to analyze, make query and detect the illegal housings. The important point here is to provide a connection between spatial and non-spatial data. At the end of the study, it is aimed to reach an effective information technology based system to monitor urban squatter settlement.

CHAPTER 4

METHODOLOGY, ALGORITHMS AND FUZZY INFERENCE

This chapter is composed of three sections: methodology, algorithms and fuzzy inference. The methodology part contains the change detection process and technique definitions. The algorithm part has different image enhancement techniques before they have to be performed change detection process. So, the result will be optimum. The fuzzy inference part is defined what it is, and how it is used in the thesis.

4.1. Methodology

PAN images have only one band and also when they are described as mathematically, each pixel has a value between 0 and 255. MS images usally have 3 bands called as RGB, red-green and blue. Sometimes, there is a near infrared band as 4^{th} band. However, thesis MS images are composed of three bands, RGB. Each band has different pixel values between 0 and 255. When these bands come together, the image can be seen as true color.

The thesis methodologies have been applied to mathematical expressions. There are four methods used. These are

- pixel by pixel extraction for panchromatic (PAN) images called as RGB individual in the thesis,
- RGB total extraction for multi-spectral (MS) images
- Equal matrix extraction both for PAN and MS images.
- Not equal matrix extraction both for PAN and MS images

Band extractions are called as “pixel extraction”, equal matrix is called as “object extraction” and not equal matrix is called as “feature extraction” in the literature. In the following sections, they are defined as mathematically. The methodology algorithm is shown in Figure 4.1.

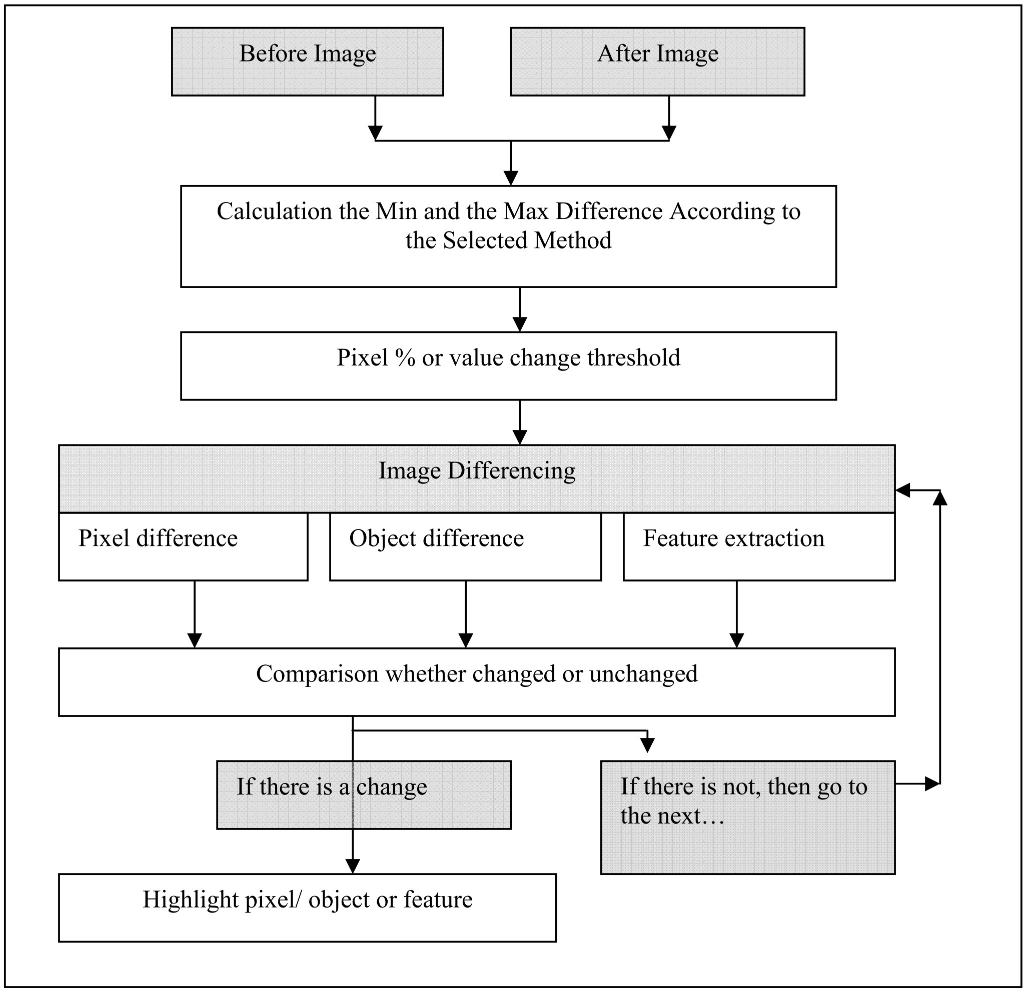


Figure 4.1. The Methodology Algortihm

According to the methodology algorithm, the first step of the process is calculation of the minimum and the maximum difference according to the selected method. After that, pixel change percentage or threshold is detected by the user. For the image differencing pixel, object or feature difference methods are chosen. According to the selected image differencing methodology, the pixels are detected as changed or unchanged. If there is a change, that pixel, object or feature is highlighted. If there is not a change, then the system goes to the next pixel, object or feature.

4.1.1. RGB Individual Method

This method is prepared for PAN images to be extracted pixel by pixel.

$$\left[pixel_{ij(change)} = \left(pixel_{ij(1)} - pixel_{ij(2)}\right)\right]$$

where

$Pixel_{ij(change)}$: Brightness value of the pixel in the i^{th} row, j^{th} column in the change image,

$Pixel_{ij(1)}$: Brightness value of the pixel in the i^{th} row, j^{th} column in the first date image,

$Pixel_{ij(2)}$: Brightness value of the pixel in the i^{th} row, j^{th} column in the second date image,

Threshold : Changing percentage (%)

According to the selected threshold, pixel changes are compared individually. Absolute value must be used in the formula, because pixel differences could be negative value. The negative value must be transformed to the positive value in order to be compared.

IF $\left[Threshold * pixelij(1)\right] < \left|pixel_{ij(change)}\right|$ THEN point the pixel as difference

IF $\left[Threshold * pixelij(1)\right] > \left|pixel_{ij(change)}\right|$ THEN go to next pixel (there is no change)

4.1.2. RGB Total Method

This method is prepared for MS images to be extracted pixel by pixel. The formula above is valid for this method. However, while calculating, 3 bands are aggregated, RGB. For each band, the maximum change detection value can be 255. Because of being 3 bands, the RGB max total changing value can be 765 (255*3 = 765).

$$\left(pixel_{ij(change)} = \sum_{b=1}^{3}(pixel_{ij(1)}) - \sum_{b=1}^{3}(pixel_{ij(2)})\right)$$

where

$Pixel_{ij(change)}$: Brightness value of the pixel in the i^{th} row, j^{th} column in the change image,

$Pixel_{ij(1)}$: Total brightness value (three bands) of the pixel in the i^{th} row, j^{th} column in the first date image,

$Pixel_{ij(2)}$: Total brightness value (three bands) of the pixel in the i^{th} row, j^{th} column in the second date image,

B : Number of bands

Threshold : Changing percentage (%)

IF $\left(Threshold * \sum_{b=1}^{3}(pixel_{ij(1)})\right) < \left|pixel_{ij(change)}\right|$ THEN point the pixel as difference

IF $(Threshold * totalpixelvalue) > |totalpixelchange|$ THEN go to next pixel (there is no change)

For example; if the threshold is % 10, then point the pixel where the pixel difference is more than 77. In other words, according to this methodology, for 10 % changing threshold, if the pixel difference is more then 77, then there is a minimum 10 % changing. In other words, if the pixel difference is less then 77, then there is no change. Additionally, if the threshold is % 50, then point the pixel where the pixel difference is more than 383. For 50 % changing threshold, if the pixel difference is more then 383, then there is a minimum 50 % changing. Else, if the pixel difference is less then 383, then there is no change.

4.1.3. Equal Matrix Method

In this methodology, the main goal is to extract the selected two equal size matrices, explained in formula. Their size depends on the area's density, building shape or size, the user's need and the change percentage. The selected matrix size is searched in the image. This is called as object based changed detection in the literature.

For a (nxn) matrix, $b1_{nxn}$, $b2_{nxn}$ and $b3_{nxn}$ are the bands of the matrix.

$$\left(\sum_{i=1}^{n} \sum_{j=1}^{n} (b1_{ij} + b2_{ij} + b3_{ij})\right) = K$$

where

i= number of row and

j= number of column.

K= nxn matrix total pixels value

IF $(Threshold * K) < |pixel_{ij(change)}|$ THEN point the pixel as difference

IF $(Threshold * totalpixelvalue) > |totalpixelchange(\mathrm{Pixel}_{ij(change)})|$ THEN go to next pixel (there is no change)

For example; for a 2x2 matrix, the maximum changing value is 3060. If the threshold is % 10, then point the matrix where the matrix difference is more than 306. In other words, for 10 % changing threshold, if the matrix difference is more then 306, then there is a minimum 10 % changing. On the contrary, if the matrix difference is less then 306, then there is no change. Additionally, if the threshold is % 50, then point the matrix where the matrix difference is more than 1530. According to this methodology, for 50 % changing threshold, if the matrix difference is more then 1530, then there is a minimum 50 % changing. Otherwise, if the matrix difference is less then 1530, then there is no change.

4.1.4. The Not Equal Matrix Method

The not equal matrix is composed of the comparison of 2 different matrixes. The small one is searched into the big one, shown in formula 4 and 5. According to the building density of the area, it needs to be searched small features into the big ones. This is called as feature-based change detection in the literature.

For a (nxn) matrix, $b1_{nxn}$, $b2_{nxn}$ and $b3_{nxn}$ are the bands of the matrix.

$$\left(\sum_{i=1}^{n} \sum_{j=1}^{n} (b1_{ij} + b2_{ij} + b3_{ij})\right) = K$$

for a (mxm) matrix, $b1_{mxm}$, $b2_{mxm}$ and $b3_{mxm}$ are the bands of the matrix.

$$\left(\sum_{i=1}^{m} \sum_{j=1}^{m} (b1_{ij} + b2_{ij} + b3_{ij})\right) = L$$

where $n<m$
i= number of row and
j= number of column.
K= nxn matrix total pixels value
L= mxm matrix total pixels value

IF $(Threshold * K) < |K - L|$ THEN point the pixel as difference

IF $(Threshold * K) > |K - L|$ THEN go to next pixel of the matrix (there is no change)

4.2. Image Enhancement Algorithms

This section is composed of defitions of the some enhancements, used in the thesis. As general, image enhancement may be defined as that to improve the interpretability or perception of information in images for human viewers, or to provide `better' input for other automated image processing techniques (The University of Edinburgh, School of Informatics 2007). These are categorized as radiometric, spatial and spectral enhancements.

4.2.1. Radiometric Enhancement

Radiometric enhancement can define as improving the interpretation of the radiometric information in an image using speckle and spatial filters (Glossary of Remote Sensing Words 2007). There are several radiometric image enhancement techniques. Histogram equalization, emboss, gaussian, smooth, glow and blur are the used methods in the thesis as radiometric enhancement.

4.2.1.1. Histogram Equalization

Histogram equalization is a technique in image processing of contrast adjustment using the image’s histogram (Wikipedia (a) 2007). In other words, *histogram equalization assigns the intensity values of pixels in the input image such that the output image contains a uniform distribution of intensities. It improves contrast and the goal of histogram equalization is to obtain a uniform histogram. This technique can be used on a whole image or just on a part of an image (*CoderSource.net *2007)*.

Figures 4.1 and 4.2 show the case area satellite image, the first one is the original PAN view, the second is the view after histogram equalization. Additionally, figures 4.3 and 4.4 represent histograms of these two images.

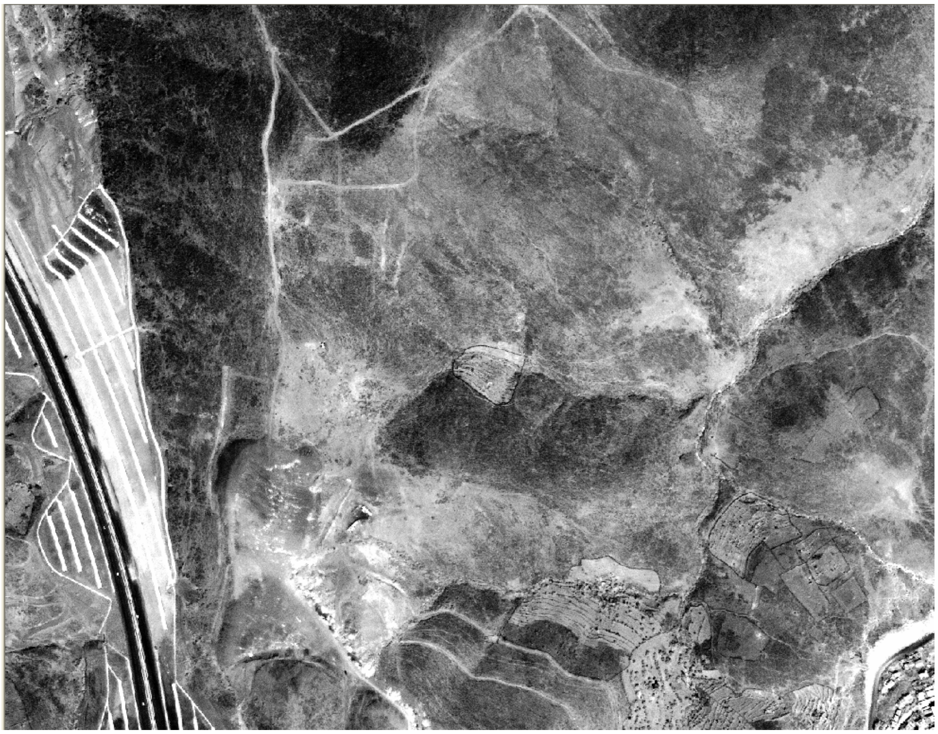


Figure 4.2. The case area 2001 view – original

Figure 4.3. The case area 2001 view after histogram equalization

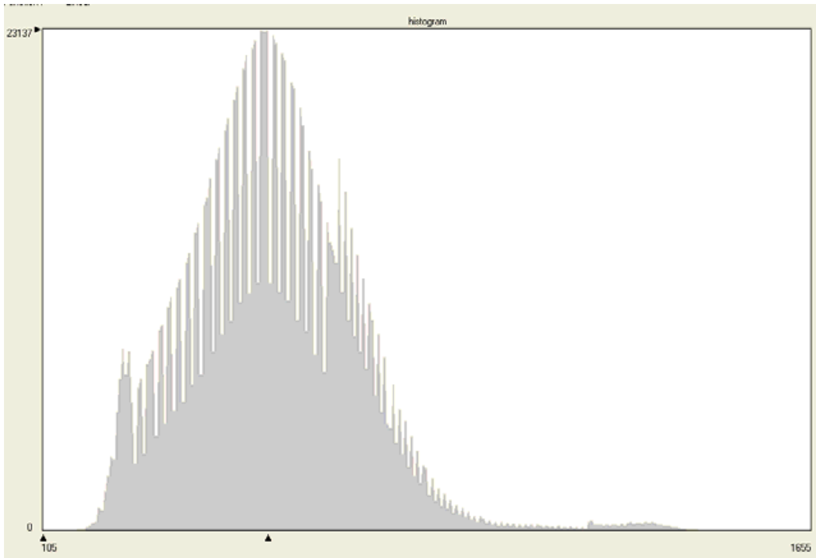


Figure 4.4. Histogram for the original view

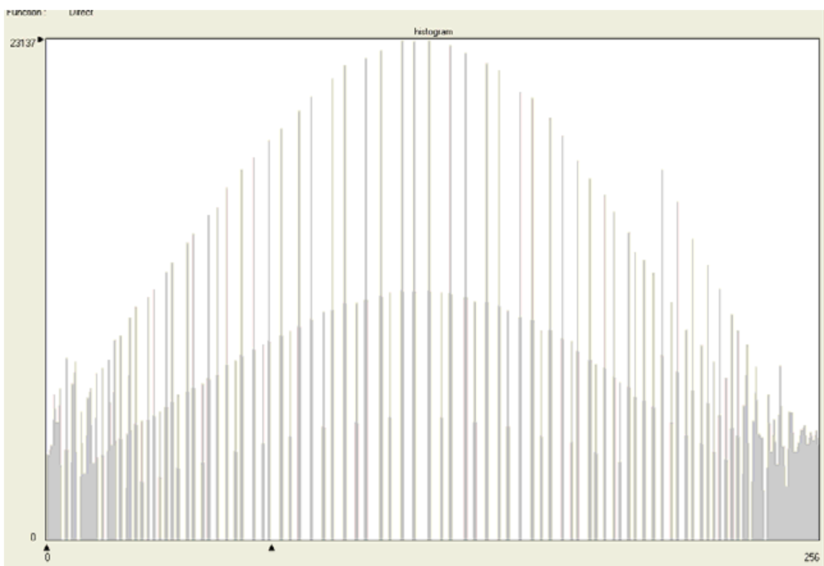


Figure 4.5. Histogram for after histogram equalization

In order to get these results, the following mathematical expressions have been used.

1) Histogram Formation

2) New Intensity Values calculation for each Intensity Levels

3) Replace the previous Intensity values with the new intensity values

In step 2, new intensity values are calculated for each intensity level by applying the following equation:

$$Oi = \left(\sum_{j=0}^{i} Ni\right) x \frac{Max.IntensityLevel}{NumberOfPixels}$$

The meaning of Max Intensity Levels is maximum intensity level which a pixel can get. For example, if the image is in the grayscale domain, then the count is 255. And if the image is of size 256x256 then, the No. of pixels is 65536. And the expression is the bracket means that the no. of pixels having the intensity below the output intensity level or equal to it. For example, if we are calculating the output intensity level for 1 input intensity level, then it means that the no. of pixels in the image having the intensity below or equal to 1 means 0 and 1. If we are calculating the output intensity level for 5 input intensity level, then the it means that the no. of pixels in the image having the intensity below or equal to 5 means 0, 1, 2, 3, 4, 5. Thus, if we are calculating the output intensity level for 255 input intensity level, then the it means that the no. of pixels in the image having the intensity below or equal to 255 means 0 , 1 , 2 , 3 , ... , 255. That is how new intensity levels are calculated for the previous intensity levels.

The next step is to replace the previous intensity level with the new intensity level. This is accomplished by putting the value of Oi in the image for all the pixels, where Oi represents the new intensity value, whereas i represent the previous intensity level.

4.2.1.2. Emboss

An image appears to be embossed when highlights and shadows replace light/dark boundaries and low contrast areas are set to a gray background (Victor Image Processing Library 2007). In other words, the Emboss filter makes a selection appear raised or stamped by suppressing the color within the selection and tracing its edges with black. Figure 4.6, 4.7 and 4.8 the results of emboss filtering as light, medium and dark.

Figure 4.6. The result of emboss light example

var mxEmbossLight:TGraphicFilter
=(FilterType:ftLinear;MatrixSize:mx3;
Matrix:

0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	−1	0	0	0
0	0	0	0	0	0	0
0	0	0	1	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0

Divisor:1;
Bias:192;
FilterName:'Emboss light (Effects linear)';);

Figure 4.7. The result of emboss medium

```
var mxEmbossMedium:TGraphicFilter
    =(FilterType:ftLinear;MatrixSize:mx3;
     Matrix:
0   0   0   0   0   0   0
0   0   0   0   0   0   0
0   0   −1  −2  −1  0   0
0   0   0   0   0   0   0
0   0   1   2   1   0   0
0   0   0   0   0   0   0
0   0   0   0   0   0   0
     Divisor:1;
     Bias:192;
```

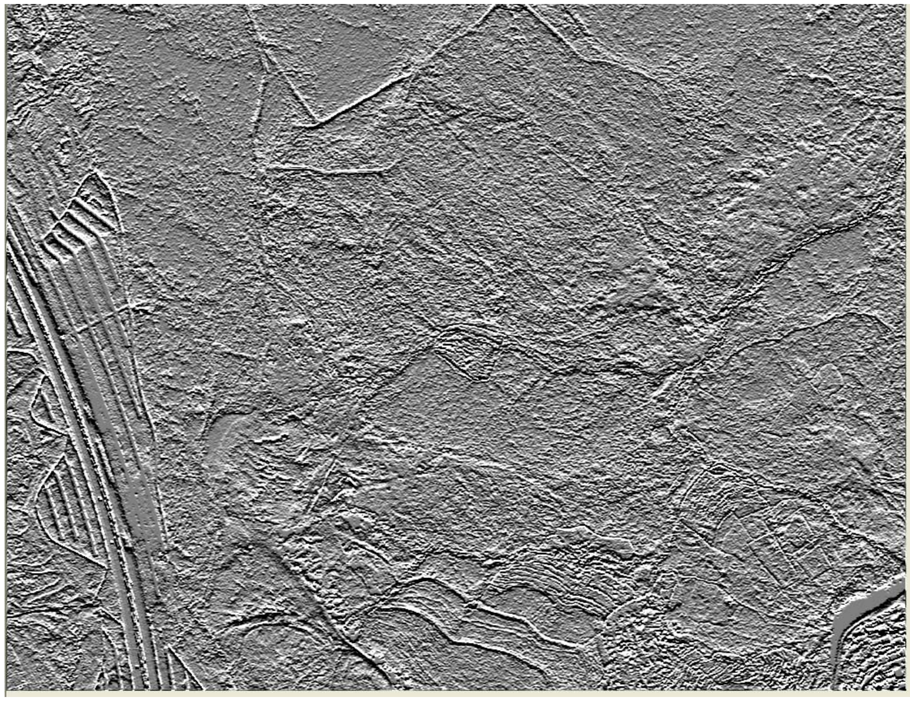


Figure 4.8. The result of emboss dark

var mxEmbossDark:TGraphicFilter
=(FilterType:ftLinear;MatrixSize:mx3;
Matrix:

0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	−1	−2	−1	0	0
0	0	0	0	0	0	0
0	0	1	2	1	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0

Divisor:1;
Bias:128;
FilterName:'Emboss Dark (Effects linear)';);

4.2.1.3. Glow

A glow filter creates a diffuse lighting effect around the edges of an object to make the object appear as if it is glowing. This standard effect appears in many image processing applications (Quartz Composer Programming Guide 2007). Figures 4.9 shows the glow filter result.

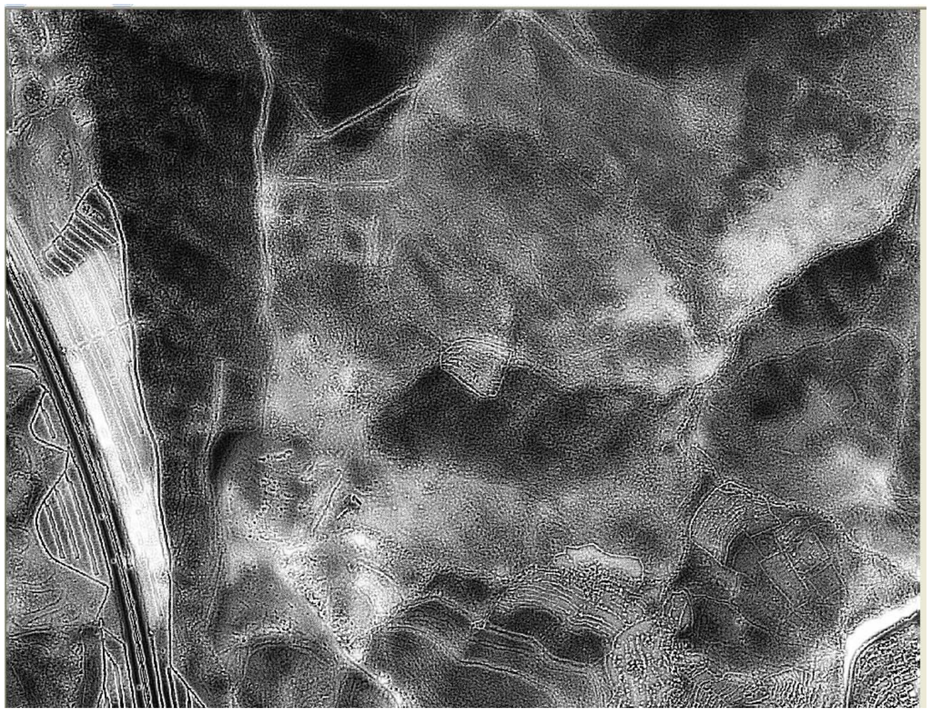


Figure 4.9. The result of the glow filter

```
var mxGlow:TGraphicFilter
    =(FilterType:ftLinear;MatrixSize:mx7;
    Matrix:
0    0    0    0    0    0    0
0    1    2    2    2    1    0
0    2    0    0    0    2    0
0    2    0  -20    0    2    0
0    2    0    0    0    2    0
0    1    2    2    2    1    0
0    0    0    0    0    0    0
    Divisor:8;
    Bias:0;
    FilterName:'Glow (Effects linear)';);
```

4.2.1.4. Smooth

The smooth filter lets you smooth edges in an image. Smooth filter reduces noise within an image by applying low pass filters (University of Oslo, Department of Informatics 2007). Figure 4.10 presents the result of the smooth filter.

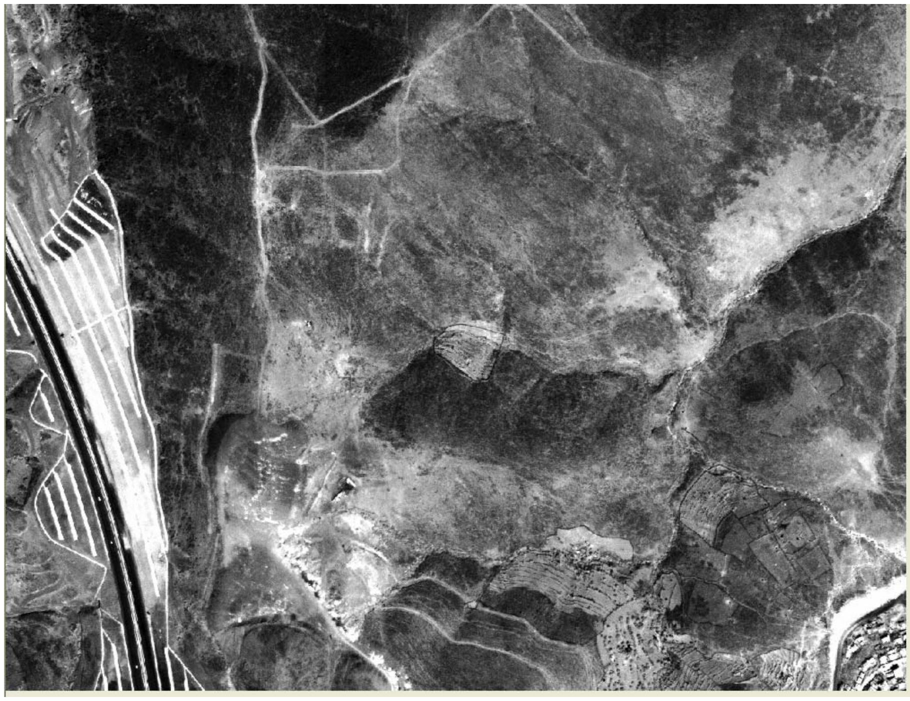


Figure 4.10. The result of the smooth filter

4.2.1.5. Blur

Blur filter produces an effect similar to that of an out of focus camera shot. To produce it, the filter takes the average of the present pixel value and the value of adjacent pixels and sets the present pixel to that average value. Filter advantage is its calculation speed. It suits big images. Filter disadvantage is that its action is hardly perceptible on big images, but very strong on small images.

Gaussian blur is a widely used effect in graphics in order to reduce image noise and reduce detail levels. Gaussian smoothing is used as a pre-processing stage in computer vision algorithms in order to enhance image structures at different scales—see scale-space representation and scale-space implementation (Wikipedia (b) 2007). Figure 4.11, 4.12, 4.13 and 4.14 represent the results of blur Gaussian, blur bartlet, blur softly and blur more filters.

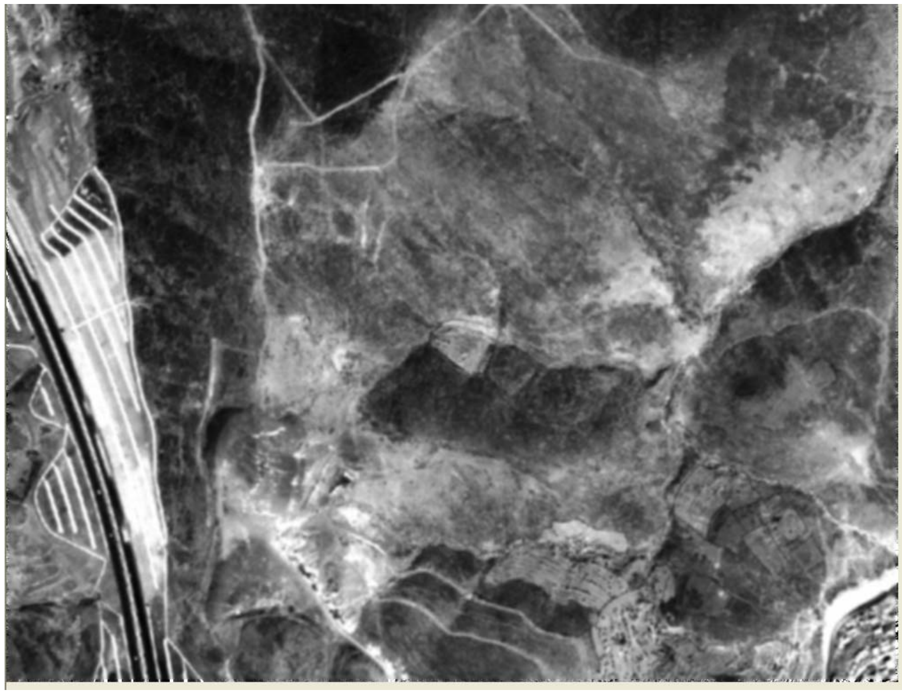


Figure 4.11. The result of blur gaussian

```
var mxBlurGaussian:TGraphicFilter
     =(FilterType:ftLinear;MatrixSize:mx7;
      Matrix:
 1    4    8   10    8    4    1
 4   12   25   29   25   12    4
 8   25   49   58   49   25    8
10   29   58   67   58   29   10
 8   25   49   58   49   25    8
 4   12   25   29   25   12    4
 1    4    8   10    8    4    1
     Divisor:999;
     Bias:0;
     FilterName:'Blur Gaussian (Blur linear)';);
```

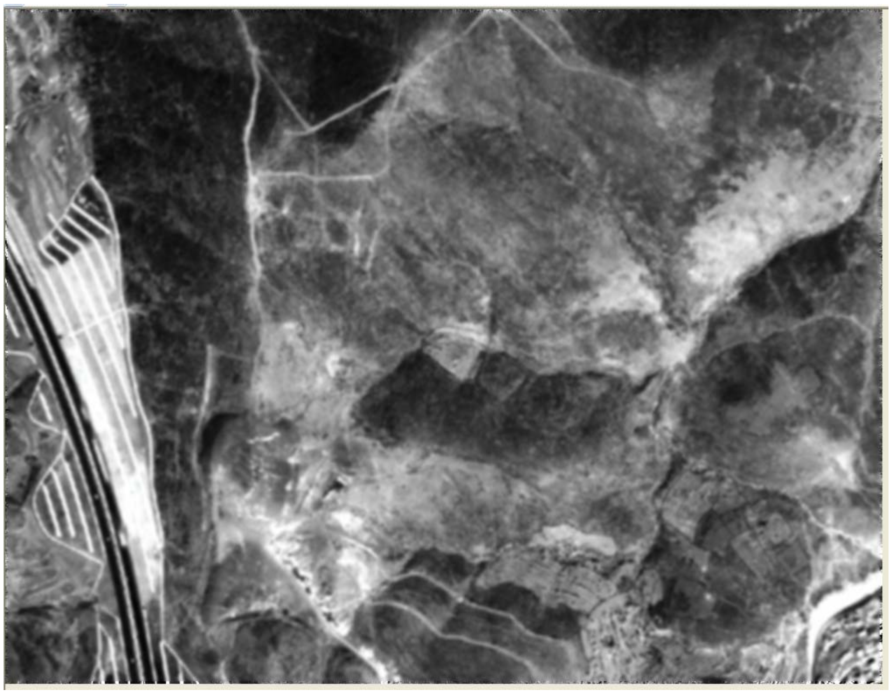


Figure 4.12. The result of the blur bartlet

```
var mxBlurBartlett:TGraphicFilter
     =(FilterType:ftLinear;MatrixSize:mx7;
      Matrix:
 1    2    3    4    3    2    1
 2    4    6    8    6    4    2
 3    6    9   12    9    6    3
 4    8   12   16   12    8    4
 3    6    9   12    9    6    3
 2    4    6    8    6    4    2
 1    2    3    4    3    2    1
     Divisor:256;
      Bias:0;
      FilterName:'Blur Bartlett (Blur linear)';);
```

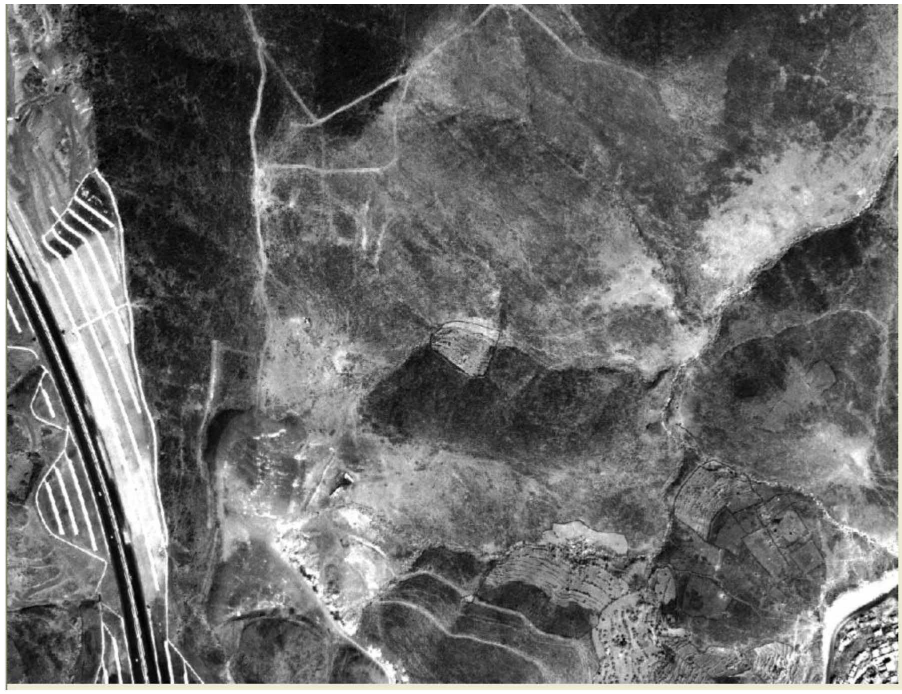


Figure 4.13. The result of the blur softly

```
var mxBlurSoftly:TGraphicFilter
    =(FilterType:ftLinear;MatrixSize:mx3;
    Matrix:
0   0   0   0   0   0   0
0   0   0   0   0   0   0
0   0   1   3   1   0   0
0   0   3   16  3   0   0
0   0   1   3   1   0   0
0   0   0   0   0   0   0
0   0   0   0   0   0   0
    Divisor:32;
    Bias:0;
    FilterName:'Blur softly (Blur linear)';);
```

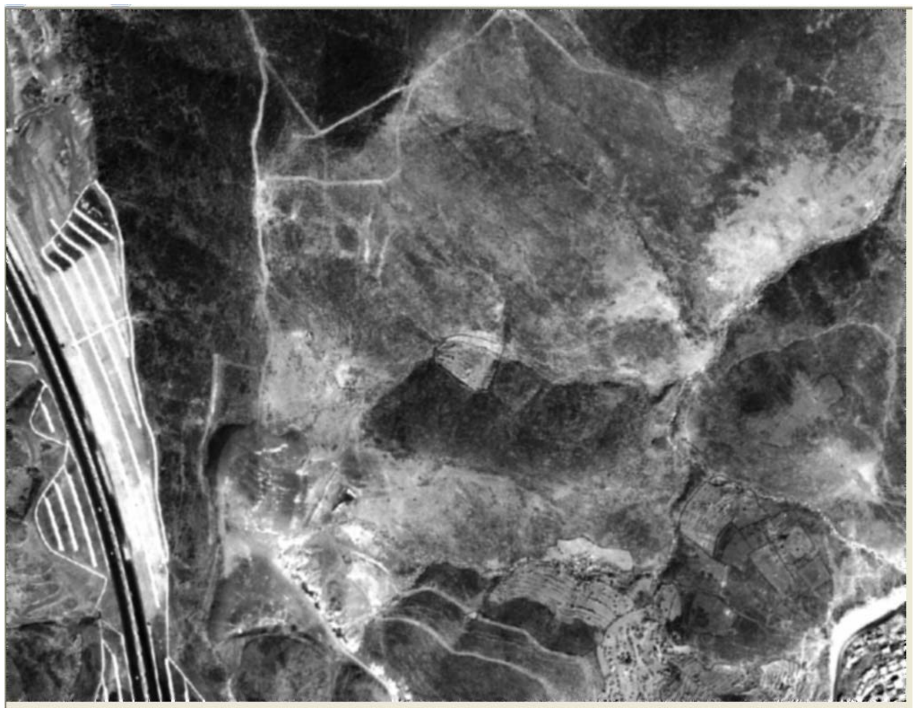


Figure 4.14. The result of the blur more

```
var mxBlurMore:TGraphicFilter
    =(FilterType:ftLinear;MatrixSize:mx5;
    Matrix:
0   0   0   0   0   0   0
0   0   1   2   1   0   0
0   1   4   6   4   1   0
0   2   6   8   6   2   0
0   1   4   6   4   1   0
0   0   1   2   1   0   0
0   0   0   0   0   0   0
    Divisor:64;
    Bias:0;
    FilterName:'Blur more (Blur linear)';);
```

4.2.2. Spatial Enhancement

Spatial enhancement is that enhancing values of pixels in an image relative to surrounding pixels (Conservation Management Institute, Glossary of GIS and Remote Sensing Terms 2007). Edge detection (sobel, prewitt), glowing edge, sandy, laplacian and trace contour are the used methods in the thesis as spatial enhancement.

4.2.2.1. Edge Detection (Sobel and Prewitt)

The aim of edge detection process is to mark the points in a digital image at which the luminous intensity changes sharply. Sharp changes in image properties usually reflect important events and changes in properties of the world. These include (i) discontinuities in depth, (ii) discontinuities in surface orientation, (iii) changes in material properties and (iv) variations in scene illumination. There are many methods for edge detection, but most of them can be grouped into two categories, search-based and zero-crossing based. The search-based methods detect edges by looking for maxima and minima in the first derivative of the image, usually local directional maxima of the gradient magnitude. The zero-crossing based methods search for zero crossings in the second derivative of the image in order to find edges, usually the zero-crossings of the Laplacian or the zero-crossings of a non-linear differential expression (Wikipedia (c) 2007). In this section, sobel and prewitt edge detection operator will be presented. In the following sections, the other operator will be examined such as trace contour and laplacian.

4.2.2.1.1. Sobel Operator

The Sobel operator performs a 2-D spatial gradient measurement on an image and so emphasizes regions of high spatial gradient that correspond to edges. Typically it is used to find the approximate absolute gradient magnitude at each point in an input grey scale image (Mathematics and Computer Science Courses at Heriot-Watt University, Edinburgh, Scotland 2007).

The operator consists of a pair of 3×3 convolution masks as shown in Figure 4.15.

$$\begin{array}{|ccc|}\hline -1 & 0 & +1 \\ -2 & 0 & +2 \\ -1 & 0 & +1 \\ \hline \end{array} \qquad \begin{array}{|ccc|}\hline +1 & +2 & +1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \\ \hline \end{array}$$

Gx Gy

Figure 4.15. Sobel convolution masks (Source: Mathematics and Computer Science Courses at Heriot-Watt University, Edinburgh, Scotland 2007)

These are designed in order to respond maximally to edges running vertically and horizontally relative to the pixel grid, one mask for each of the two perpendicular orientations. They also can be applied separately to the input image, to produce separate measurements of the gradient component in each orientation (call these *Gx* and *Gy*). Additionally, these can then be combined together to find the absolute magnitude of the gradient at each point and the orientation of that gradient. The gradient magnitude is given by (Mathematics and Computer Science Courses at Heriot-Watt University, Edinburgh, Scotland 2007):

$$|G| = \sqrt{G_x^2 + G_y^2}$$

Although typically, an approximate magnitude is computed using:

$$|G| = |Gx| + |Gy|$$

which is much faster to compute.

The angle of orientation of the edge (relative to the pixel grid) giving rise to the spatial gradient is given by:

$$\theta = \arctan(Gy / Gx) - 3\pi / 4$$

The two components of the gradient are conveniently computed and added in a single pass over the input image using the pseudo-convolution operator shown in Figure 4.16. Figure 4.17 presents the result of edge enhance. Additionally, figure 4.18 and 4.19 represent the results of strong and weak edge detection. On the other hand, figure 4.20 shows the result of the sobel operator.

P_1	P_2	P_3
P_4	P_5	P_6
P_7	P_8	P_9

Figure 4.16. Pseudo-convolution masks used to quickly compute approximate gradient magnitude (Source: Mathematics and Computer Science Courses at Heriot-Watt University, Edinburgh, Scotland 2007)

Using this mask the approximate magnitude is given by (Mathematics and Computer Science Courses at Heriot-Watt University, Edinburgh, Scotland 2007):

$$\|G| = |(P_1 + 2\times P_2 + P_3) - (P_7 + 2\times P_8 + P_9)| + |(P_3 + 2\times P_6 + P_9) - (P_1 + 2\times P_4 + P_7)\|$$

Code example of edge enhance is:

```
var mxEdgeEnhance:TGraphicFilter
   =(FilterType:ftLinear;MatrixSize:mx3;
    Matrix:
 0    0    0    0    0    0    0
 0    0    0    0    0    0    0
 0    0   -1   -2   -1    0    0
 0    0   -2   16   -2    0    0
 0    0   -1   -2   -1    0    0
 0    0    0    0    0    0    0
 0    0    0    0    0    0    0
    Divisor:4;
    Bias:0;
    FilterName:'Edge enhance (Sharpen linear)';);
```

Figure 4.17. The result of the edge enhance 2001

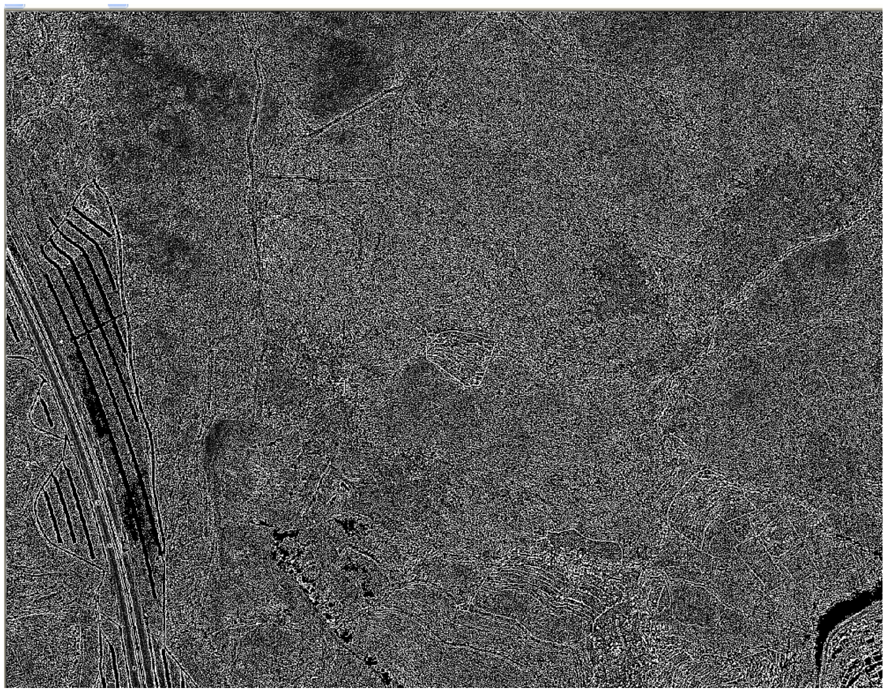


Figure 4.18. The result of the edge detection strong

```
var mxEdgesStrong:TGraphicFilter
    =(FilterType:ftLinear;MatrixSize:mx3;
    Matrix:
  0    0    0    0    0    0    0
  0    0    0    0    0    0    0
  0    0    1    3    1    0    0
  0    0    3  -16    3    0    0
  0    0    1    3    1    0    0
  0    0    0    0    0    0    0
  0    0    0    0    0    0    0
    Divisor:1;
    Bias:0;
    FilterName:'Edges strong (Edge detect linear)';);
```

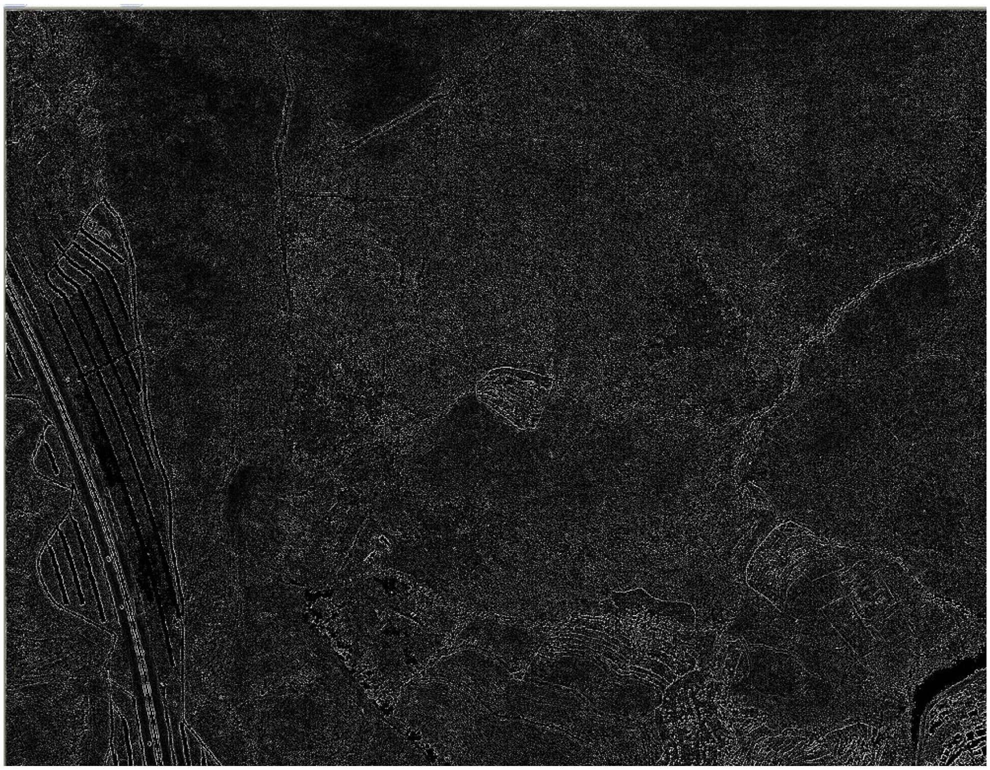


Figure 4.19. The result of the edge detection weak

```
var mxEdgesWeak:TGraphicFilter
    =(FilterType:ftLinear;MatrixSize:mx3;
    Matrix:
```

$$\begin{matrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & -4 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{matrix}$$

```
    Divisor:1;
    Bias:0;
    FilterName:'Edges weak (Edge detect linear)';);
```

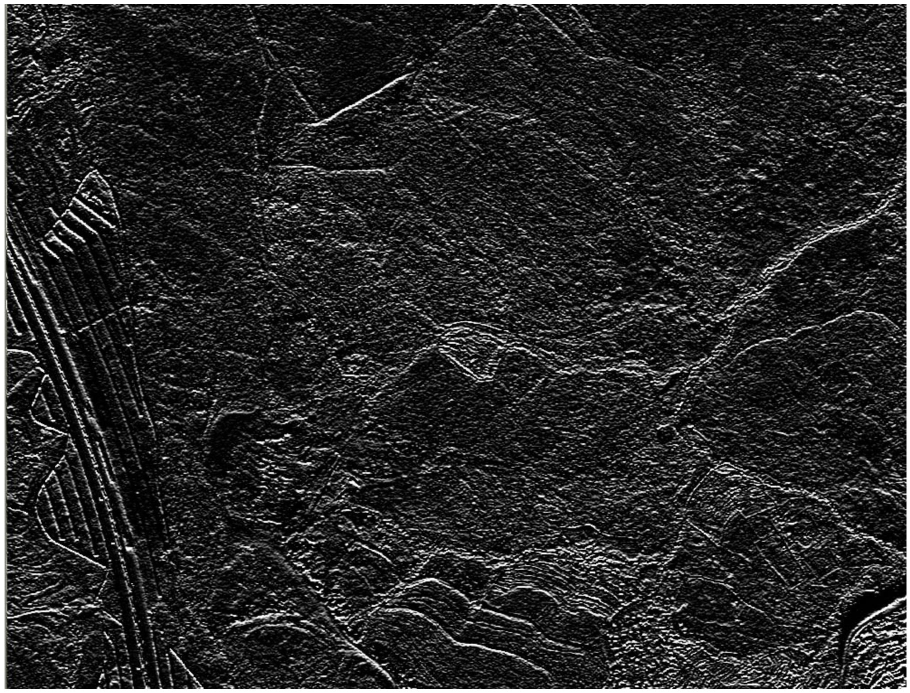


Figure 4.20. The result of the sobel operator

```
var mxSobelPass:TGraphicFilter
    =(FilterType:ftLinear;MatrixSize:mx3;
    Matrix:
 0   0   0   0   0   0   0
 0   0   0   0   0   0   0
 0   0   1   2   1   0   0
 0   0   0   0   0   0   0
 0   0  −1  −2  −1   0   0
 0   0   0   0   0   0   0
 0   0   0   0   0   0   0
    Divisor:1;
    Bias:0;
    FilterName:'Sobel pass (Edge detect linear)';);
```

4.2.2.1.2. Prewitt

Prewitt is an edge detection method which calculates the maximum response of a set of convolution kernels to find the local edge orientation for each pixel. Various kernels may be used for this operation. *The whole set of 8 kernels is produced by taking one of the kernels and rotating its coefficients circularly. Each of the resulting kernels is sensitive to an edge orientation ranging from 0° to 315° in steps of 45°, where 0° corresponds to a vertical edge (*Wikipedia (d) 2007). Figure 4.21 presents the result of the Prewitt edge detection.

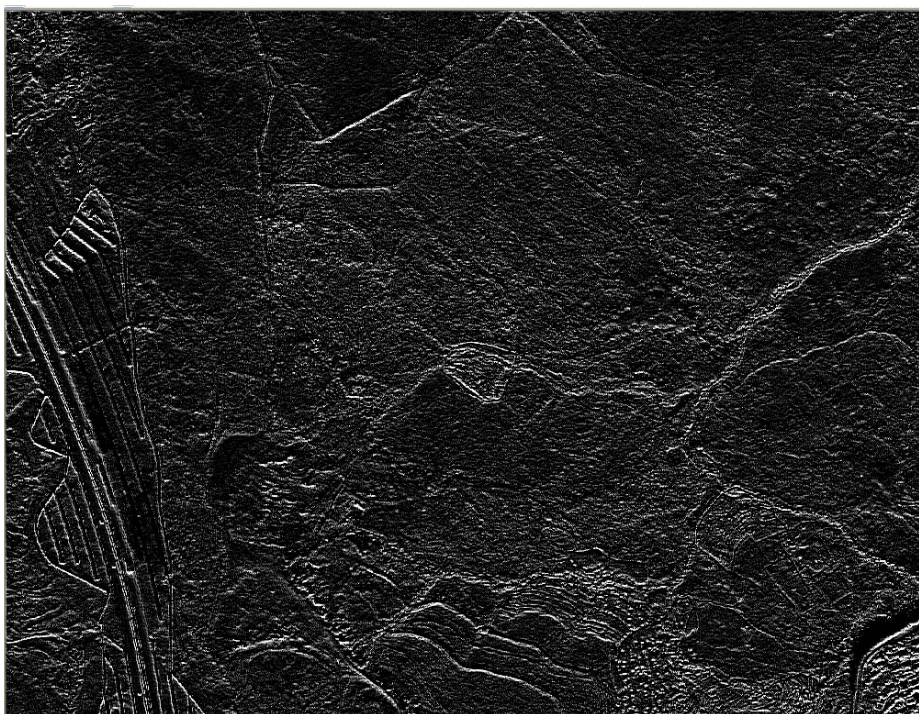


Figure 4.21. The result of the prewitt 2001

```
var mxPrewitt:TGraphicFilter
    =(FilterType:ftLinear;MatrixSize:mx3;
    Matrix:
 0    0    0    0    0    0    0
 0    0    0    0    0    0    0
 0    0    1    1    1    0    0
 0    0    1   -2    1    0    0
 0    0   -1   -1   -1    0    0
 0    0    0    0    0    0    0
 0    0    0    0    0    0    0
    Divisor:1;
    Bias:0;
    FilterName:'Prewitt (Edge detect linear)';);
```

4.2.2.2. Sandy

Figure 4.22 shows the result of sandy filter.

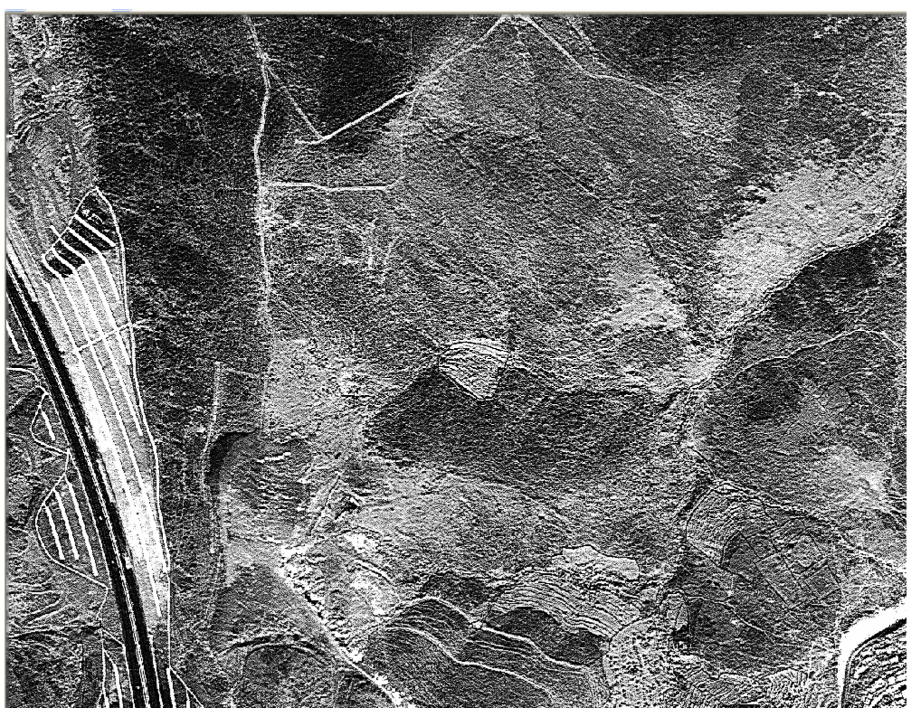


Figure 4.22. The result of the sandy

4.2.2.3. Glowing Edge

Glowing Edges turns the edges into brightly colored lines against a black background. It works especially well with busy pictures with lots of edges. (InformIT 2007). Figure 4.23 shows the result of glowing edge.

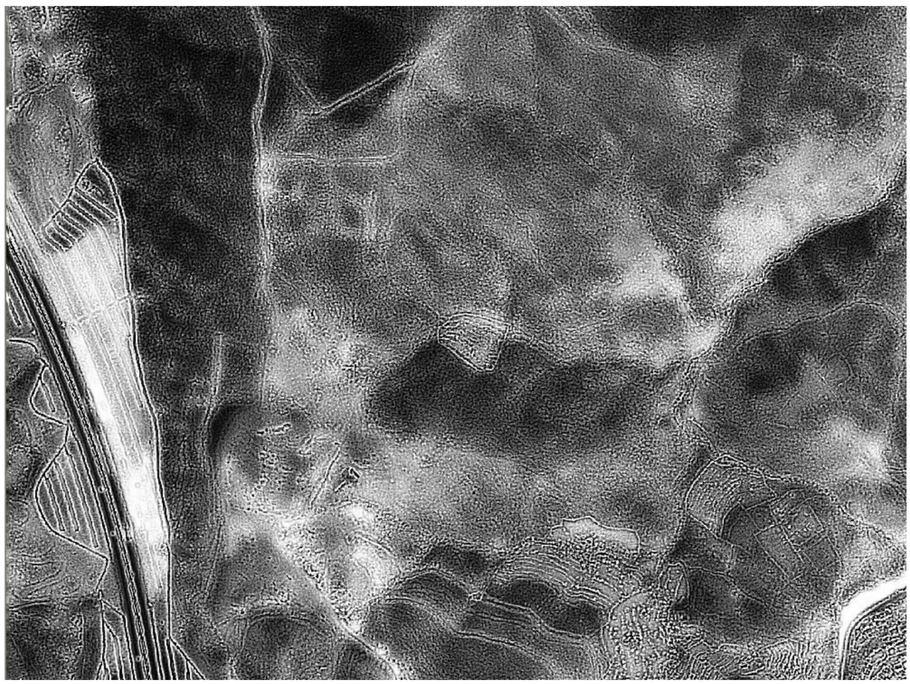


Figure 4.23. The result of the glowing edge

```
var mxGlow:TGraphicFilter
    =(FilterType:ftLinear;MatrixSize:mx7;
    Matrix:

  0    0    0    0    0    0    0
  0    1    2    2    2    1    0
  0    2    0    0    0    2    0
  0    2    0  -20    0    2    0
  0    2    0    0    0    2    0
  0    1    2    2    2    1    0
  0    0    0    0    0    0    0
    Divisor:8;
    Bias:0;
    FilterName:'Glow (Effects linear)';);
```

4.2.2.4. Laplacian

*The Laplacian is a 2-D isotropic measure of the 2nd spatial derivative of an image. The Laplacian of an image highlights regions of rapid intensity change and is therefore often used for edge detection (see zero crossing edge detectors). The Laplacian is often applied to an image that has first been smoothed with something approximating a Gaussian smoothing filter in order to reduce its sensitivity to noise, and hence the two variants will be described together here. The operator normally takes a single gray level image as input and produces another gray level image as output (*The University of Edinburgh, School of Informatics 2007*).*

The Laplacian *L(x,y)* of an image with pixel intensity values *I(x,y)* is given by:

$$L(x,y) = \frac{\partial^2 I}{\partial x^2} + \frac{\partial^2 I}{\partial y^2}$$

It can be calculated using a convolution filter. As the input image is represented as a set of discrete pixels, it has to be found a discrete convolution kernel that can approximate the second derivatives in the definition of the Laplacian. Two commonly used small kernels are shown in Figure 4.24. Additionally, figure 4.25 and 4.26 present the results of the Laplacian hw and omni.

0	–1	0
–1	4	–1
0	–1	0

–1	–1	–1
–1	8	–1
–1	–1	–1

Figure 4.24. Laplacian filter example.

Source: (The University of Edinburgh, School of Informatics 2007)

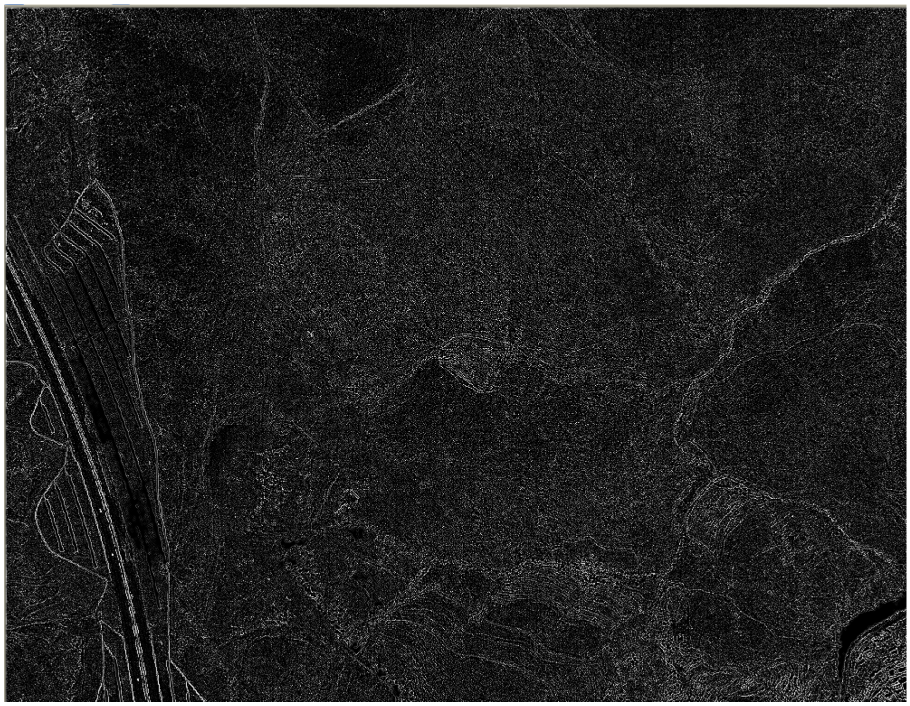


Figure 4.25. The result of the laplacian hw

```
var mxLaplacianHV:TGraphicFilter
    =(FilterType:ftLinear;MatrixSize:mx3;
    Matrix:
 0    0    0    0    0    0    0
 0    0    0    0    0    0    0
 0    0    0   −1    0    0    0
 0    0   −1    4   −1    0    0
 0    0    0   −1    0    0    0
 0    0    0    0    0    0    0
 0    0    0    0    0    0    0
Divisor:1;
    Bias:0;
    FilterName:'Laplacian horz./vert. (Edge detect linear)';);
```

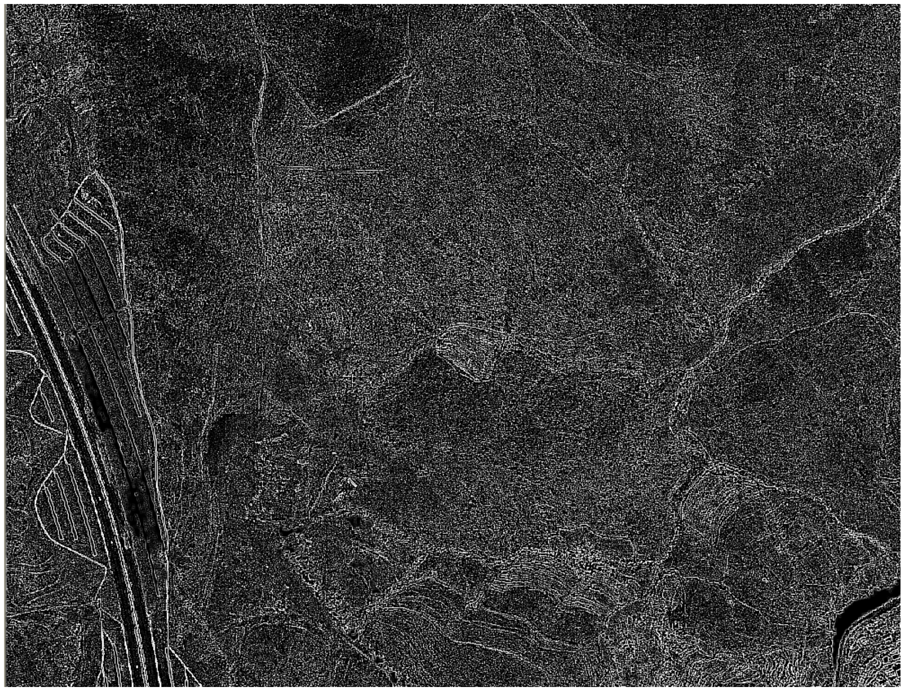


Figure 4.26. The result of the laplacian - omni

```
var mxLaplacianOmni:TGraphicFilter
    =(FilterType:ftLinear;MatrixSize:mx3;
    Matrix:
 0    0    0    0    0    0    0
 0    0    0    0    0    0    0
 0    0   −1   −1   −1    0    0
 0    0   −1    8   −1    0    0
 0    0   −1   −1   −1    0    0
 0    0    0    0    0    0    0
 0    0    0    0    0    0    0
    Divisor:1;
    Bias:0;
    FilterName:'Laplacian omnidir. (Edge detect linear)';)
```

4.2.2.5. Trace Contour

Trace Contour looks at relative brightness levels rather than the usual contrast edges, and surrounds similar areas with a one-pixel-wide line. When it moves the Threshold slider, it can be clearly seen the difference it makes, moving from the dark areas at a low Threshold value to light areas at higher Threshold values. As with Find

Edges and Glowing Edges, it’s best to immediately follow this filter by modifying the blending mode and opacity (Graphics.Com 2007). Figure 4.27 shows the result of the trace contour.

Figure 4.27. The result of the trace contour

```
var mxTraceContour:TGraphicFilter
    =(FilterType:ftLinear;MatrixSize:mx3;
    Matrix:
 0    0    0    0    0    0    0
 0    0    0    0    0    0    0
 0    0   -6   -2   -6    0    0
 0    0   -1   32   -1    0    0
 0    0   -6   -2   -6    0    0
 0    0    0    0    0    0    0
 0    0    0    0    0    0    0
    Divisor:1;
    Bias:240;
    FilterName:'Trace contour (Edge detect linear)';);
```

4.2.3. Spectral Enhancement

Spectral enhancement is modifying pixel values in an image to enhance certain feature over others (Conservation Management Institute, Glossary of GIS and Remote Sensing Terms 2007). Negative, convert to gray and sharpen are the used methods in the thesis as spectral enhancement.

4.2.3.1. Negative

The visible wavelength light flux emitted from each region of the negative is proportional to the silver density of the original negative, even at extremely low densities. The fluorescent light emitted can be detected, integrated, and thereby enhanced by many methods, including rephotography, fluorescence microscopy, or digital image processing methods. The fluorescence image enhancement method is nondestructive and applicable to both underexposed imagery and low-optical-density regions of properly exposed imagery (The Smithsonian/NASA Astrophysics Data System 2007). Figure 4.28 presents the result of negative.

```
var mxNegative:TGraphicFilter
    =(FilterType:ftLinear;MatrixSize:mx3;
    Matrix:
 0   0   0   0   0   0   0
 0   0   0   0   0   0   0
 0   0   0   0   0   0   0
 0   0   0  -1   0   0   0
 0   0   0   0   0   0   0
 0   0   0   0   0   0   0
 0   0   0   0   0   0   0
    Divisor:1;
    Bias:255;
    FilterName:'Negative (Effects linear)';);
```

Figure 4.28. The result of the negative

4.2.3.2. Convert to Grey

Selecting this option will convert any colors in the raster image to the corresponding grey intensity. Figure 4.29 shows the result of convert to grey.

4.2.3.3. Sharpen

The Sharpen filter accentuates the edges in the image by finding the edges and increasing the contrast between adjacent pixels. By default sharpening applied for Lightness color channel only, to avoid halo artifacts and to minimize file size increasing. Parameter Threshold lets you minimize noise amplification in the non edge areas (VIMAS Technologies, Image Processing 2007). Figure 4.30, 4.31, 4.32 and 4.33 show the results of sharpen normal, more, less and directional.

Figure 4.29. The result of the convert to grey - MS image - 2001

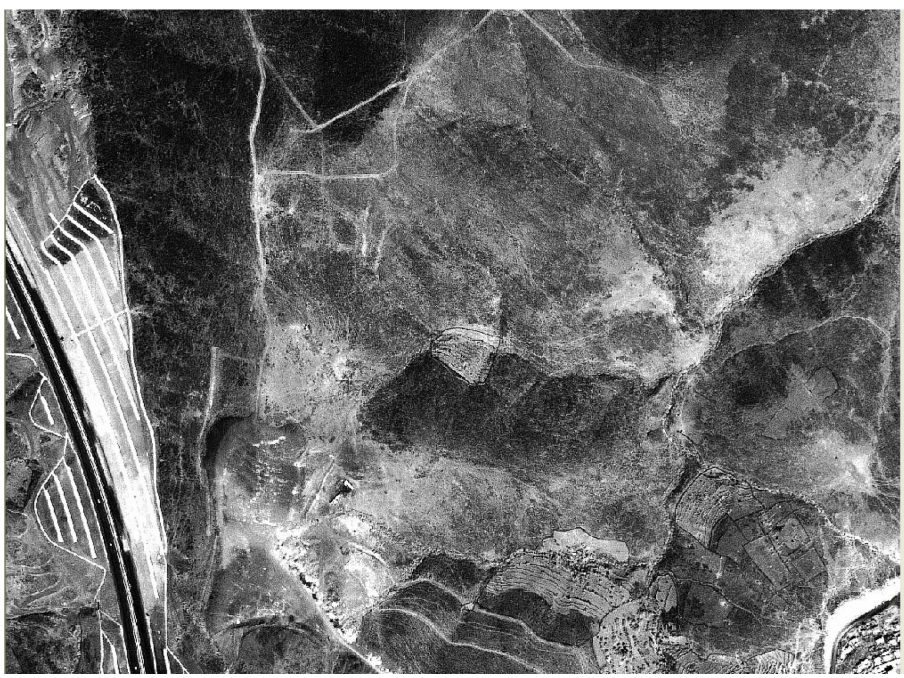


Figure 4.30. The result of the sharpen normal

```
var mxSharpen:TGraphicFilter
    =(FilterType:ftLinear;MatrixSize:mx3;
    Matrix:
 0    0    0    0    0    0    0
 0    0    0    0    0    0    0
 0    0   -1   -1   -1    0    0
 0    0   -1   16   -1    0    0
 0    0   -1   -1   -1    0    0
 0    0    0    0    0    0    0
 0    0    0    0    0    0    0
    Divisor:8;
    Bias:0;
    FilterName:'Sharpen (Sharpen linear)';);


var mxSharpenMore:TGraphicFilter
    =(FilterType:ftLinear;MatrixSize:mx3;
    Matrix:
 0    0    0    0    0    0    0
 0    0    0    0    0    0    0
 0    0   -1   -1   -1    0    0
 0    0   -1   12   -1    0    0
 0    0   -1   -1   -1    0    0
 0    0    0    0    0    0    0
 0    0    0    0    0    0    0
    Divisor:4;
    Bias:0;
    FilterName:'Sharpen more (Sharpen linear)';);

var mxSharpenLess:TGraphicFilter
    =(FilterType:ftLinear;MatrixSize:mx3;
    Matrix:
 0    0    0    0    0    0    0
 0    0    0    0    0    0    0
 0    0   -1   -1   -1    0    0
 0    0   -1   24   -1    0    0
 0    0   -1   -1   -1    0    0
 0    0    0    0    0    0    0
 0    0    0    0    0    0    0
    Divisor:16;
    Bias:0;
    FilterName:'Sharpen less (Sharpen linear)';);
```

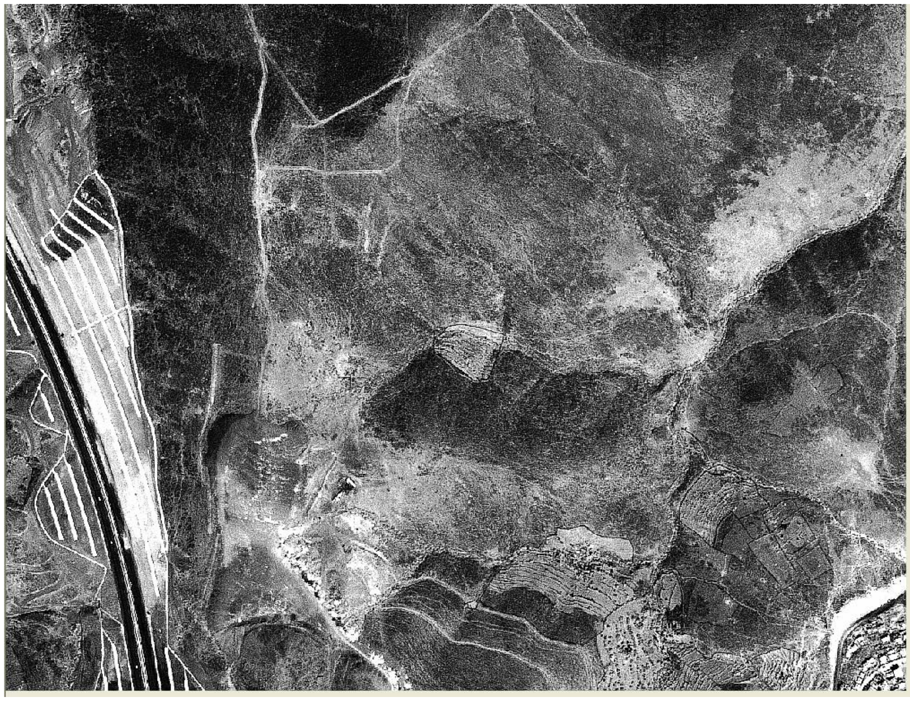


Figure 4.31. The result of the sharpen more

Figure 4.32. The result of the sharpen less

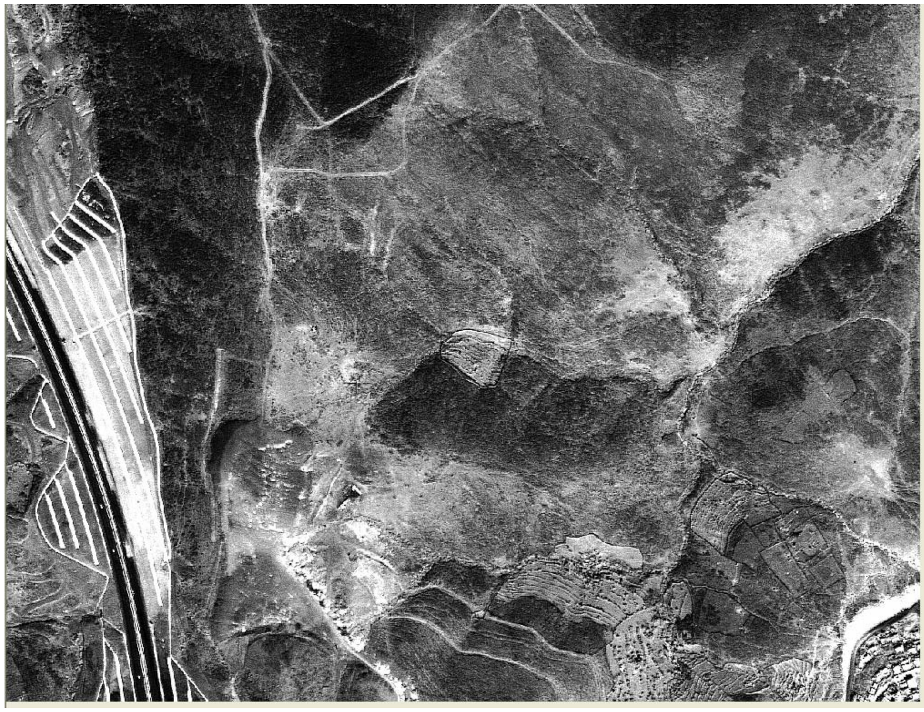


Figure 4.33. The result of the sharpen directional

```
var mxSharpenDirectional:TGraphicFilter
    =(FilterType:ftLinear;MatrixSize:mx3;
    Matrix:
 0    0    0    0    0    0    0
 0    0    0    0    0    0    0
 0    0   -3   -3   -3    0    0
 0    0    0   16    0    0    0
 0    0    1    1    1    0    0
 0    0    0    0    0    0    0
 0    0    0    0    0    0    0
    Divisor:10;
    Bias:0;
    FilterName:'Sharpen directional (Sharpen linear)';);
```

4.3. Fuzzy Inference

Fuzzy inference is the process of formulating the mapping from a given input to an output using fuzzy logic. The mapping then provides a basis from which decisions can be made, or patterns discerned. The process of fuzzy inference involves all of the pieces that are described in the previous sections: Membership Functions, Logical Operations, and If-Then Rules (The MathWorks (a) ,2007).

Fuzzy inference systems can be successfully applied in fields such as automatic control, data classification, decision analysis, expert systems, and computer vision. Because of its multidisciplinary nature, fuzzy inference systems are associated with a number of names, such as fuzzy-rule-based systems, fuzzy expert systems, fuzzy modeling, fuzzy associative memory, fuzzy logic controllers, and simply (and ambiguously) fuzzy systems.

There are two types of fuzzy inference systems that can be implemented in the Fuzzy Logic Toolbox: Mamdani-type and Sugeno-type. Nedeljkovic (2004) has stated that Mamdani's fuzzy inference method is the most commonly seen fuzzy methodology and it expects the output membership functions to be fuzzy sets. After the aggregation process, there is a fuzzy set for each output variable that needs defuzzification. On the other hans, Sugeno-type systems can be used to model any inference system in which the output membership functions are either linear or constant. Sugeno output membership functions (z, in the following equation) are either linear or constant. A typical rule in a Sugeno fuzzy model has the following form:

If Input 1 = x and Input 2 = y, then Output is $z = ax + by + c$

For a zero-order Sugeno model, the output level z is a constant ($a=b=0$).

A Sugeno rule operates as shown in the following diagram, in Figure 4.34.

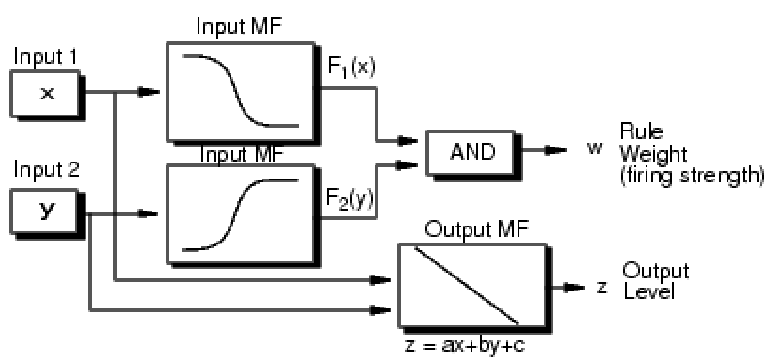


Figure 4.34. Interpreting the fuzzy inference diagram

(Source: The MathWorks (b), 2007)

Fuzzy sets and fuzzy operators are the subjects and verbs of fuzzy logic. Usually the knowledge involved in fuzzy reasoning is expressed as rules in the form:
If x is A Then y is B

where x and y are fuzzy variables and A and B are fuzzy values.

The if-part of the rule "x is A" is called the input or premise, while the then-part of the rule "y is B" is called the result or conclusion. Statements in the input (or result) parts of the rules may well involve fuzzy logical connectives such as ‘AND’ and ‘OR’. In the if-then rule, the word "is" gets used in two entirely different ways depending on whether it appears in the input or the result part.

CHAPTER 5

DETECTION OF ENVIRONMENTAL CHANGES: THE CASE STUDY IN IZMIR

5.1. Characteristics of the Thesis

In this chapter, information about the study area, the data used and the processes for preparing remotely sensed data are provided. First, the study area will be described and the main reasons for selecting the site and the investigation period will be explained. Then, the remotely sensed and ancillary data used during this study will be described. Finally, the preparation of vector data which is integrated into change detection process and its use will be described.

5.1.1. The Study Area and Data

The study area, shown in Figure 5.1, is located is the south of İzmir. It contains the districts, called Limontepe, Cennetçeşme, Salih Omurtak and Yüzbaşı Şerafettin. It is approximately covering 30 km^2. The case area, represented some parts in Figure 5.2, is in Konak because Konak is the biggest district in terms of settlement density and also the center of İzmir. On the other hand, archive satellite images obtained from firms effected the site selection. For example, a cloudy image cannot be used for change detection process. This area has the clearest scene among available the archive images of the other districts.

Figure 5.1. İzmir and the case area

(Source: Google Earth, 2006)

Figure 5.2. Some part of the case area, 2006-11-30

(Source: Google Earth, 2006)

Table 5.1 shows the coordinates of the study area as UTM both metric and degree types. Point 1 is at the bottom of the left corner, point 2 is at the bottom of the right corner, point 3 is at the top of the right corner and point 4 is at the top of the left corner of a rectangle.

Table 5.1: UTM coordinates of the study area

Point number	Y	X	Y	X
1	505700,322	4244866,271	27°03' 54.84756"	38°21' 04.67356"
2	505707,498	4250429,086	27°03' 55.30550"	38°24' 05.15030"
3	510707,836	4250429,086	27°07' 21.45627"	38°24' 04.98498"
4	510707,836	4244903,119	27°07' 21.15377"	38°21' 05.70386"

Monitoring urban change provides a basis for the description and maintenance of environmental resources and urban activities. This monitoring process can be made in a variety of time: annually, monthly or daily depending on the needs. However, the greatest efficiency could be achieved if the monitoring is achieved continuously.

Figure 5.3 and 5.4 represent the panchromatic and multi spectral IKONOS images some part of the area. As shown in the figure buildings can more easily detec t in panchromatic image because of the high resolution. In the figure 4 band combinations are true color, in other words band combination is 1, 2, and 3.

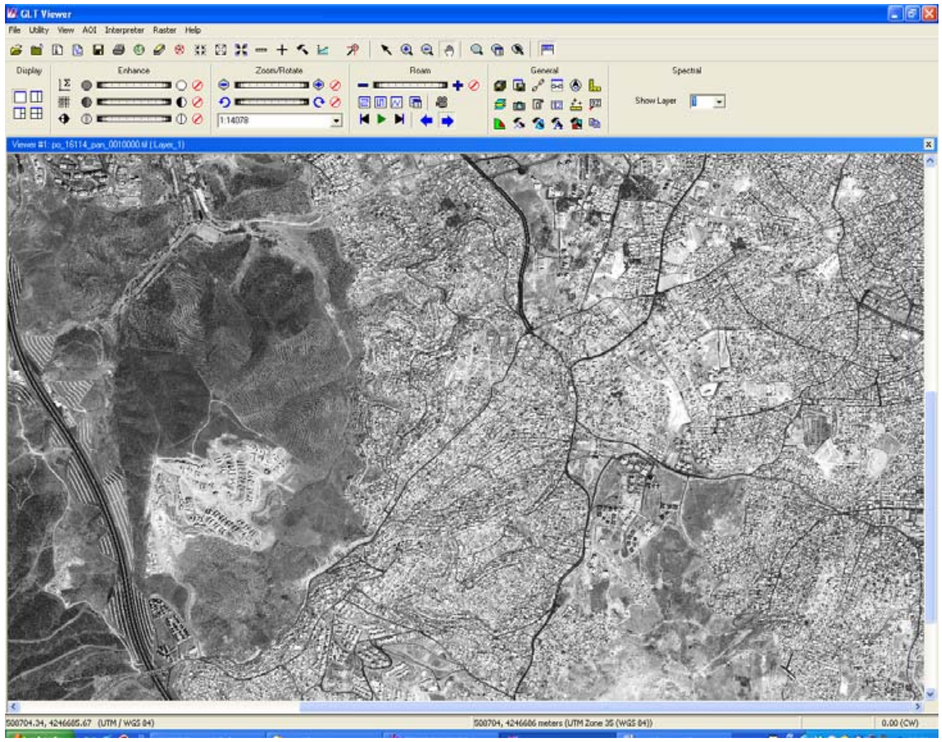


Figure 5.3. The panchromatic view of the area

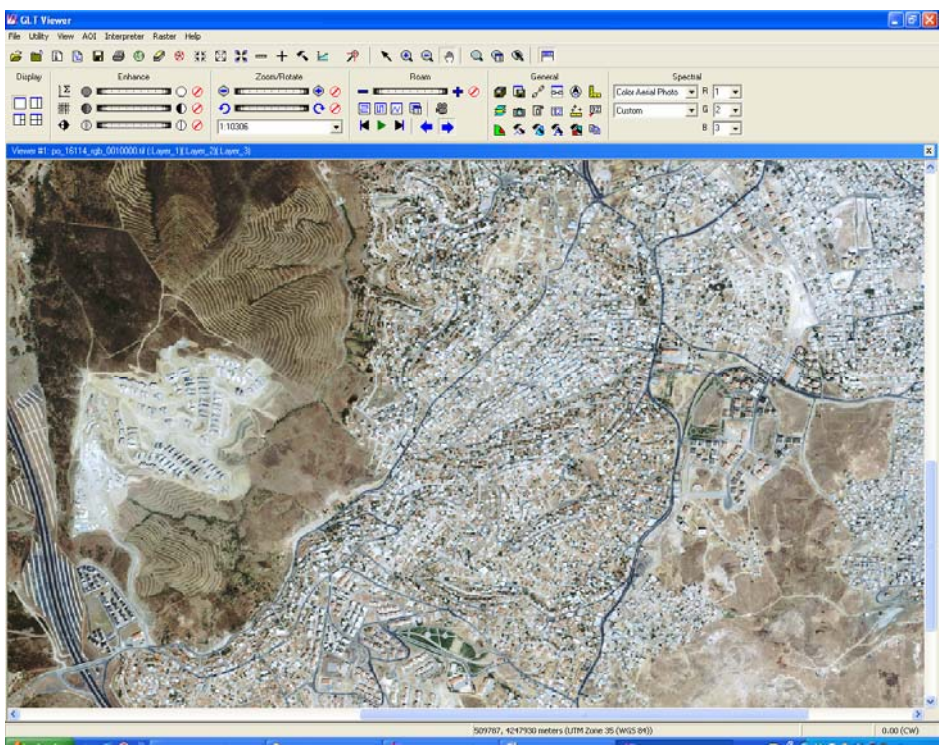


Figure 5.4. The multi spectral view of the area

5.1.2. Algorithms of the Thesis

This thesis contains 3 different types of algorithms, shown in Figure 5.5. These are data preparation, change detection and GIS algorithms. They all have a relationship each step of the case. They will be explained detaily in the following sections.

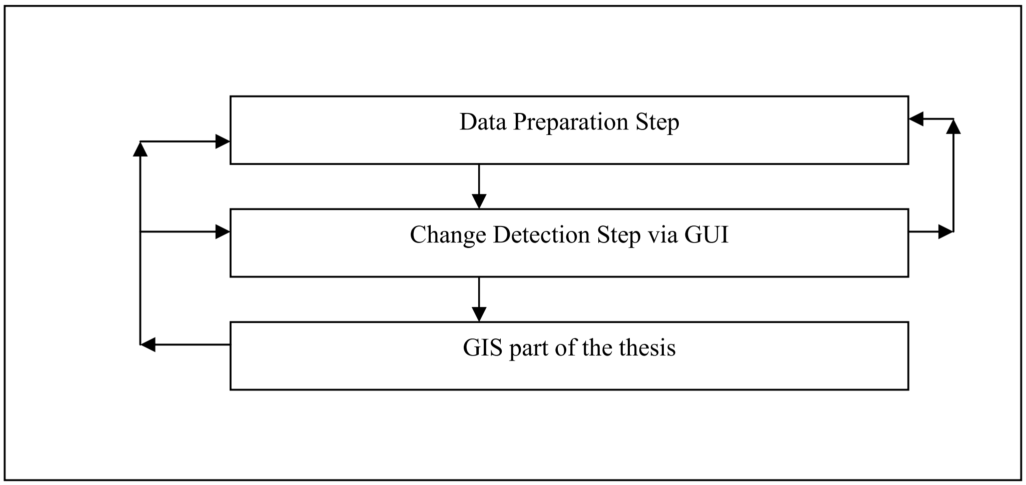


Figure 5.5. The relations of the algorithms

5.1.2.1. Data Preparation Algorithm

Remotely sensed data preparation for change detection process, shown in Figure 5.6, has been started with mosaicking images and performing geometric correction. Different datum usage while coordinating a satellite image or a digital map causes to geometic shifts. In order to reduce this shifting, geometric correction has been used. However, nevertheless, there never has obtained a % 100 success for geometric correction, because the satellites' could not pass at the same place at the same angle. Because of the high file sizes of the big images, they should be divided into small pieces after geometric correction. This makes the change detection process more accurate and has less time to be completed. Although geometric correction has been performed at first, controlling geometric shifts could be neccessary for the small pieces. At the end of this step, the result has to be converted to TIFF format.

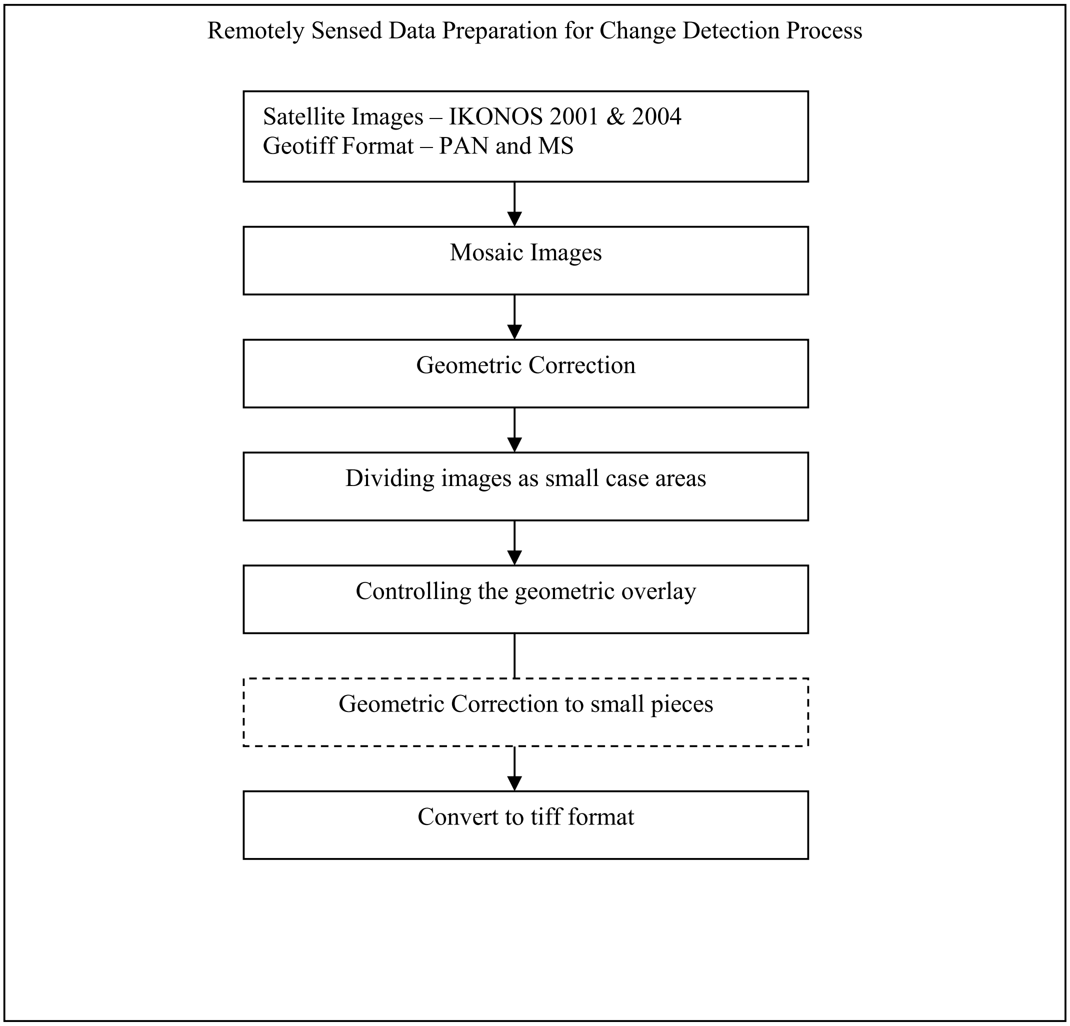


Figure 5.6. Data preparation algorithm

5.1.2.2. Graphical User Interface Algorithm

As represented in Figure 5.7, images are chosen as a source and a target. After that, coordinate information is entered. The left upper point of the images will be the first coordinate. X coordinate increases as going to the right, y coordinate decreases as going to the down.

Different spatial, spectral and radiometric image enhancement methods are used to increase the accuracy of the change detection result. Which algorithm should be used to which image, how many times and which order are the questions needs to be answered. These algorithms could be made filtering during the process. At the end of these processes the certain source and target is chosen for the comparison. Then, the difference percentage and the methodology are decided. When the “difference” has got, it could be saved or transferred the coordinates into an Access file. Therefore, these coordinates could be used to be linked with GIS, in MapInfo. At the end, the result is controlled.

5.1.2.3. GIS Part Algorithm

Figure 5.8 presents GIS part of algorithm. There are two types of data in GIS part of the thesis: (i) digital (vectorel) data and (ii) satellite images (raster data). The raster data should be registered. Additionally, geometric shift between raster and vector is controlled. Then, the “difference” result and the digital map are overlaid. Moreover, layer buttons created in MapBasic environment are used to order the layer arrangement.

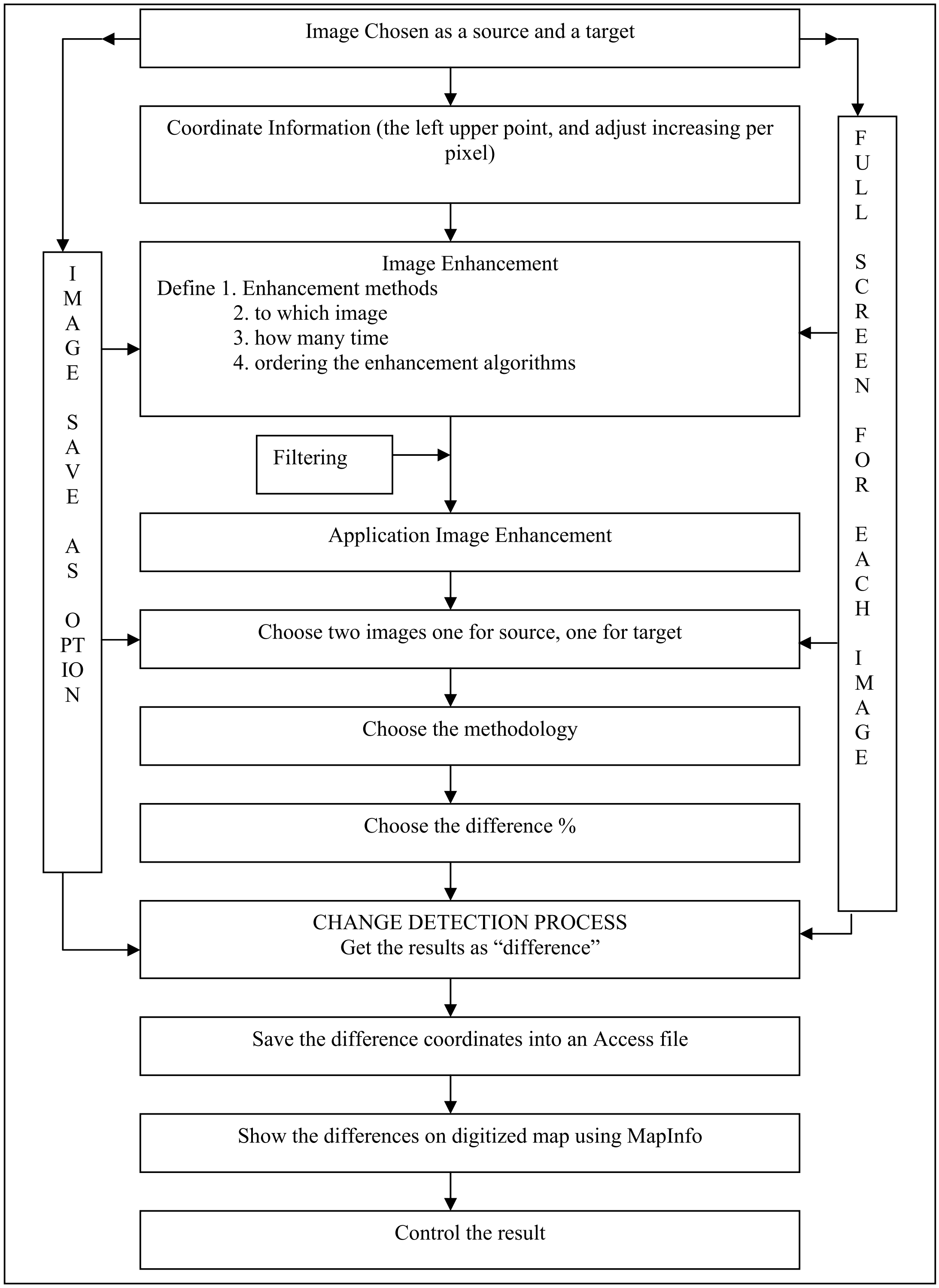


Figure 5.7. Change detection algorithm

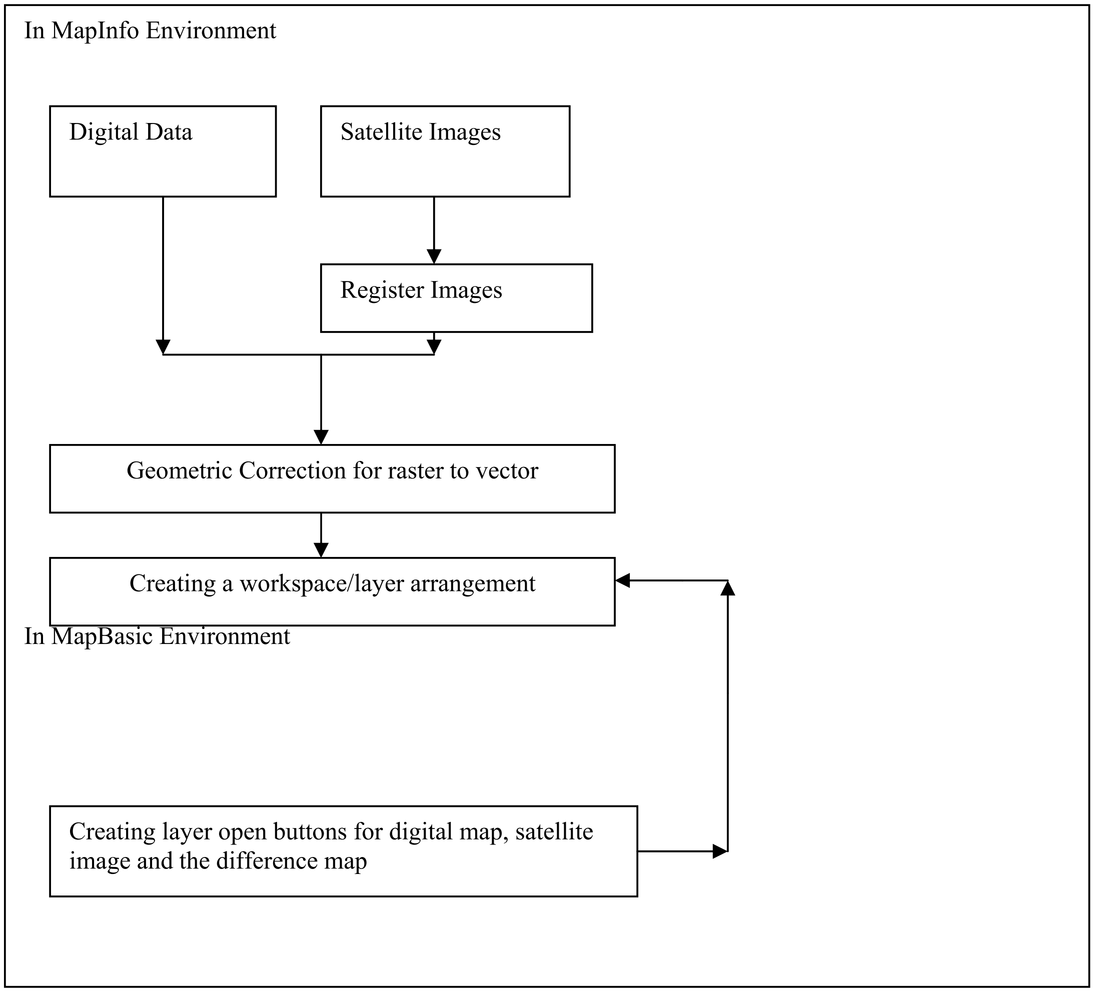


Figure 5.8. GIS algortihm

5.2. Components of the Thesis

Detection of environmental change process is composed of three parts: (i) system definition, (ii) system design and (iii) system realization.

(i) The system definition consists of the determination of the present situation, necessities and expectations of the local governments.
(ii) The system design is composed of data, process and physical design.
(iii) The system realization involves pilot area selection, preparation of data and graphical user interface, system test and analyses.

The present situation, necessities and expectations of the local governments were cited in the previous chapters. Therefore, this chapter basically deals with the system design and realization.

5.2.1. The System Design

The system design can be divided into three parts such as data, process and physical designs. The following sections will discuss these design types.

5.2.1.1. Physical design

The physical design needs to be examined according to software and hardware necessities. The detection of environmental change process requires a Pentium IV 3.0GHz computer with 1 GB of RAM (2 GB is preferred), minimum 100 GB hard disk and a DVDRW.

Change detection process, in this thesis contains five different software:

1. ERDAS: It is used in order to make mosaic, geometric correction, to create sub-areas from satellite images, and also to convert them to tiff format.
2. Delphi: The graphical user interface (GUI) is created using this software.
3. MS Access 2003: It is used in order to save the difference coordinates, so the result can be able to link GIS environment.

4. MapInfo: It is used in order to compare and make overlay the change detection result and the digital as-is map.
5. Map Basic: MapInfo Macro Language, which gives the opportunity to link Delphi GUI to MapInfo. It is also used in order to be created layer icons on MapInfo.

There are several reasons why MapInfo is selected, as a map based application software. Firstly, MapInfo software has a Turkish version. So, the staff in the local governments who do not know English can easily learn and use. In addition, MapInfo can use all kinds of vector or raster-based geographical data whether in CAD or GIS formats. Moreover, all Windows users are MapInfo user at the same time because, Microsoft uses MapX technology in the MS Excel Datamap process and MapInfo supports Sequential Query Language (SQL), the most well-known database management query language. This allows users to perform queries on MapInfo. As a result, MapInfo database can be adapted to other software easily because MapInfo has interchangeable database file formats. Interactive Object Database Connectivity (ODBC) option in MapInfo allows users to connect other databases (even from different locations) and get all kinds of data and to use them in SQL and Oracle. MapInfo can also accept ASCII, dBASE DBF, Lotus 1-2-3, Ms Excel, MS Access, Informix, Sybase, Ingres file formats. Database servers are often used with MapInfo applications as on-line interactive data exchange.

MapInfo file is composed of different type of extensions. These are:

a. File.TAB: table structure information.
b. File.ID: reference file of the table.
c. File.MAP: the map objects.
d. File.DAT: database of the table.
e. File.IND: index files.

Map Basic is a macro programming language. Syntactically, it looks like QBasic, structurally like Pascal and Delphi. Map Basic provides MapInfo to integrate with C/C ++, Visual Basic or Delphi.

5.2.1.2. Data preparation

Satellite images, IKONOS, have been obtained from a private firm in Ankara. These are Geotiff format at the beginning of the thesis. First of all, the images are mosaicked in order to derive Digital Elevation Models (DEMS) and thematic content suitable for GIS analysis, because satellite images remain the primary data source. In addition, they can be interpreted for landscape features and heights. When images are mosaicked together they cover a larger area with similar nominal scale, thereby acting as planimetric maps (GIS Vision 2006). Then, geometric correction process is performed. *The geometric correction alters data to correspond with true ground or image space in a known coordinate system (*Richland County GEOgraphic Information Systems 2006). This process has to be performed for satellite images, because satellites never pass the same place at the same angle while taking photos. When these different angled photos are overlaid, there observes a shift between two images. There is no way to make 0 (zero) shift for these images. However, geometric correction gives the better result to adjust the images in order to perform change detection process correctly. Figure 5.9 and 5.10 show the geometric correction process made by ERDAS. The more ground control point (GCP) gives the better results for geometric correction.

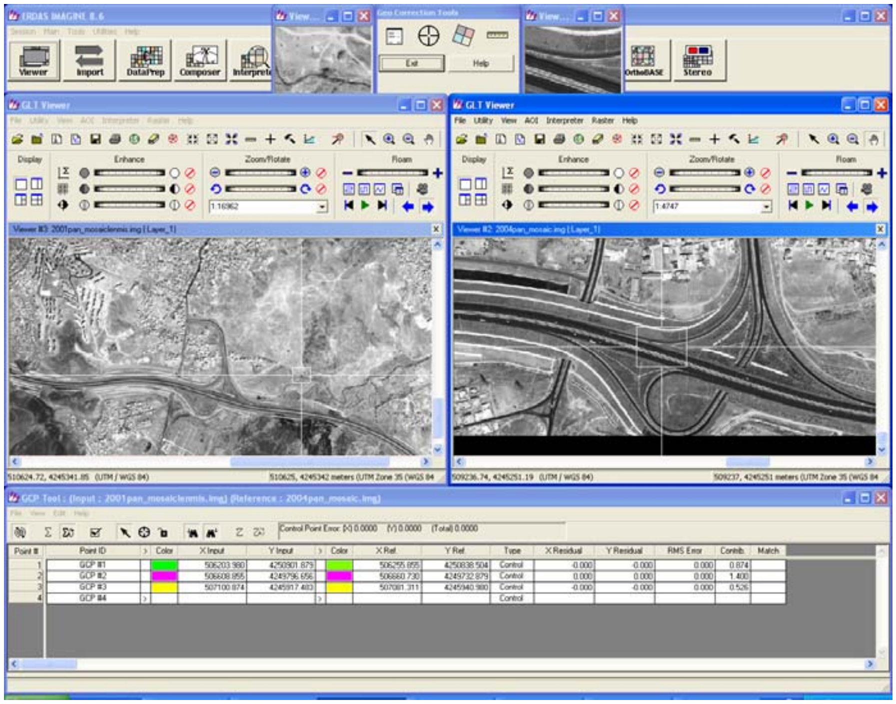


Figure 5.9. Geometric correction – step 1

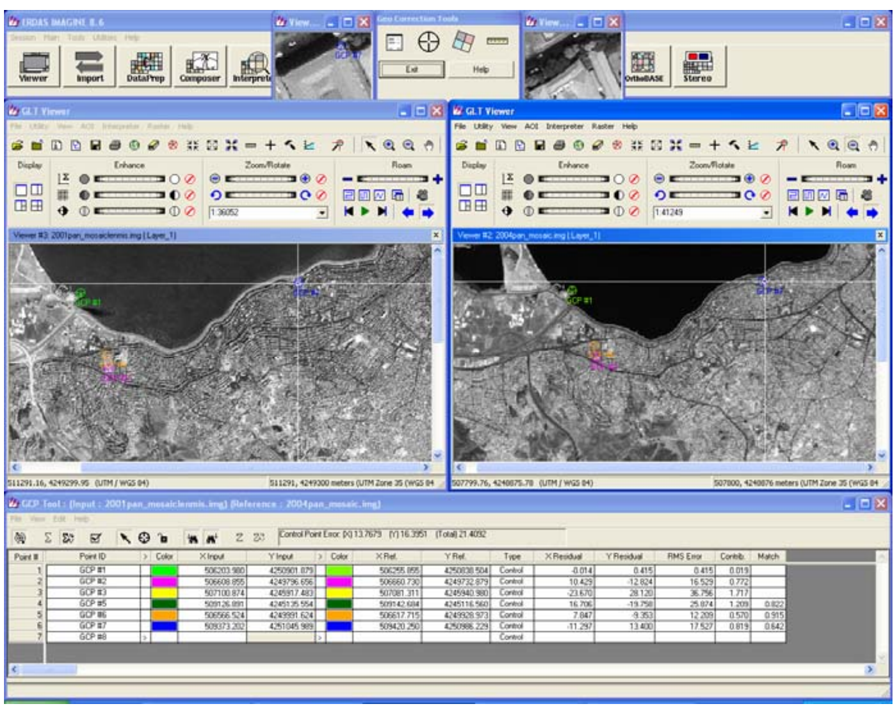


Figure 5.10. Geometric correction – step 2

The next step in the data preparation is to divide images small sub-areas. The sub-areas have fewer features, so the computer can easily detect the difference between two images. Figure 5.11 and 5.12 show the examples of the sub-area preparation. The importat points of the division process are:

- To link 2 images spatially (geometrically)
- To crete subsets in the same areas
- To control their geometric corrections again
- To convert them to TIFF format

The divided images for the case study have 945 x 843 pixels. In other words, each image is composed of 796.635 pixels. As the image resolutions increase, the total pixel umbers will increase, too.

The left upper points of the images have to be the same point, so there is no mistake to be coordinated. While the change detection process, that point is used for the beginning of the coordinates.

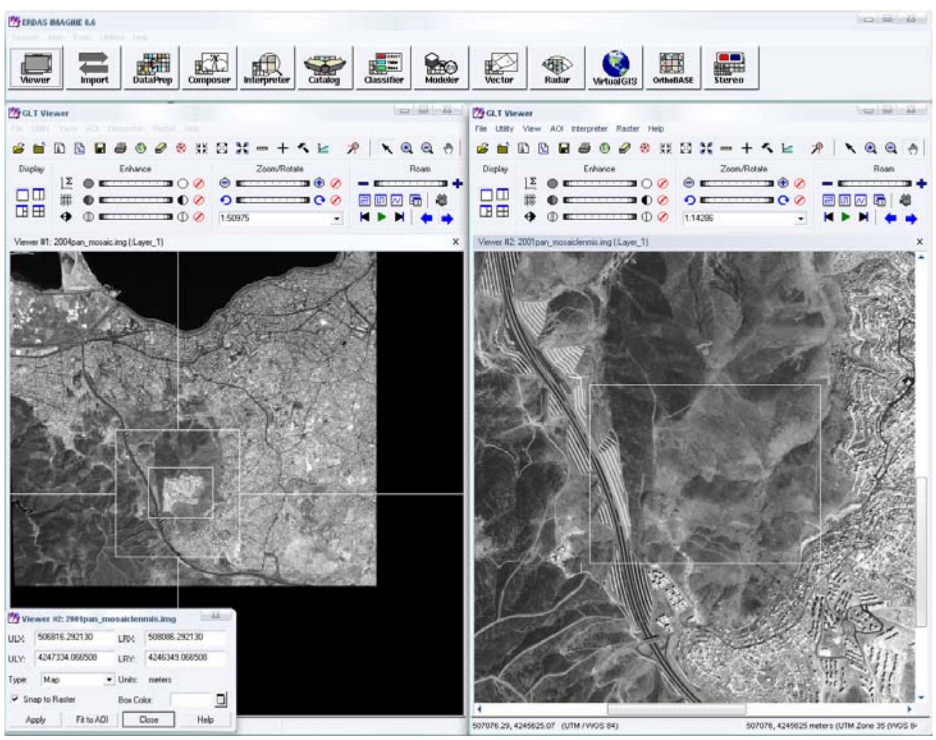


Figure 5.11. Creating subset areas from PAN images

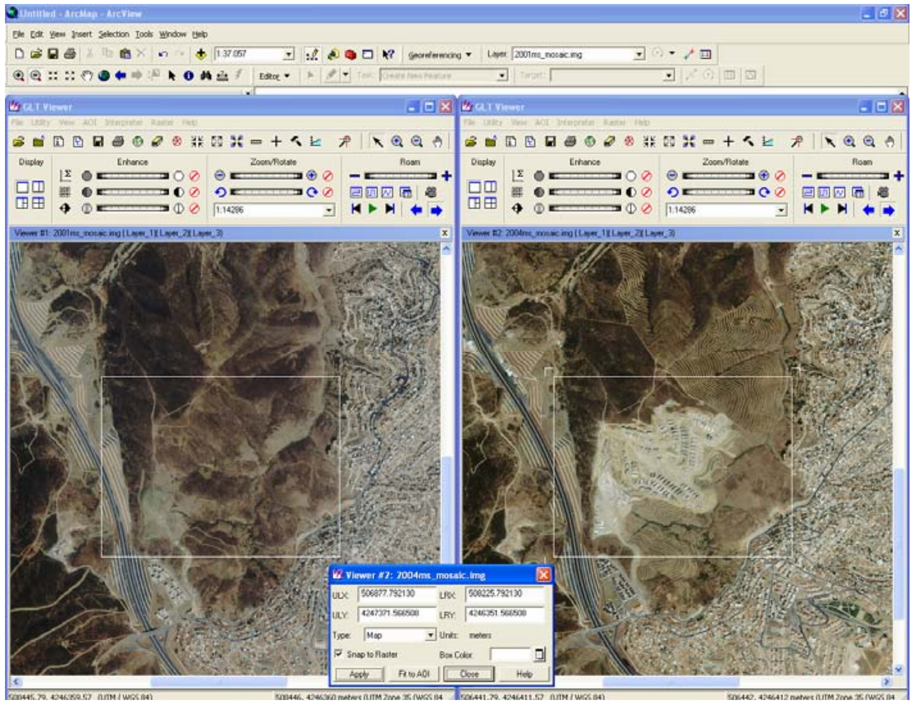


Figure 5.12. Creating subset areas from MS images

5.2.1.3. Process Design

This section of this thesis is composed of the definition of the GUI. It has 3 different pages. In this concept, figure 5.13 shows the first page of the GUI. It has open and clear commands for the source and the target. As being a TIFF format image, both of the images have to be coordinated using "coordinate information" part. The important thing here is x and y coordinates must be at the left upper coordinates. The algorithm of the coordinate was created as increasing to the x axis and decreasing to the y axis. The increase and the decrease values are determined using "X++" and "Y++" parts. In this thesis, coordinate increase and decrease value is 1; because, IKONOS panchromatic images are used for change detection, and their resolution is 1 m/pixel.

"Background" and "difference" parts contain the color information of the difference image. They could be set manually, and also users could show the colors simultaneously. When the source and the target are opened, program automatically calculates the minimum and the maximum pixel difference. At the end of the calculation, the results are written in front of the "Max difference" and "Min difference" places. Then "pixel difference" and "pixel % difference" will be active. According to the chosen of "difference type", the pixel difference and % difference will be changed. The user could detect the difference or the % manually. This proportion of difference could depend on the satellite image resolution, the selected algorithm and the area which is wanted to be detected such as building or green areas

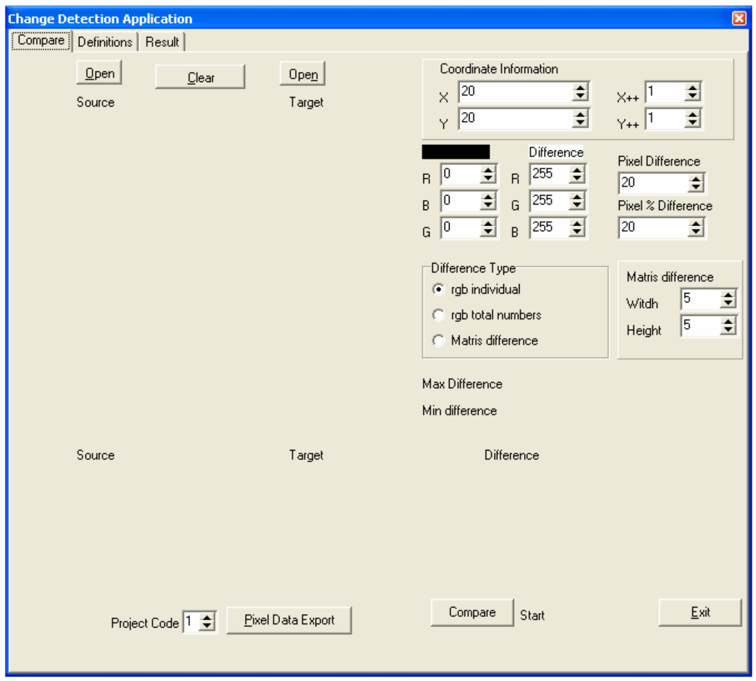


Figure 5.13. The first page of the GUI

There are 4 types of difference type in this thesis. The first one, rgb individual, is composed of the calculation the layers one by one. The second, rgb total numbers, contains total pixel value whole layers. Matris difference requires a matris definition as width and height. The chosen matris will be compared both the source and the target. The last approach is shown in the figure 5.14 called different matrises comparison. In lecture review, it is called as feature extraction. "Neighbor control" must be checked for using this algorithm.

This page also has "project code" information and "pixel data export" command. After detecting the difference places, its difference pixels could be exported to MS Access with X and Y coordinates information. The "GIS connection" command provides the user show the results in MapInfo environment. So, the difference could easily be linked to GIS environment and overlaid with as-is situation. In addition to these commands, there are also 2 commands in this page called "compare" and "exit".

The “compare” is used to start the comparison process. The “exit” is used to exit the program.

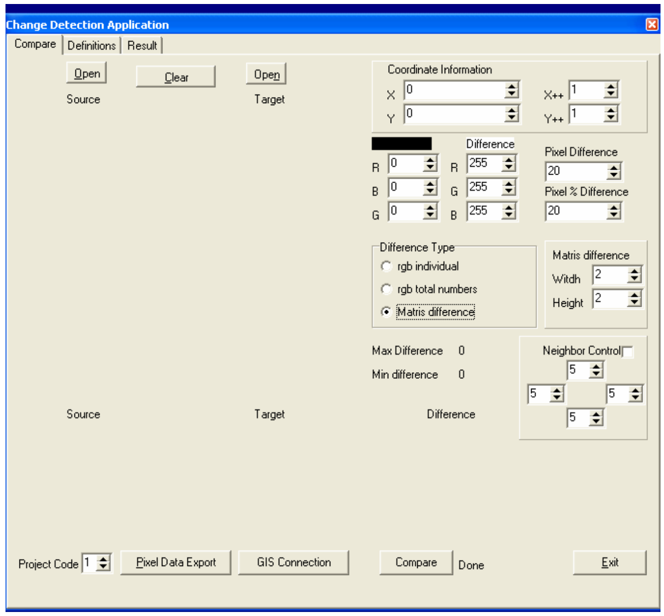


Figure 5.14. Matrix and neighbor control frame in the first page

The second page of the GUI contains the algorithm definition step, shown in Figure 5.15. There are different questions need to be answered; for example:

- Which algorithm is used for which image?
- How many times that algorithm is used?
- Which order is used for algoritms?

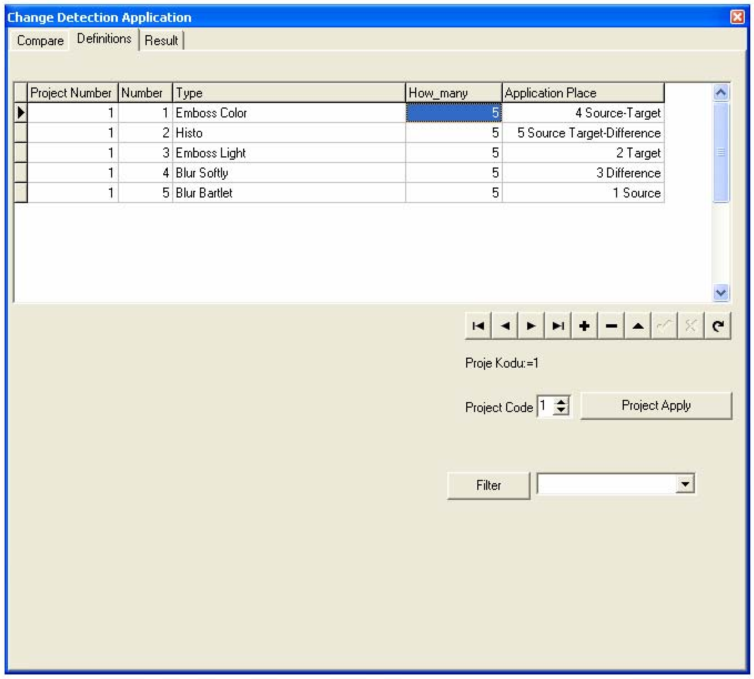


Figure 5.15. The second page of GUI

There is no limitation for making combinations in these algorithms. Table 5.3 shows the icons meanings.

Table 5.2. Icons definitions

Icon	Meaning
+	To add a row
–	To remove a row
▲	To make the list button active
◀	Previous row
▶	Next row
⏮	The first row
⏭	The last row
✓	OK
×	Delete
⟳	Refresh

"Project code" means a number for each change detection application performed by the user. Additionally, selected project number could be applied using "Project Apply" button. "Filter" part is used to list selected images algortihms in the second page, an example is shown in Figures 5.16 and 5.17. So, the user could easily follow which algorithm is used for which image.

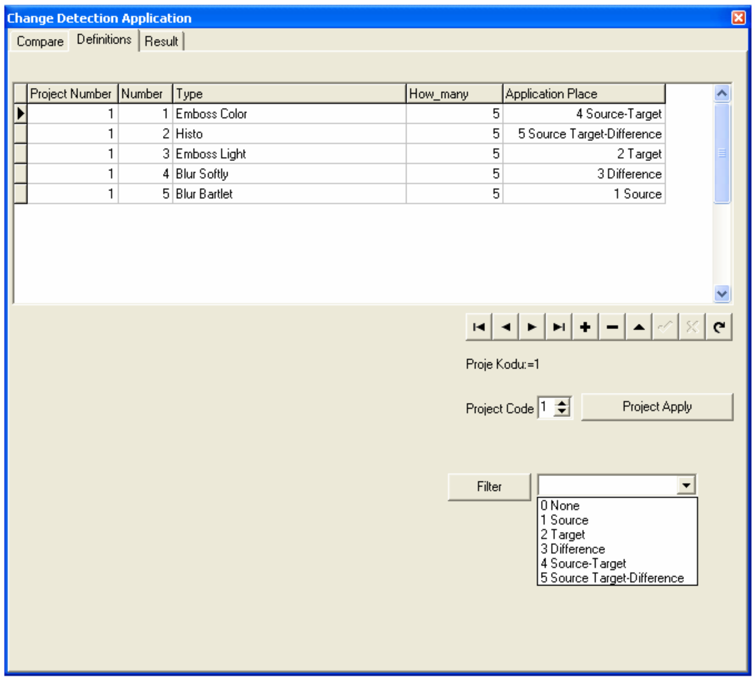


Figure 5.16. Filter command view

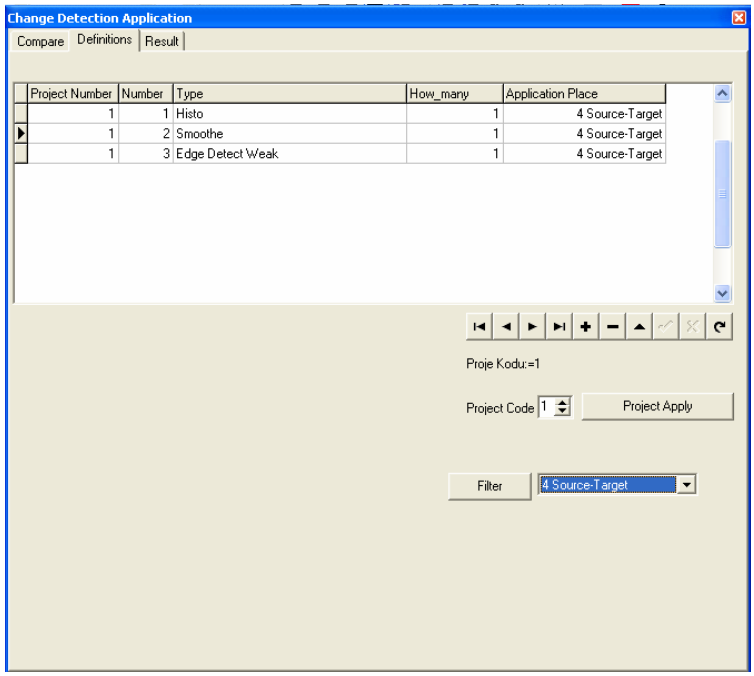


Figure 5.17. A filter example for source and target

The algorithms are listed below and also each algorithm has been explained in the previous chapter, also shown in Figure 5.18. These are:

- Histogram Equalization
- Emboss (color-light-medium-dark)
- Glow
- Blur (Bartlet-Gaussion-softly-more)
- Edge Detection (edge enhance-strong-weak) (sobel-prewitt)
- Sharpen (normal-more-less-directional)
- Trace contour
- Lablacian (Hw-Omni)
- Glowing edge
- Sandy
- Negative
- Smoothe
- Convert to gray

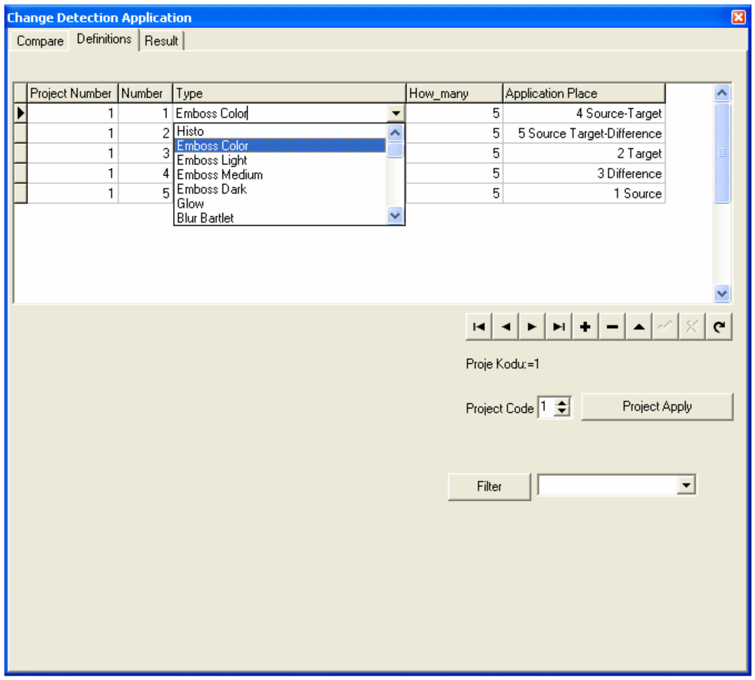


Figure 5.18. The algorithms

The result of each algorithm is shown in the third page of the GUI, presented in figure 5.19. Selected images as source and target could be picked by “source” and “target” buttons. Therefore, the selected images are sent to page one of the GUI in order to perform chage detection. For each images, there is a chance to see full screen view in another screen, represented in figure 5.20. In this screen, there is zoom in and zoom out options; also the user could select by manually zoom in and out ratio. Moreover, any image could be saved using “save” command, and “close” command is used to close the full view screen. “Save” command view is shown in Figure 5.21.

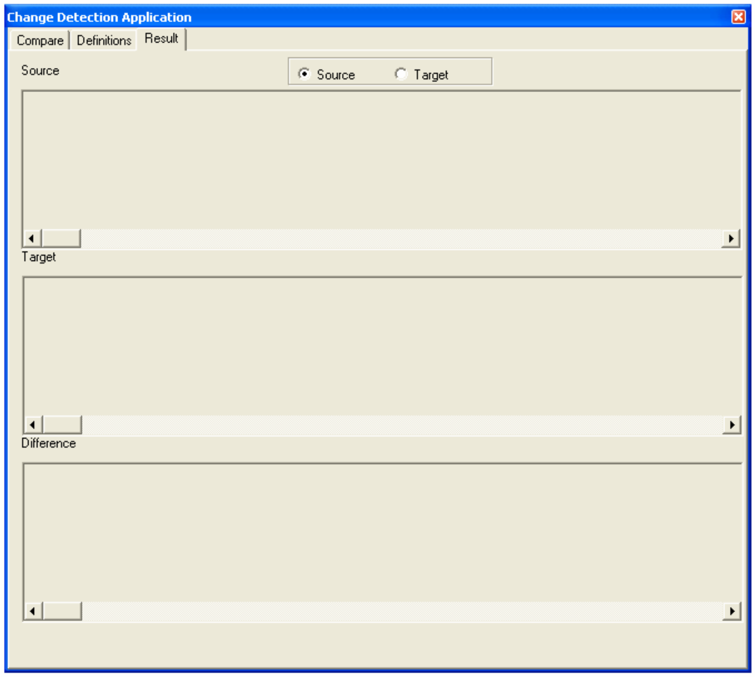


Figure 5.19. The third page of the GUI

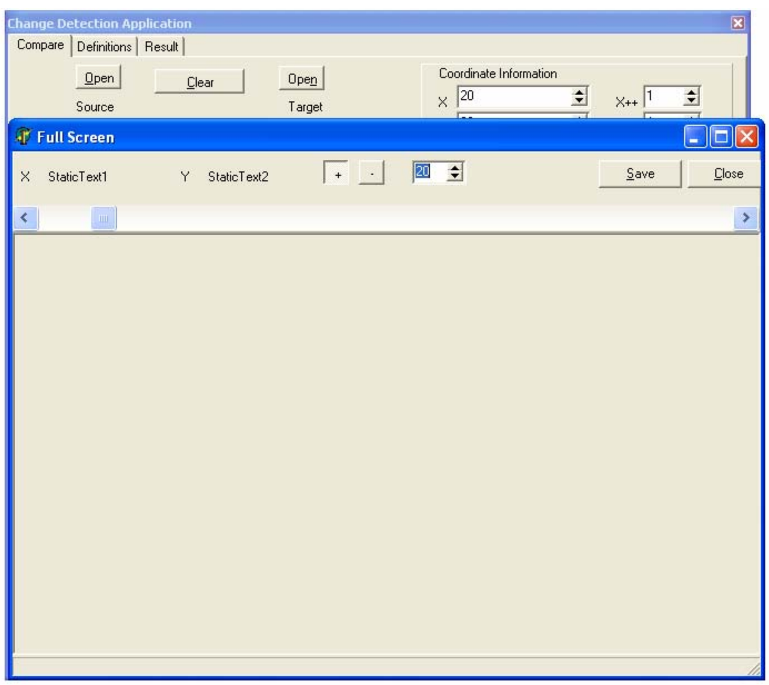


Figure 5.20. Full screen view

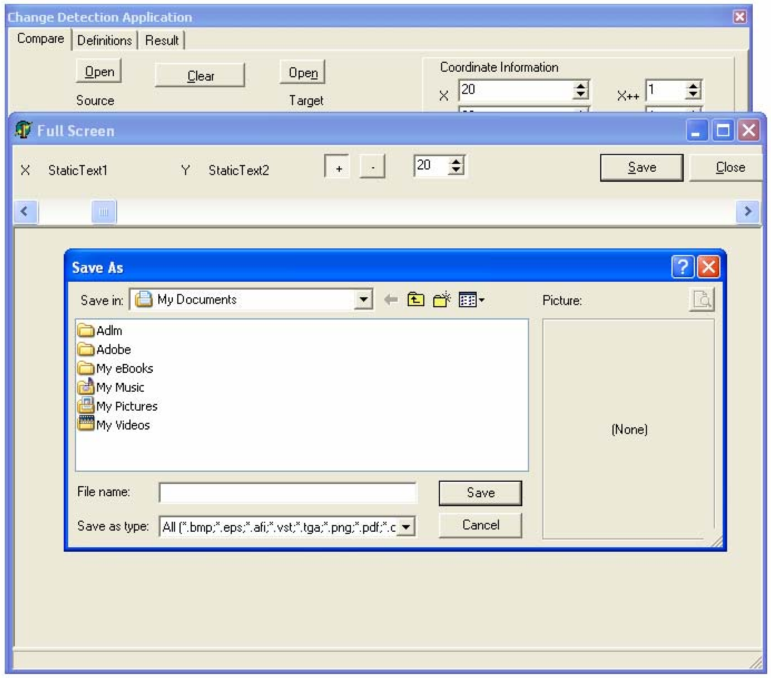


Figure 5.21. “Save” command view

5.2.2. The System Realization

This section represents the application of change detection and linking to GIS. There will be four (4) methods for detecting changes at the same area. The results of change detection processes will be compared, and then the realistic result will be suggested as default for the users. During this process, it is important that what the area contains as features. The settlement areas and the green places could not give the same results with the same algorithms. Because of this, the first example is chosen in a settlement area. The case area is located at the border of Balçova and Konak Districts, called as “Olimpiyat Köyü”. The left upper coordinate is (506811.80, 4247333.56) for PAN image, and (506878, 4247372) for MS image. Figure 5.22 shows the opening the source and the target. Figure 5.23 and 5.24 show the full screen of the images. The source image belongs to 2001 and the target is 2004. The processes until the method selection are the same. Because of this, only results are shown in the different subsections.

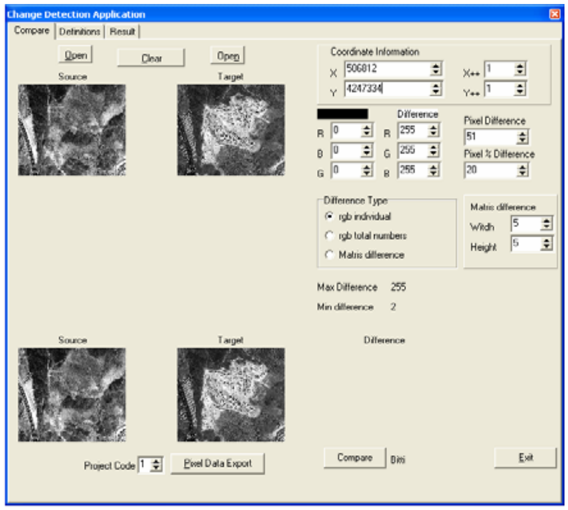


Figure 5.22. Opening the source and the target.

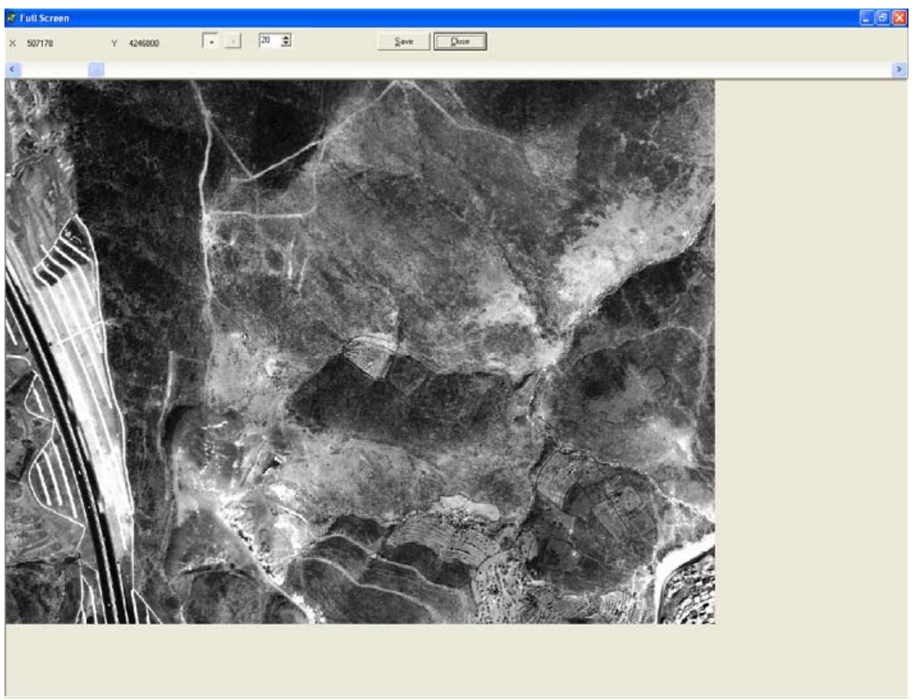


Figure 5.23. The full screen view of the source

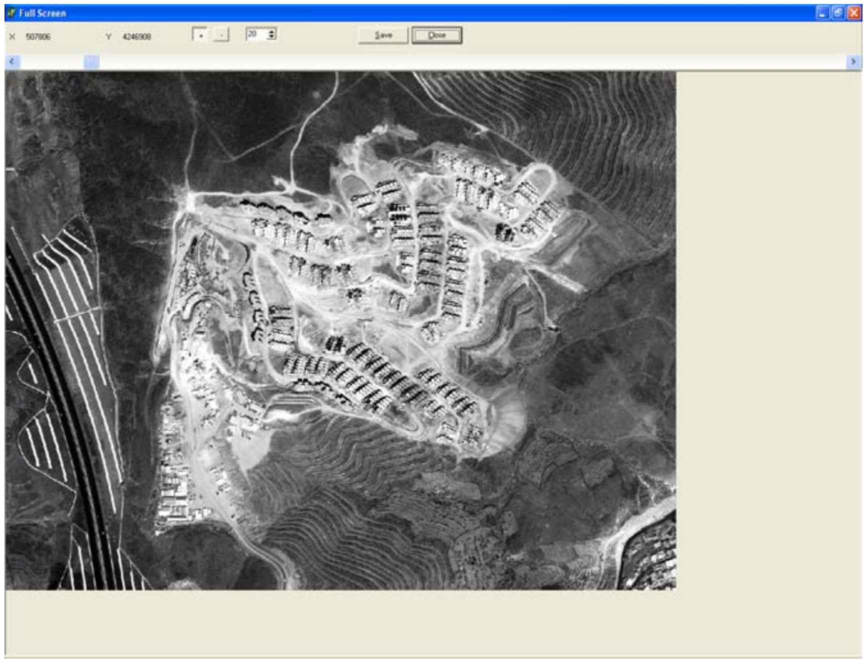


Figure 5.24. The full screen view of the target

Figure 5.25 presents the selection of the algorithms and their order. In this case, histogram equalization, smoothing and edge detection weak algorithms are used both the source and the target. Figure 5.26 shows the results. The first images are the original images as the source and the target.

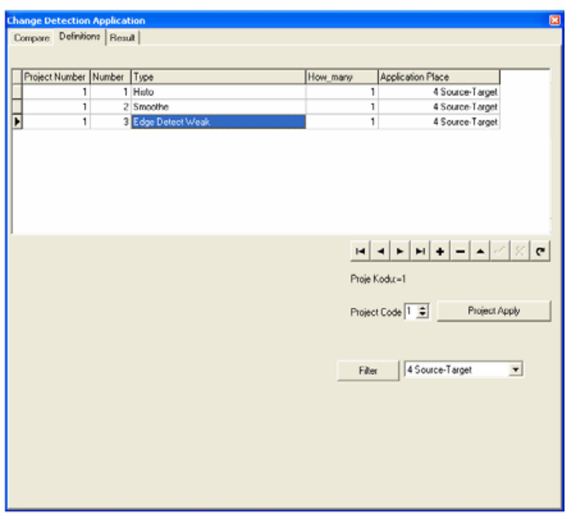


Figure 5.25. Algorithm selection

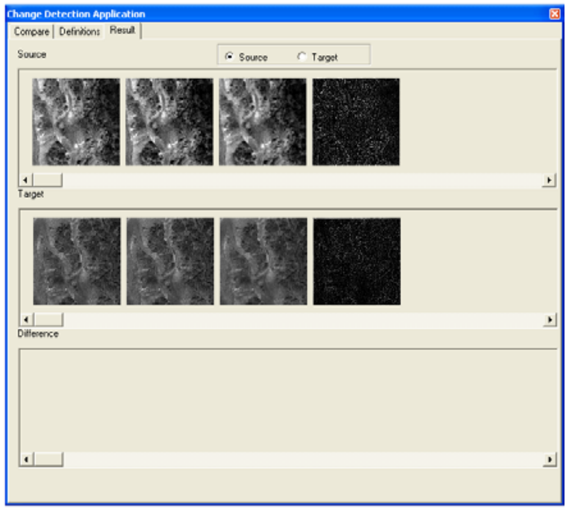


Figure 5.26. The results of the selected algorithms

Figure 5.27 and 5.28 show the full screen views of the last images. The "save" option is also used for saving the results. Any image shown in the result part could be used for comparison process.

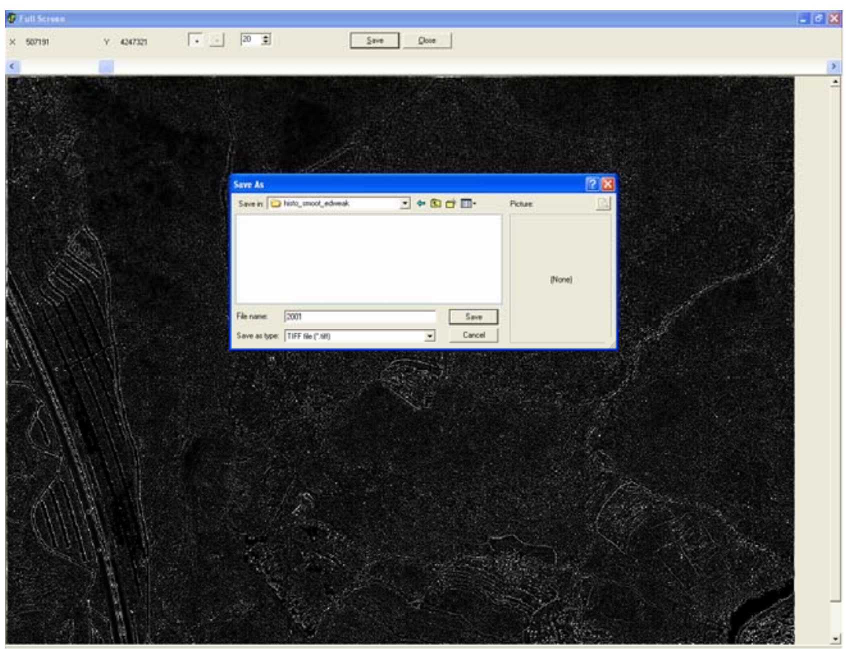


Figure 5.27. The source image result

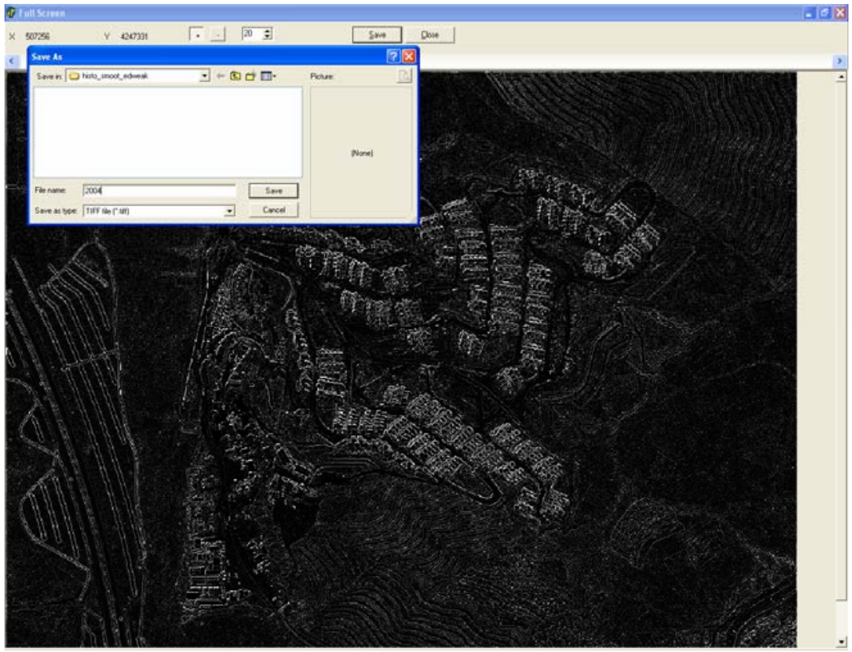


Figure 5.28. The target image result

5.2.2.1. The Results According To the Methods

In the previous section, histogram equalization, smoothing and edge detection weak algorithm have been performed on the case area. In this section, 4 different methods are used to change differences. These methods are RGB individual, RGB total, equal matrix and difference matrix respectively. Before starting the selection of method, the difference percentage should be entered. The sample cases will be realized considering their difference percentage ratio. In other words, different percentage examples will be placed in this section, for example high change percentage – 70 %, middle - 50 % and low – 20 %. When the percentage is entered, the pixel difference ratio is automatically changed. Here, the places with no change represent the black background, and the differences are white. At the end of the section, the results will be compared.

5.2.2.1.1. High Change Percentage Cases – 70 % Change

In these cases, 70 % change detection has been searched between the images.

5.2.2.1.1.1. The RGB Individual Method

Figure 5.29, 5.30 and 5.31 show the RGB individual change detection model. In this methodology, the pixels are subtracted one by one. According to the pixel difference calculation result, the maximum difference is 255 and the minimum is 2 for this case. If the subtraction result is bigger than "pixel difference" then it could be said that the area have been changed. So, that pixel is shown as "difference" pixel and colored white. The threshold is 178 for this case.

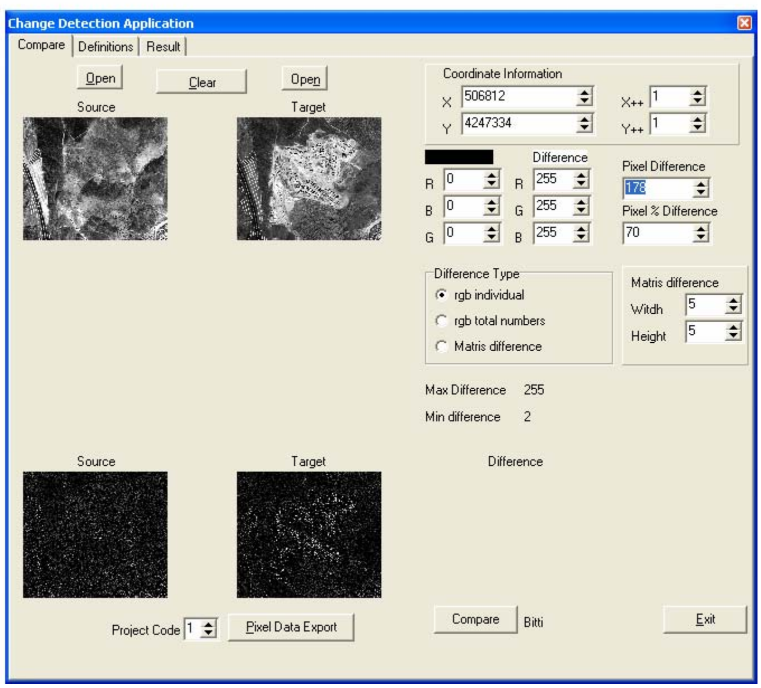


Figure 5.29. RGB individual method

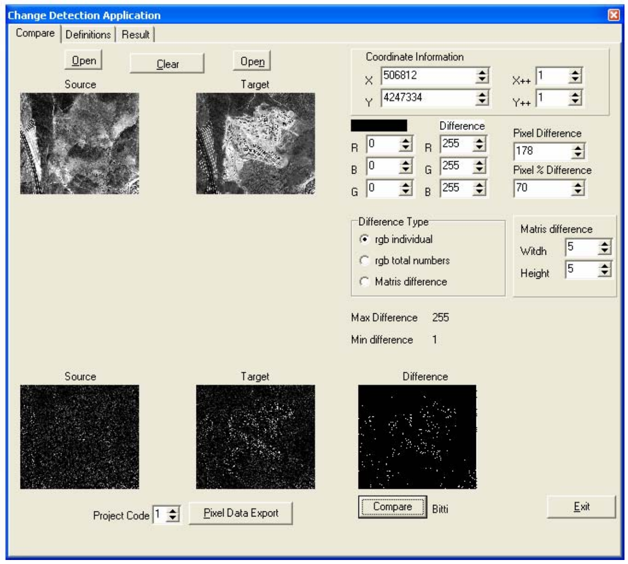


Figure 5.30. The result of the RGB individual method

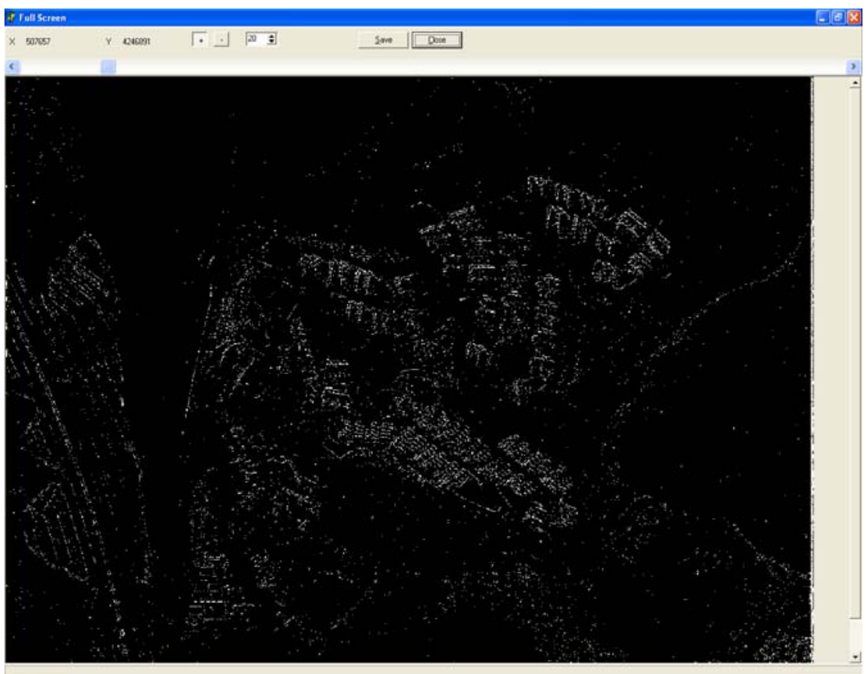


Figure 5.31. The RGB individual result details

Figure 5.32 shows the changed pixels coordinates in the MS Access format. According to the records there are changed 14404 pixels between 2001 and 2004 for the case area.

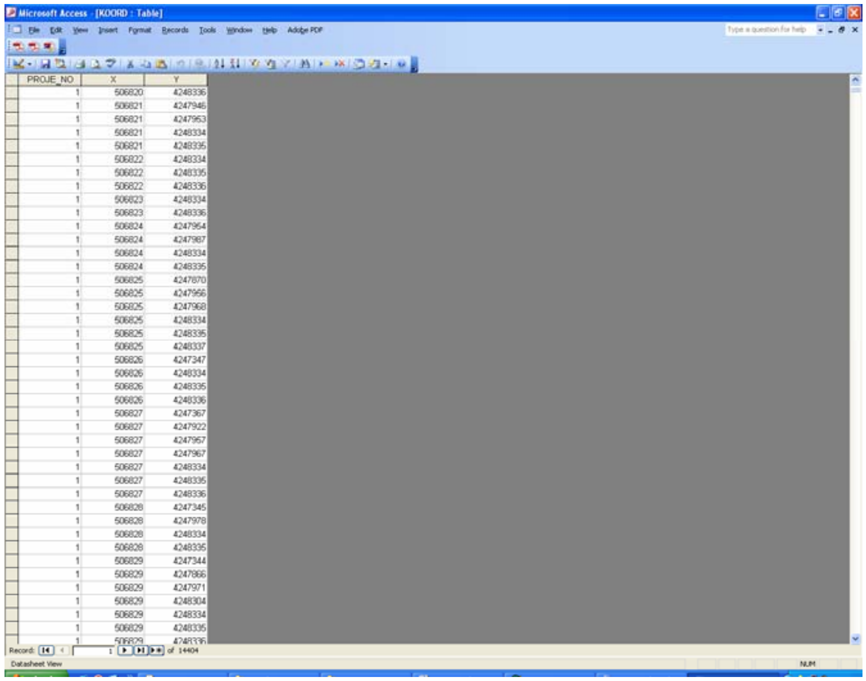


Figure 5.32. The changed pixel coordinates in MS Access – RGB individual

5.2.2.1.1.2. The RGB Total Method

Figure 5.33, 5.34 and 5.35 show the RGB total change detection model. According to the pixel difference calculation result, the maximum difference is 765 and the minimum is 6 for this case. In this methodology, the total pixels values for RGBs are subtracted. If the subtraction result is bigger than "pixel difference" then it could be said that the area have been changed. So, that pixel is shown as "difference" pixel and colored white. The threshold is 536 for this case.

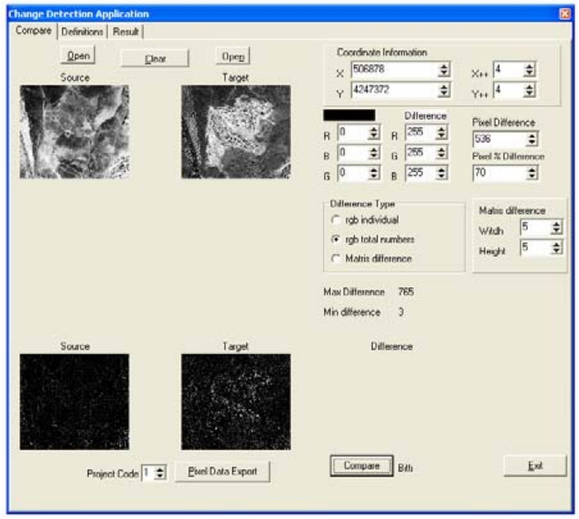


Figure 5.33. RGB total method

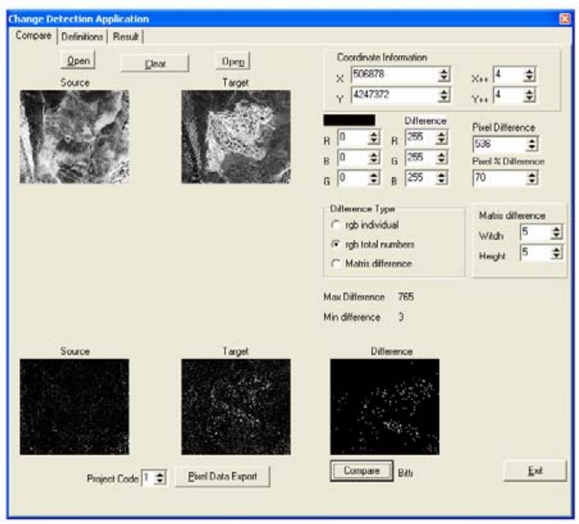


Figure 5.34. The result of the RGB total method

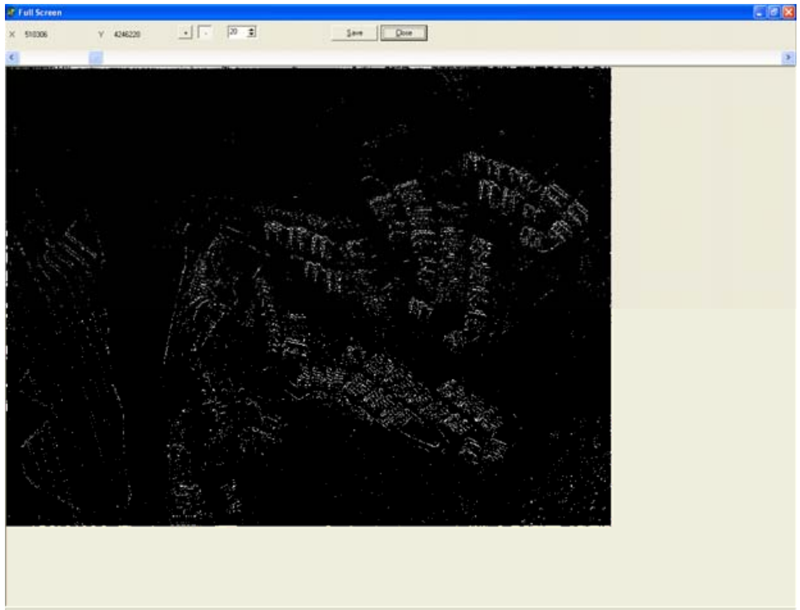


Figure 5.35. The RGB total result details

Figure 5.36 represents the changed pixels coordinates in the MS Access format. According to the records there are changed 26001 pixels between 2001 and 2004 for the case area.

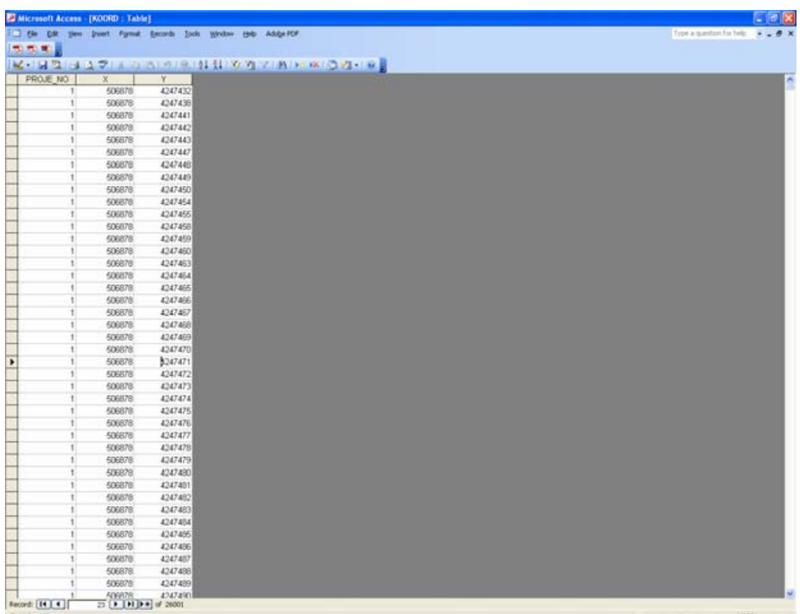


Figure 5.36. The changed pixel coordinates in MS Access – RGB total

5.2.2.1.1.3. The Equal Matrix Method

Figure 5.37 and 5.38 show the equal matrix change detection model. According to the pixel difference calculation result, the maximum difference is 6876 and the minimum is 3 for a 3x3 matrix. In this methodology, the matrix pixel values for RGBs are subtracted. If the subtraction result is bigger than "pixel difference" then it could be said that the area have been changed. So, that matrix is shown as "difference" matrix and colored white. The threshold is 4813 for this case.

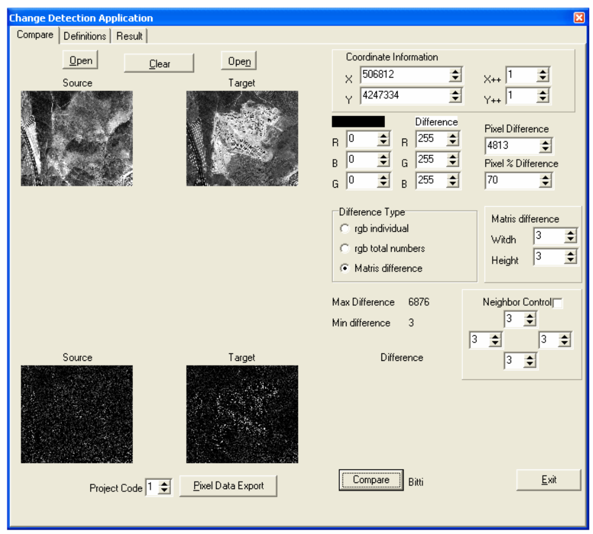


Figure 5.37. The equal matrix method – 3x3

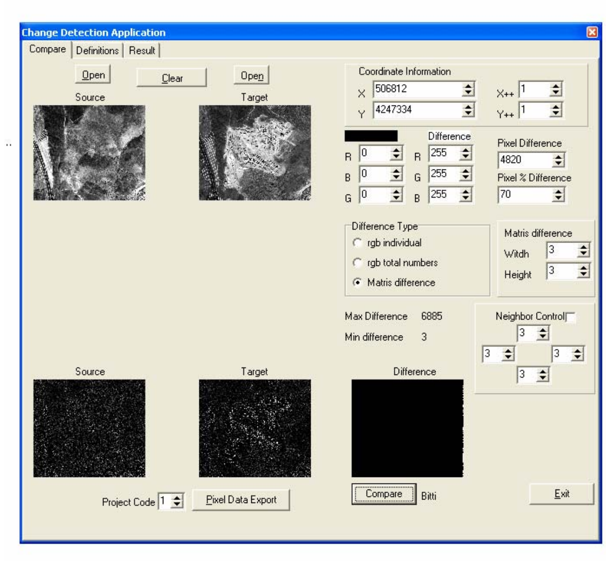


Figure 5.38. The result of the equal matrix method

According to the result, there is no change at 70 % change level.

5.2.2.1.1.4. The Not Equal Matrix Method

Figure 5.39 and 5.40 show the not equal matrix change detection model. According to the pixel difference calculation result, the maximum difference is 60.585 and the minimum is 3 for a (3x3) and a (9x9) matrix. In this methodology, the small matrix is searched in the bigger matrix. If the subtraction result is bigger than “pixel difference” then it could be said that the area have been changed. So, that matrix is shown as “difference” matrix and colored white. The threshold is 42.410 for this case. In this case, there have a 3x3 matrix in the previous section. This time, it is added 3 pixels to each side of the matrix. Therefore, the bigger matrix is 9x9.

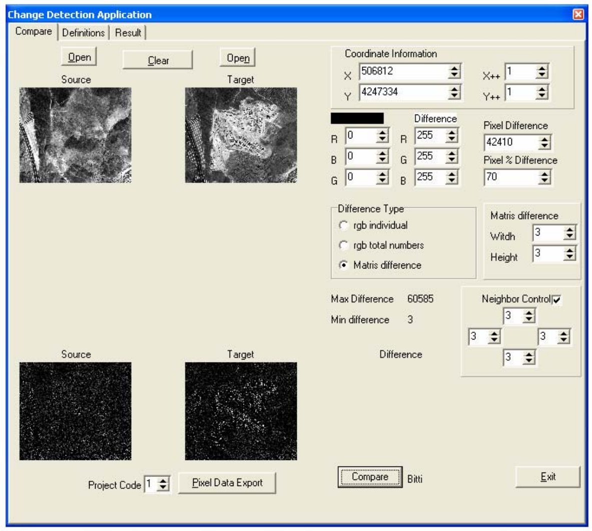


Figure 5.39. The not equal matrix method – 3x3 by 9x9

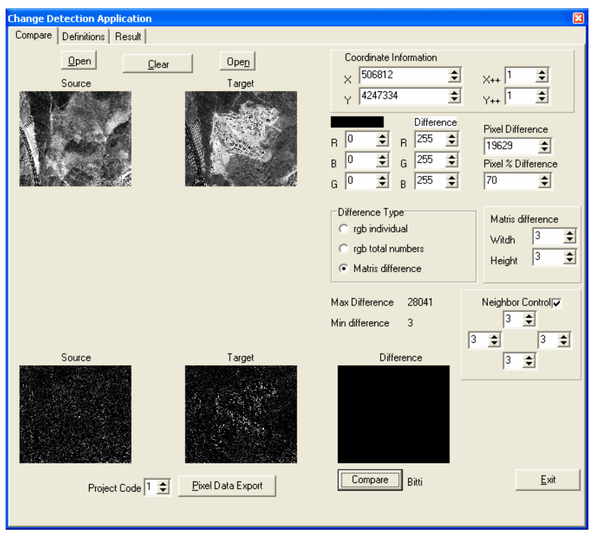


Figure 5.40. The result of the not equal matrix method

According to this method, there is no change.

5.2.2.1.2. Middle Change Percentage Cases – 50 % Change

In these cases, 50 % change detection has been searched between the images. In the previous sections, processes have been explained with their details. Because of this, middle and low change percentage sections have only the result images and their access records. All of cases have the same algorithms and the same matrix size.

5.2.2.1.2.1. The RGB Individual Method

Figure 5.41 and 5.42 represent the result of the RGB individual method under 50 % pixel difference circumstances. Figure 5.43 shows Access records of this query, there are 32071 pixels with 50 % change detection.

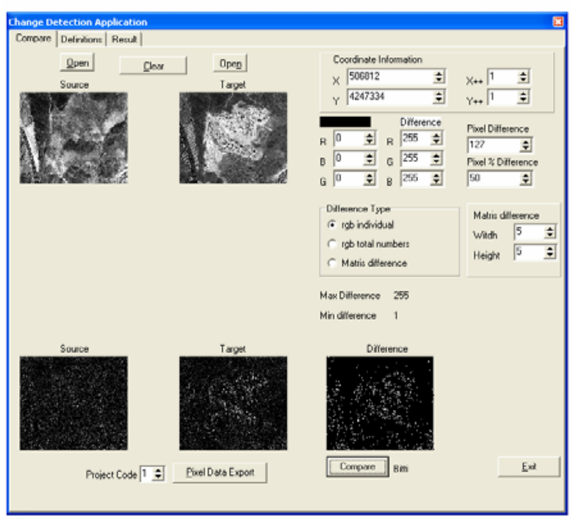


Figure 5.41. The result of the RGB individual with 50 % change

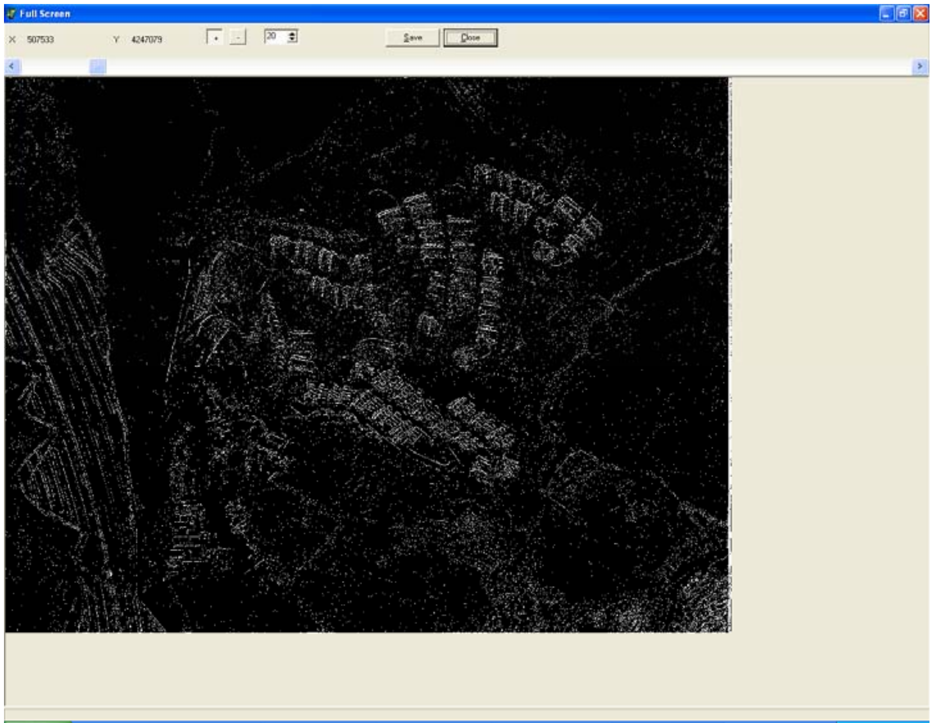
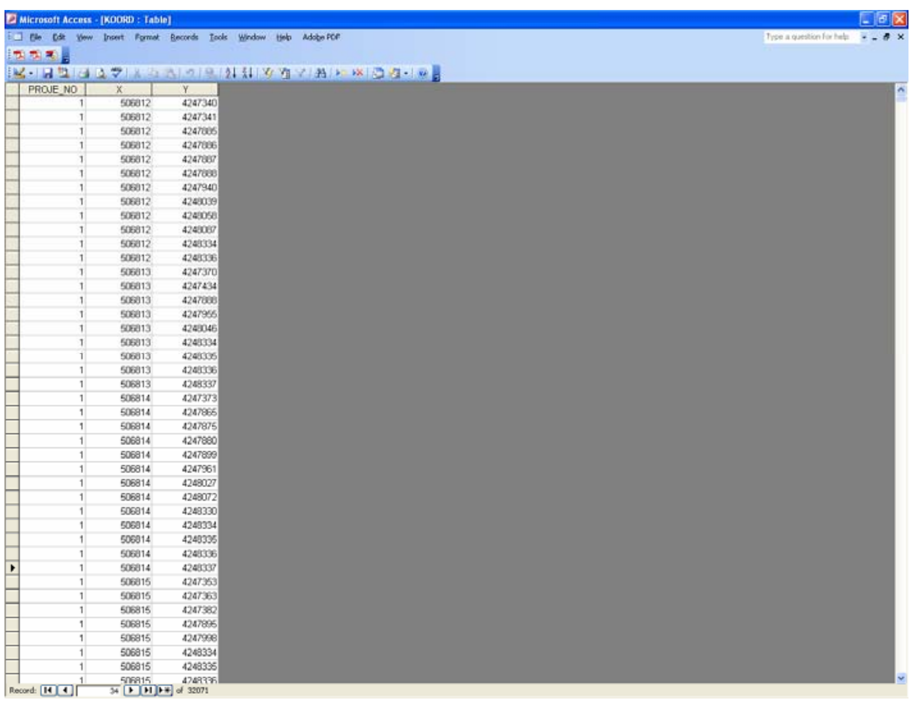


Figure 5.42. Full view of the 50 % change result - RGB individual



PROJE_NO	X	Y
1	506812	4247340
1	506812	4247341
1	506812	4247885
1	506812	4247886
1	506812	4247887
1	506812	4247888
1	506812	4247940
1	506812	4248039
1	506812	4248058
1	506812	4248087
1	506812	4248334
1	506812	4248336
1	506813	4247370
1	506813	4247434
1	506813	4247888
1	506813	4247955
1	506813	4248046
1	506813	4248334
1	506813	4248335
1	506813	4248336
1	506813	4248337
1	506814	4247373
1	506814	4247865
1	506814	4247875
1	506814	4247880
1	506814	4247899
1	506814	4247961
1	506814	4248027
1	506814	4248072
1	506814	4248330
1	506814	4248334
1	506814	4248335
1	506814	4248336
1	506814	4248337
1	506815	4247353
1	506815	4247363
1	506815	4247382
1	506815	4247895
1	506815	4247998
1	506815	4248334
1	506815	4248335
1	506815	4248336

Figure 5.43. Access records of 50 % change detection - RGB individual

5.2.2.1.2.2. The RGB Total Method

Figure 5.44 and 5.45 show the result of the RGB total method under 50 % pixel difference circumstances. Figure 46 shows Access records of this query, there are 7535 pixels with 50 % change detection.

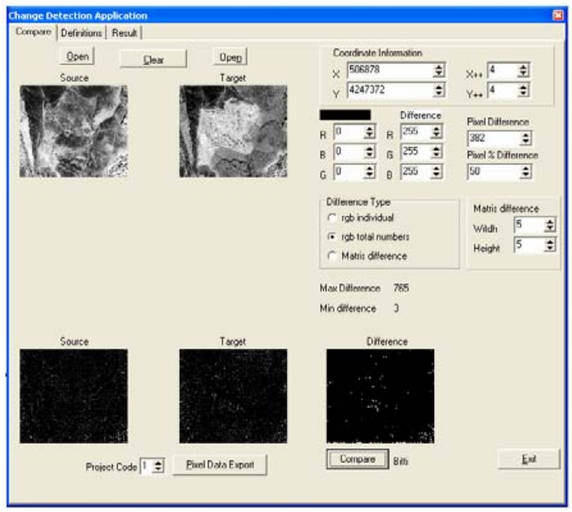


Figure 5.44. The result of the RGB total method with 50 % change detection

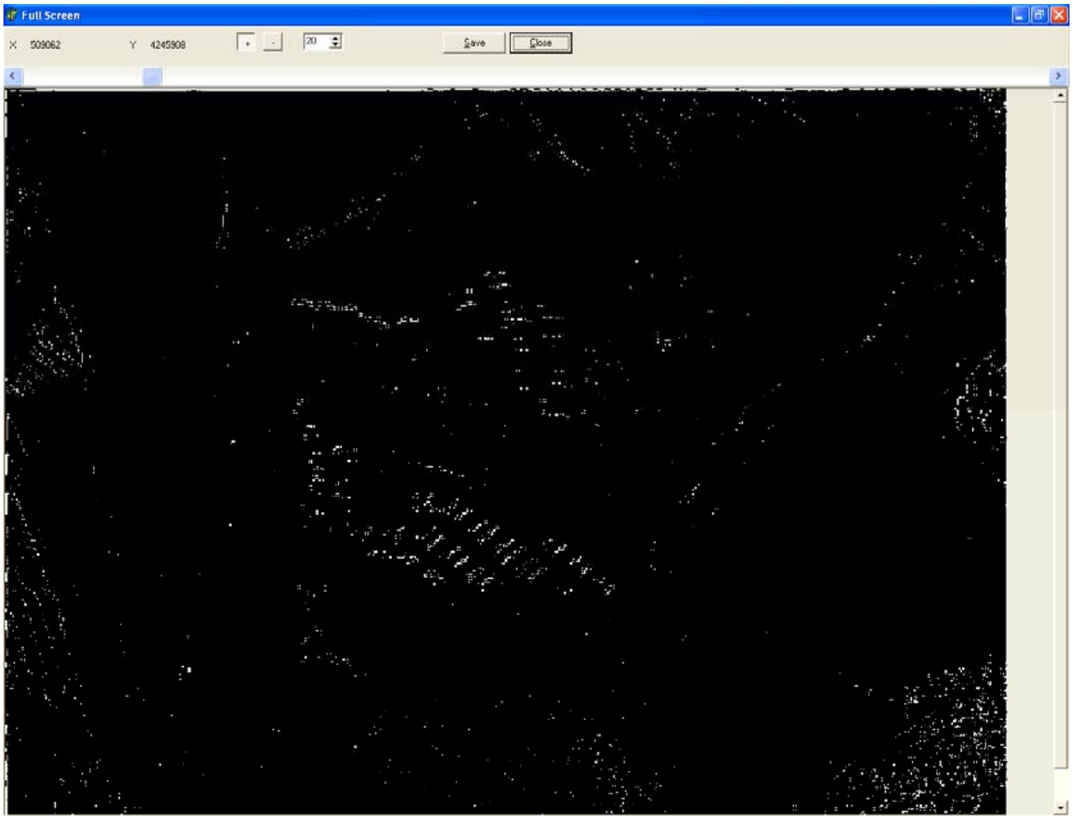
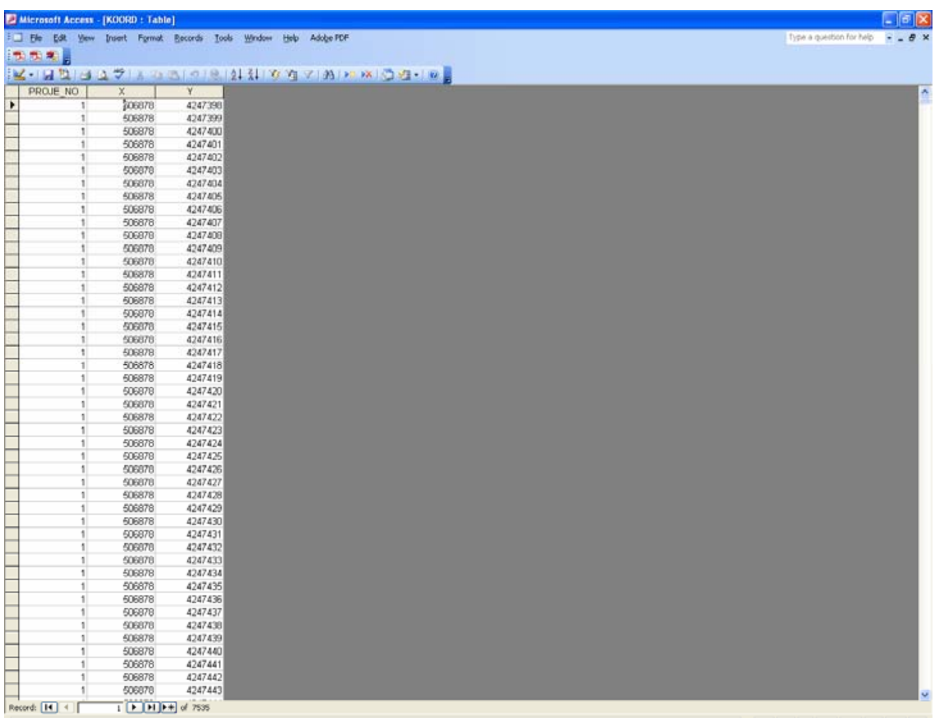


Figure 5.45. Full view of the 50 % change result – RGB Total



PROJE_NO	X	Y
1	506878	4247398
1	506878	4247399
1	506878	4247400
1	506878	4247401
1	506878	4247402
1	506878	4247403
1	506878	4247404
1	506878	4247405
1	506878	4247406
1	506878	4247407
1	506878	4247408
1	506878	4247409
1	506878	4247410
1	506878	4247411
1	506878	4247412
1	506878	4247413
1	506878	4247414
1	506878	4247415
1	506878	4247416
1	506878	4247417
1	506878	4247418
1	506878	4247419
1	506878	4247420
1	506878	4247421
1	506878	4247422
1	506878	4247423
1	506878	4247424
1	506878	4247425
1	506878	4247426
1	506878	4247427
1	506878	4247428
1	506878	4247429
1	506878	4247430
1	506878	4247431
1	506878	4247432
1	506878	4247433
1	506878	4247434
1	506878	4247435
1	506878	4247436
1	506878	4247437
1	506878	4247438
1	506878	4247439
1	506878	4247440
1	506878	4247441
1	506878	4247442
1	506878	4247443

Figure 5.46. Access records of 50 % change detection - RGB total

5.2.2.1.2.3. The Equal Matrix Method

Figure 5.47 shows the result of the equal matrix method under 50 % pixel difference circumstances. Figure 5.48 shows Access records of this query, there are 2934 pixels with 50 % change detection. However, there is detection, it can clearly be seen that the difference area is missing. In other words, because of fewer geometric shifts, there has a difference area at the left lower corner.

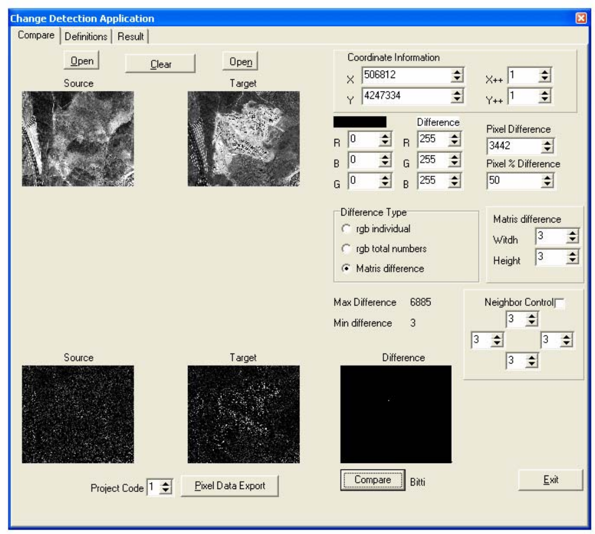


Figure 5.47. The result of the equal matrix method with 50 % change detection

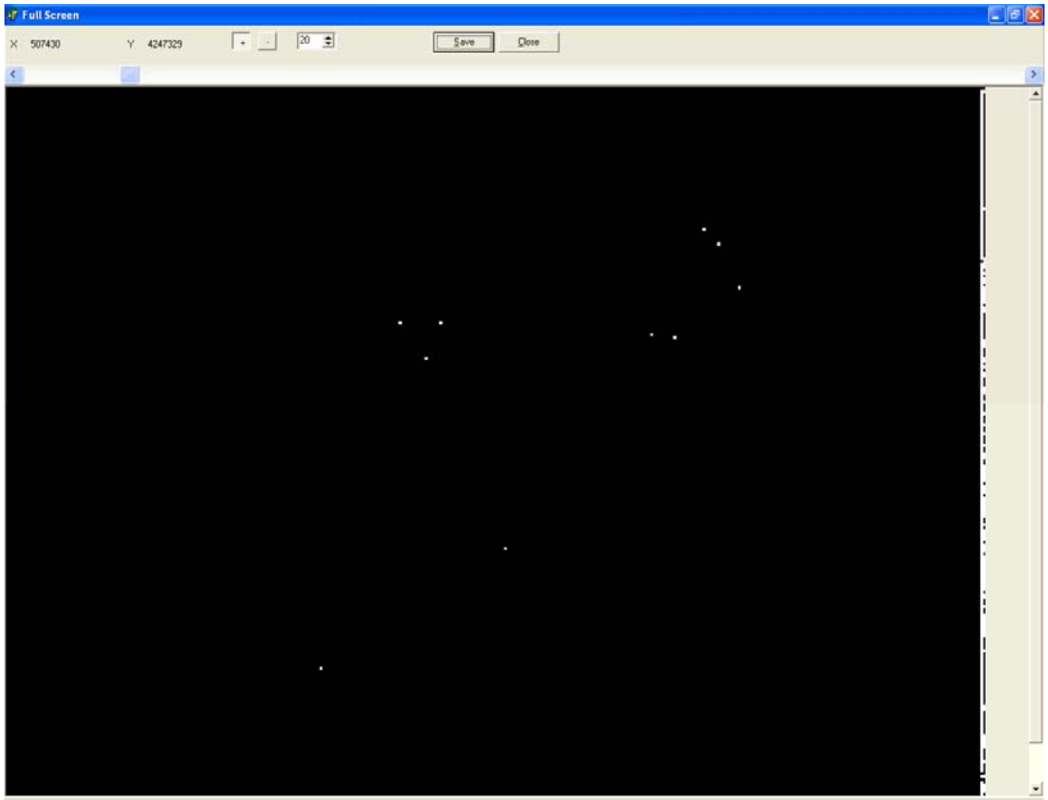


Figure 5.48. Access records of 50 % change detection – equal matrix method

5.2.2.1.2.4. The Not Equal Matrix Method

Figure 5.49 presents the result of the not equal matrix method under 50 % pixel difference circumstances.

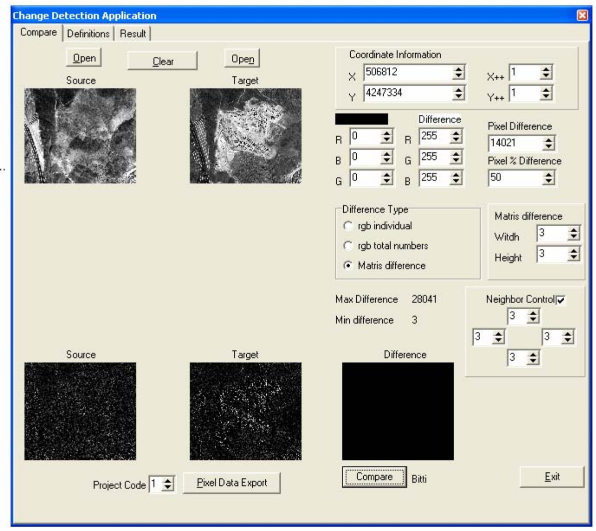


Figure 5.49. The result of the not equal matrix method with 50 % change detection

5.2.2.1.3. Low Change Percentage Cases – 20 % Change

In these cases, 20 % change detection has been searched between the images.

5.2.2.1.3.1. The RGB Individual Method

Figure 5.50 and 5.51 present the result of the RGB individual method under 20 % pixel difference circumstances. Figure 5.52 shows Access records of this query, there are 103965 pixels with 20 % change detection.

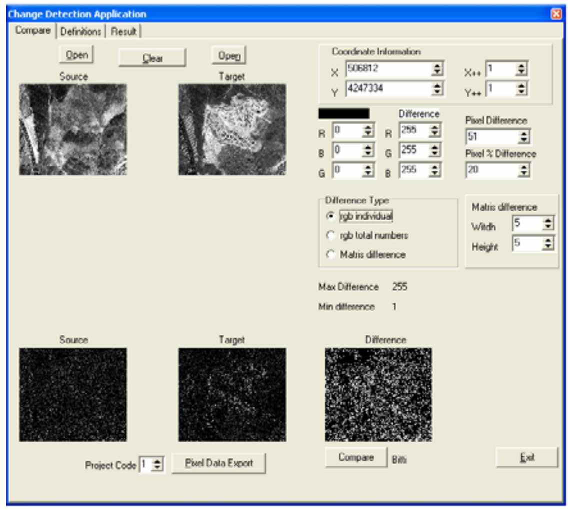


Figure 5.50. The result of the RGB individual method with 20 % change detection

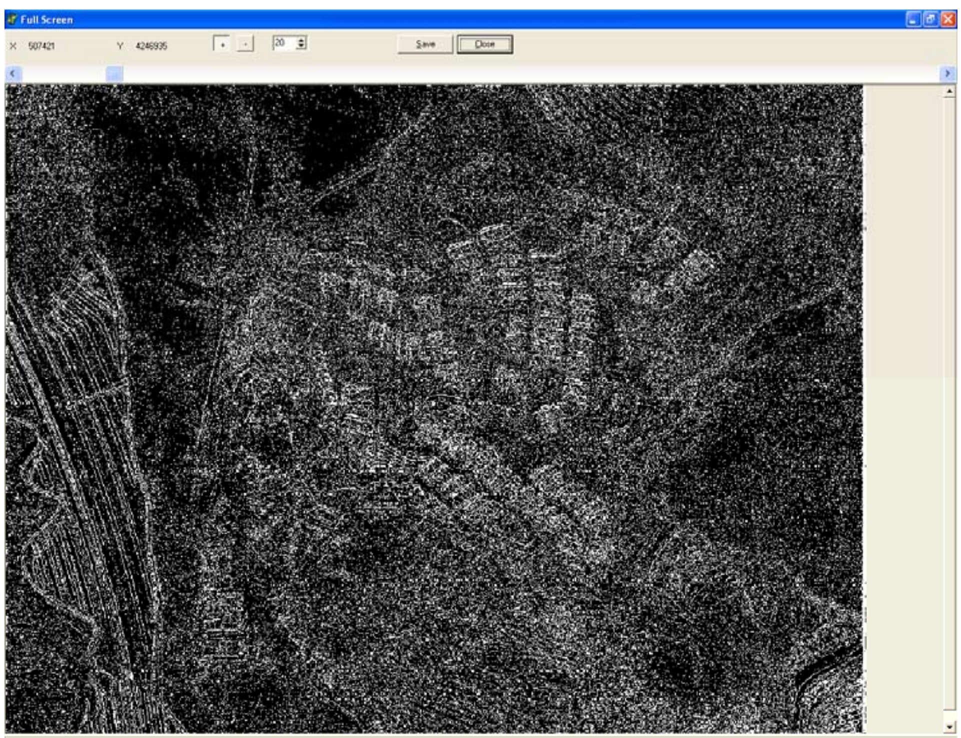


Figure 5.51. Full view of the RGB individual method with 20 % change detection

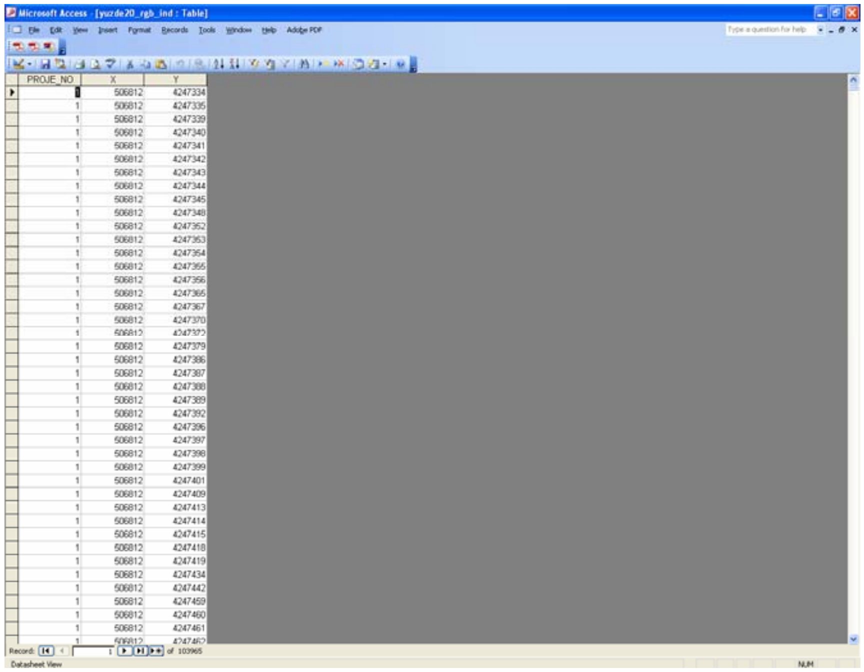


Figure 5.52. Access records of 20 % change detection – the RGB individual method

5.2.2.1.3.2. The RGB Total Method

Figure 5.53 and 5.54 show the result of the RGB total method under 20 % pixel difference circumstances. Figure 5.55 shows Access records of this query, there are 43564 pixels with 20 % change detection.

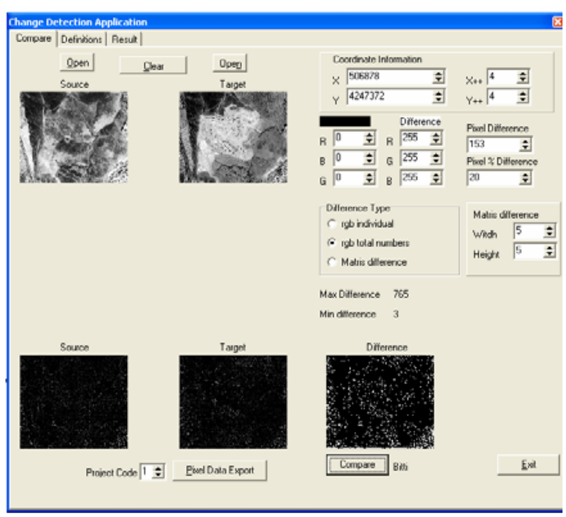


Figure 5.53. The result of the RGB total method with 20 % change detection

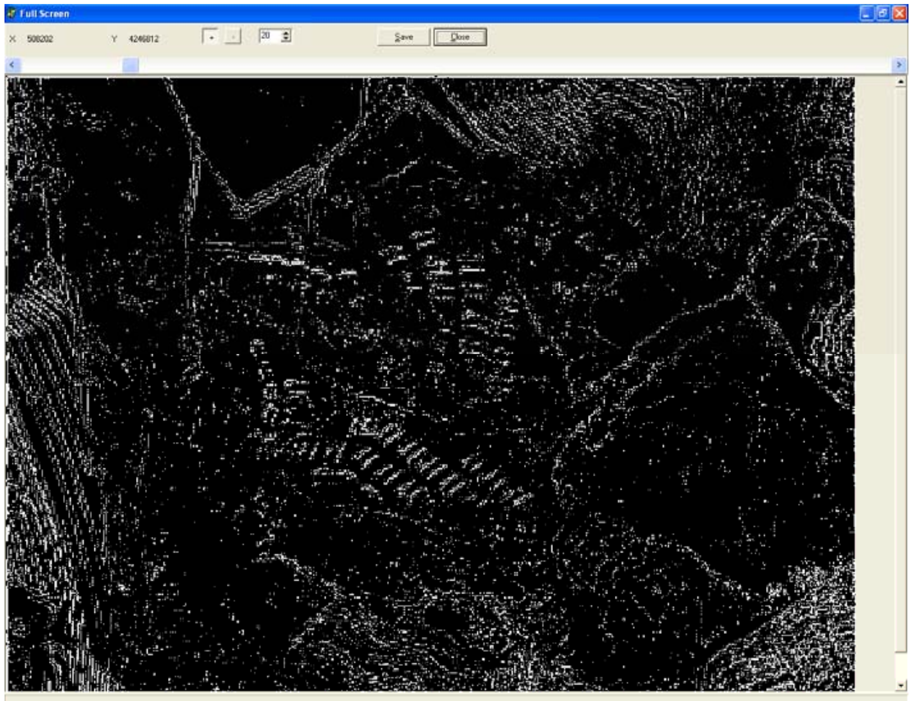


Figure 5.54. Full view of the RGB total method with 20 % change detection

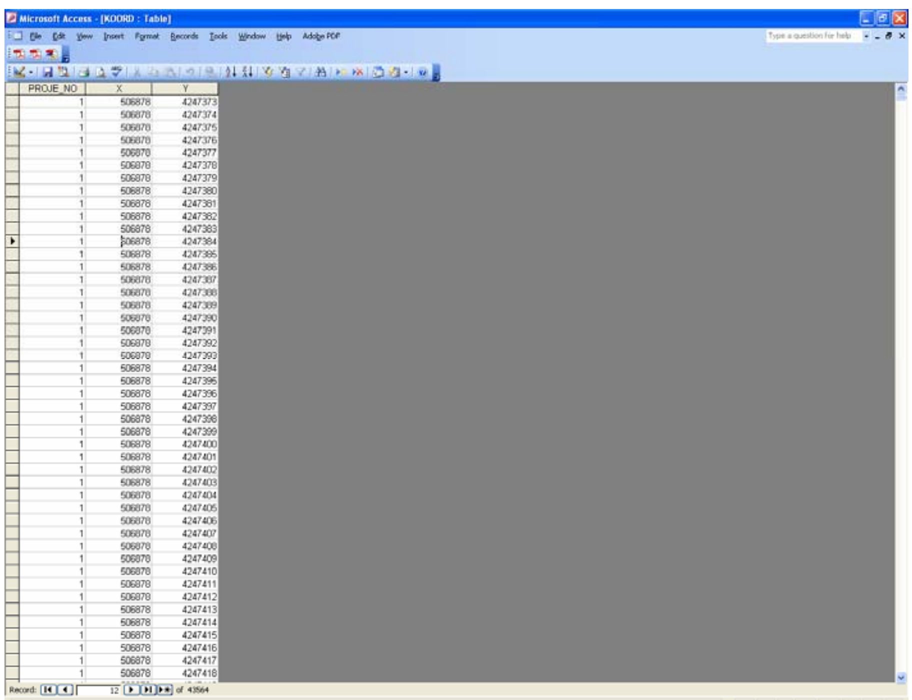


Figure 5.55. Access records of 20 % change detection – the RGB total method

5.2.2.1.3.3. The Equal Matrix Model

Figure 5.56 and 5.57 show the result of the equal matrix method under 20 % pixel difference circumstances. Figure 5.58 presents Access records of this query, there are 30.642 pixels with 20 % change detection.

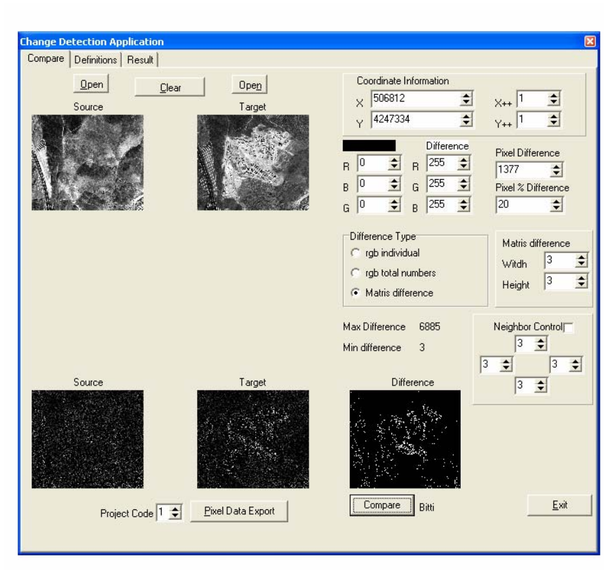


Figure 5.56. The result of the equal matrix method with 20 % change detection

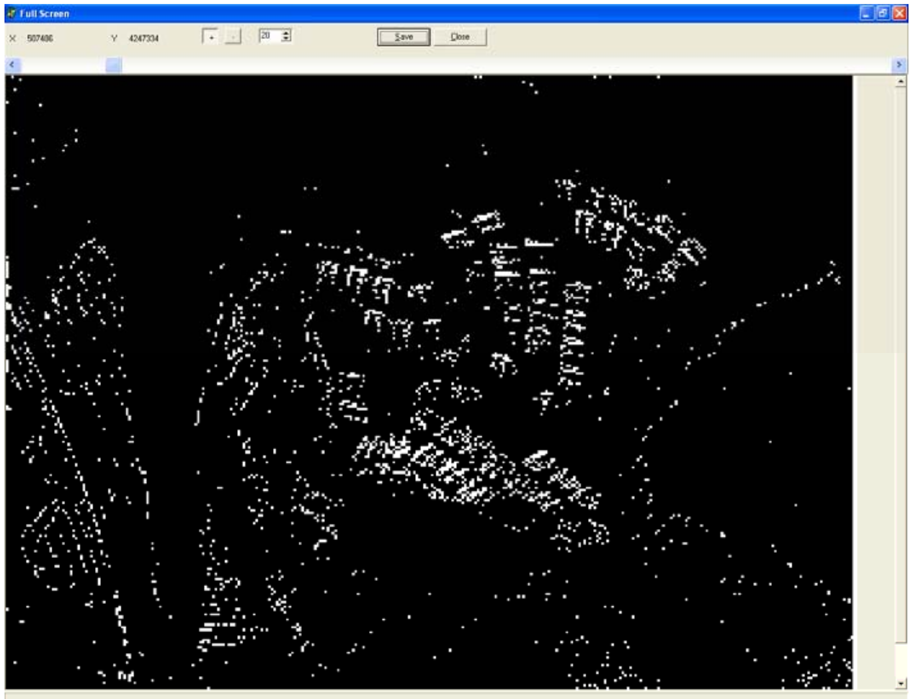
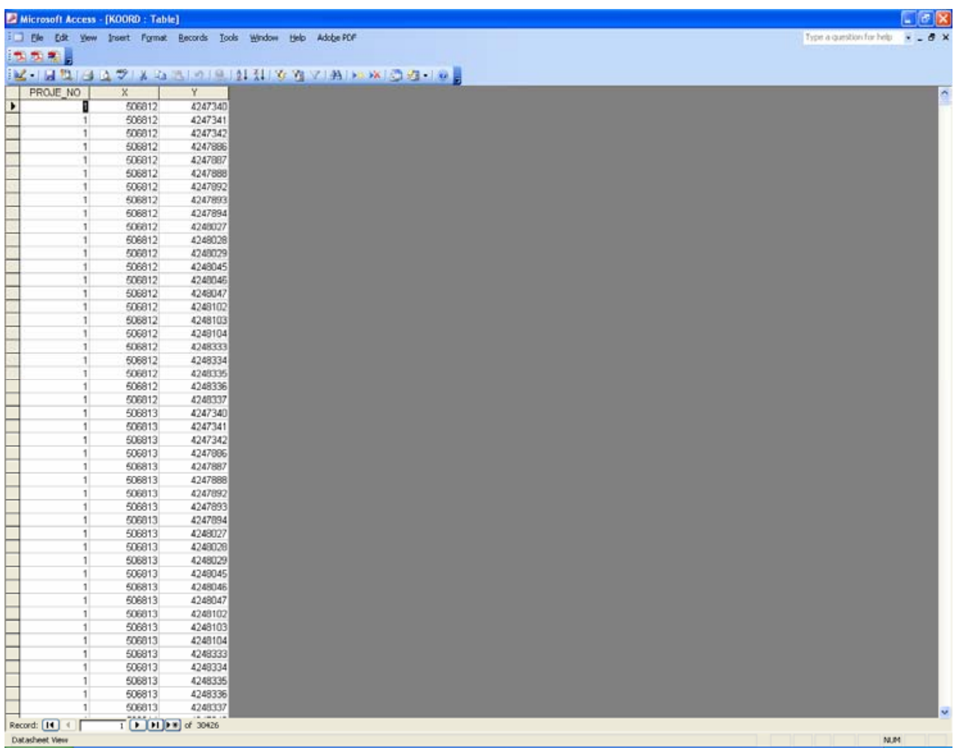


Figure 5.57. Full view of the equal matrix method with 20 % change detection



PROJE_NO	X	Y
1	506812	4247340
1	506812	4247341
1	506812	4247342
1	506812	4247886
1	506812	4247887
1	506812	4247888
1	506812	4247892
1	506812	4247893
1	506812	4247894
1	506812	4248027
1	506812	4248028
1	506812	4248029
1	506812	4248045
1	506812	4248046
1	506812	4248047
1	506812	4248102
1	506812	4248103
1	506812	4248104
1	506812	4248333
1	506812	4248334
1	506812	4248335
1	506812	4248336
1	506812	4248337
1	506813	4247340
1	506813	4247341
1	506813	4247342
1	506813	4247886
1	506813	4247887
1	506813	4247888
1	506813	4247892
1	506813	4247893
1	506813	4247894
1	506813	4248027
1	506813	4248028
1	506813	4248029
1	506813	4248045
1	506813	4248046
1	506813	4248047
1	506813	4248102
1	506813	4248103
1	506813	4248104
1	506813	4248333
1	506813	4248334
1	506813	4248335
1	506813	4248336
1	506813	4248337

Figure 5.58. Access records of 20 % change detection – the equal matrix method

5.2.2.1.3.4. The Not Equal Matrix

Figure 5.59 and 5.60 show the result of the equal matrix method under 20 % pixel difference circumstances. Figure 5.61 shows Access records of this query, there are 171.525 pixels with 20 % change detection.

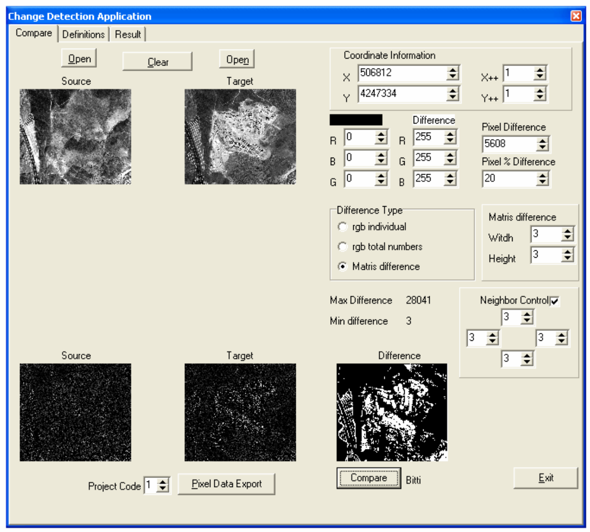


Figure 5.59. The result of the not equal matrix method with 20 % change detection

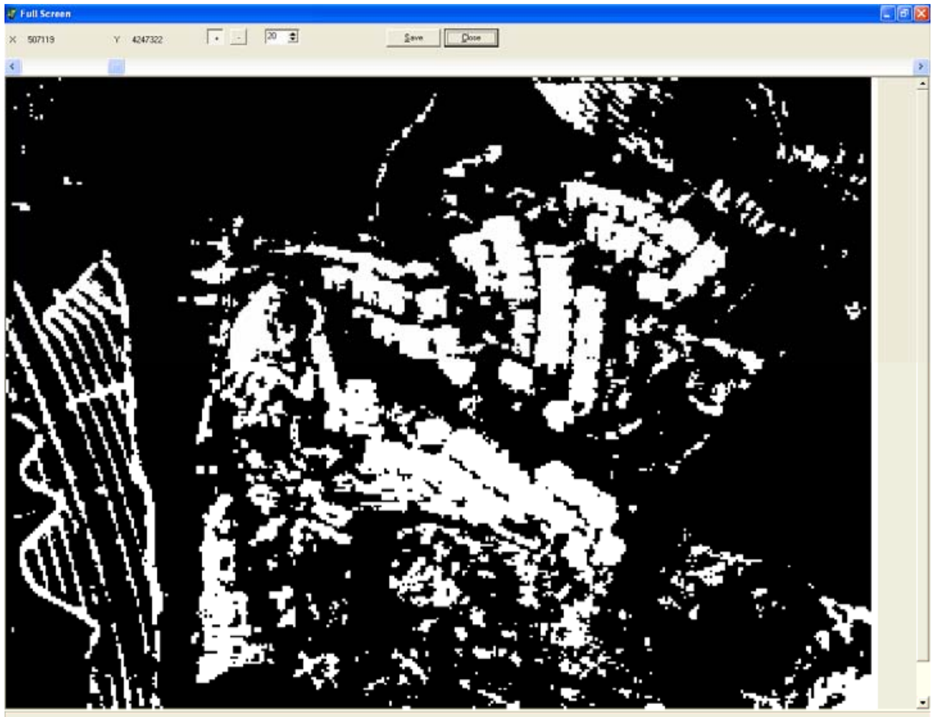
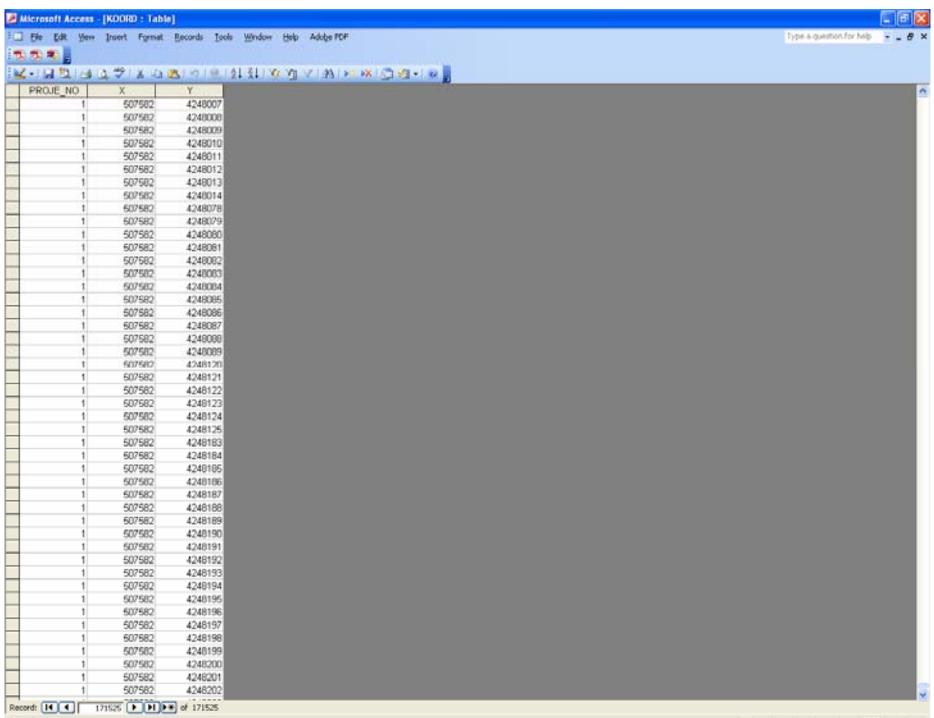


Figure 5.60. Full view of the not equal matrix method with 20 % change detection



PROJE_NO	X	Y
1	507582	4248007
1	507582	4248008
1	507582	4248009
1	507582	4248010
1	507582	4248011
1	507582	4248012
1	507582	4248013
1	507582	4248014
1	507582	4248078
1	507582	4248079
1	507582	4248080
1	507582	4248081
1	507582	4248082
1	507582	4248083
1	507582	4248084
1	507582	4248085
1	507582	4248086
1	507582	4248087
1	507582	4248088
1	507582	4248089
1	507582	4248120
1	507582	4248121
1	507582	4248122
1	507582	4248123
1	507582	4248124
1	507582	4248125
1	507582	4248183
1	507582	4248184
1	507582	4248185
1	507582	4248186
1	507582	4248187
1	507582	4248188
1	507582	4248189
1	507582	4248190
1	507582	4248191
1	507582	4248192
1	507582	4248193
1	507582	4248194
1	507582	4248195
1	507582	4248196
1	507582	4248197
1	507582	4248198
1	507582	4248199
1	507582	4248200
1	507582	4248201
1	507582	4248202

Figure 5.61. Access records of 20 % change detection – the not equal matrix method

5.3. GIS-Based Change Detection Application

GIS connection of change detection results can be made with two ways. First of them is to transfer the coordinates saved as the access format. Figure 5.62 shows creating points from coordinates. This process can be realized using MapInfo tools or “create point” GUI. The important point here is that what the projection system will be for the new layer. In order to be made overlay, all layers must have the same projection type. For this thesis, UTM WGS84, Zone 35N has been used as projection type.

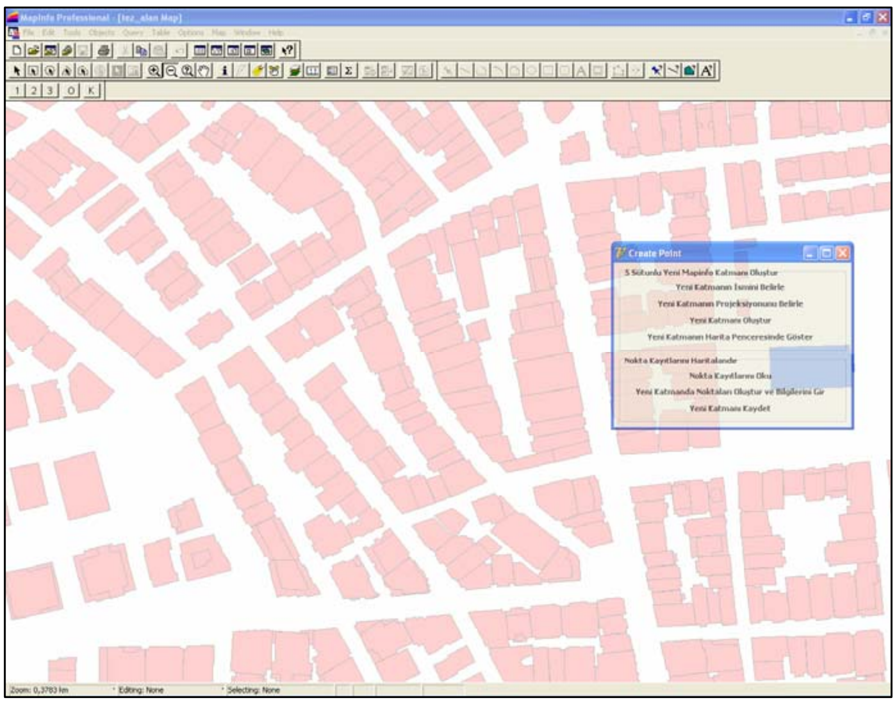


Figure 5.62. Create points from coordinates

Another way of linking the results with the digital as-is maps is to use “GIS connection” command on the GUI. Figure 5.63 presents the result of detection 70 % with RGB individual methodology. After detecting changes, the results can be transferred on GIS environment via “GIS connection” command. The process is shown in 5.64, 5.65 and 5.66.

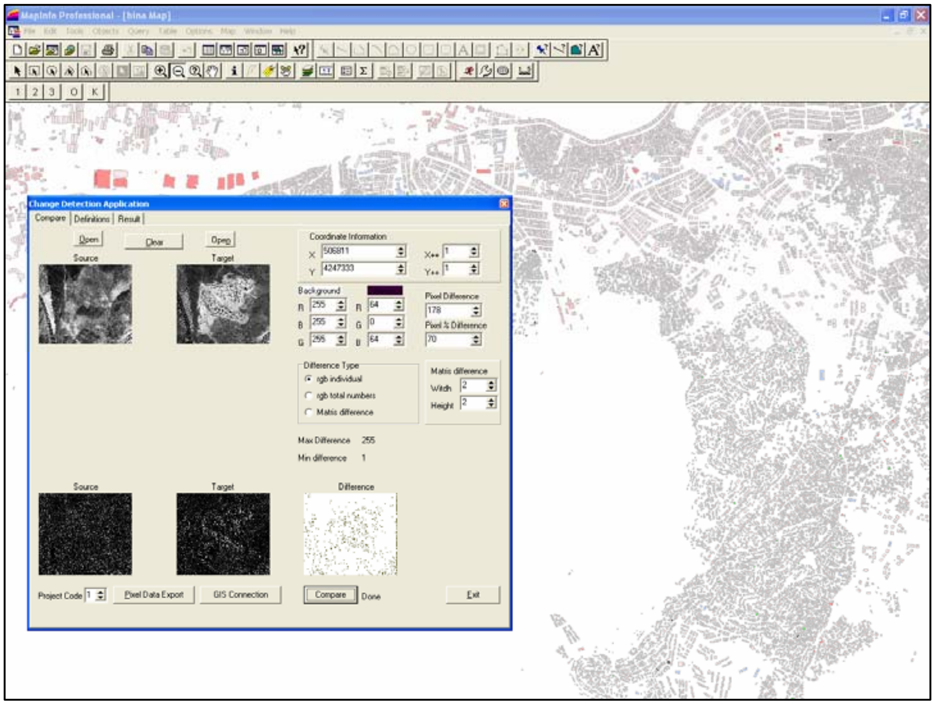


Figure 5.63. Before the connection

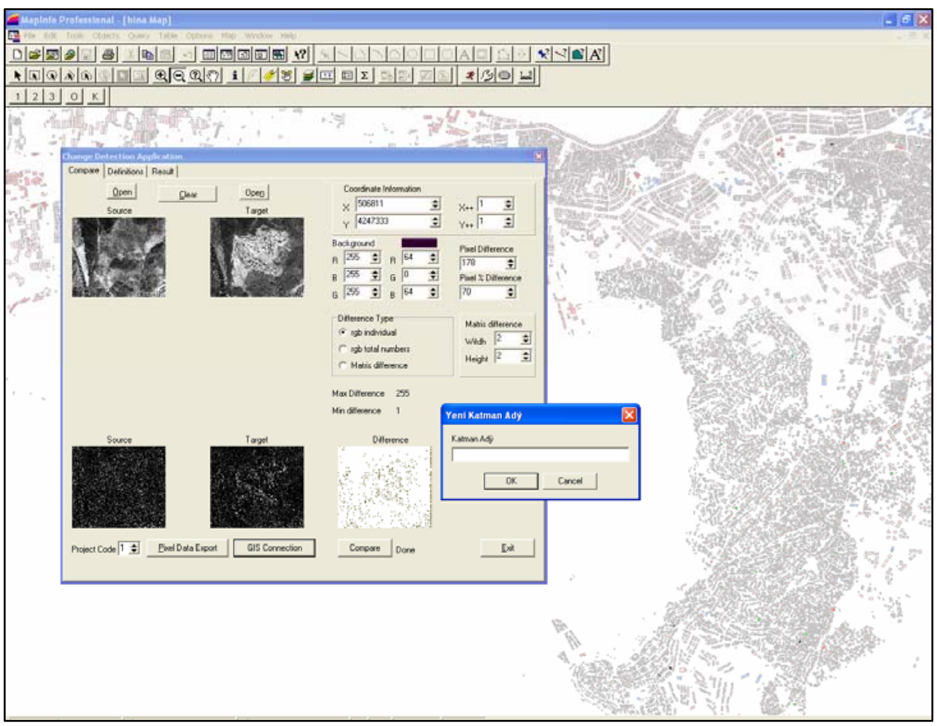


Figure 5.64. Creating a new layer

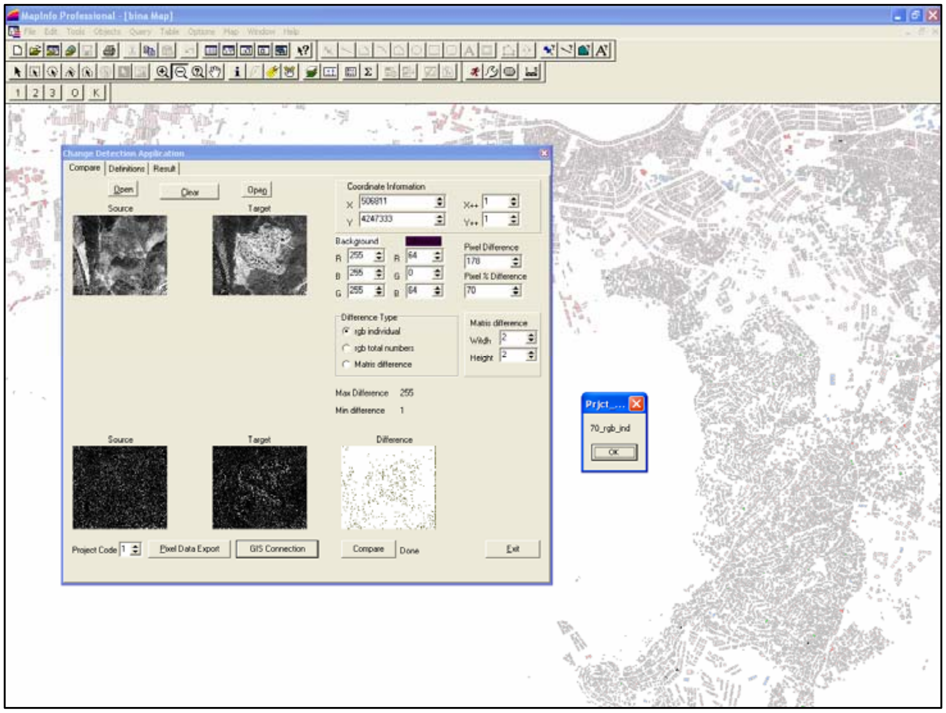


Figure 5.65. The result of adding the new layer

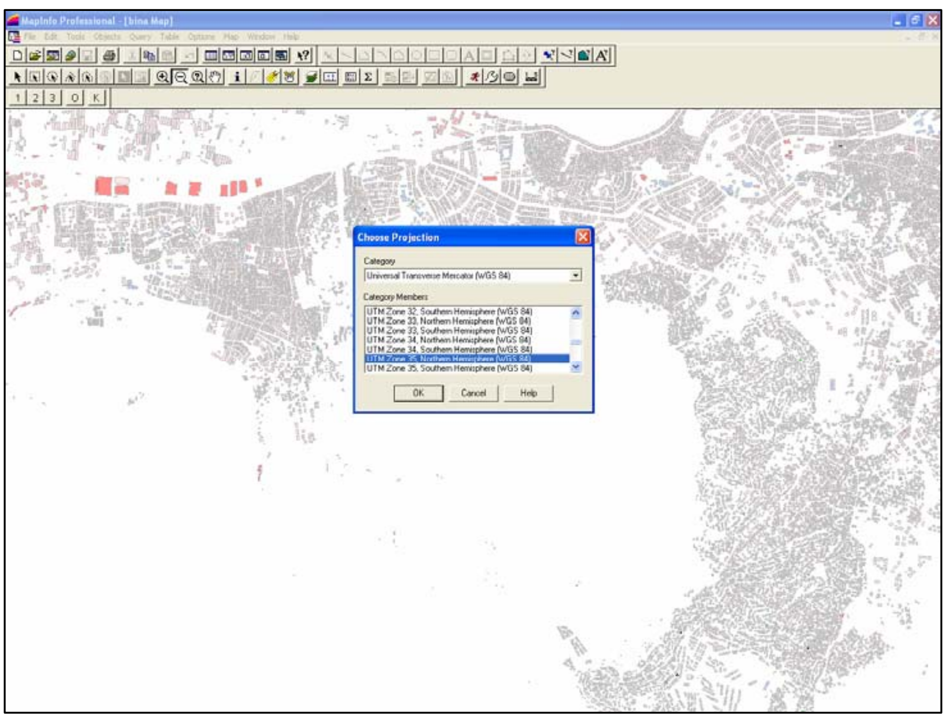


Figure 5.66. Selection of the projection type

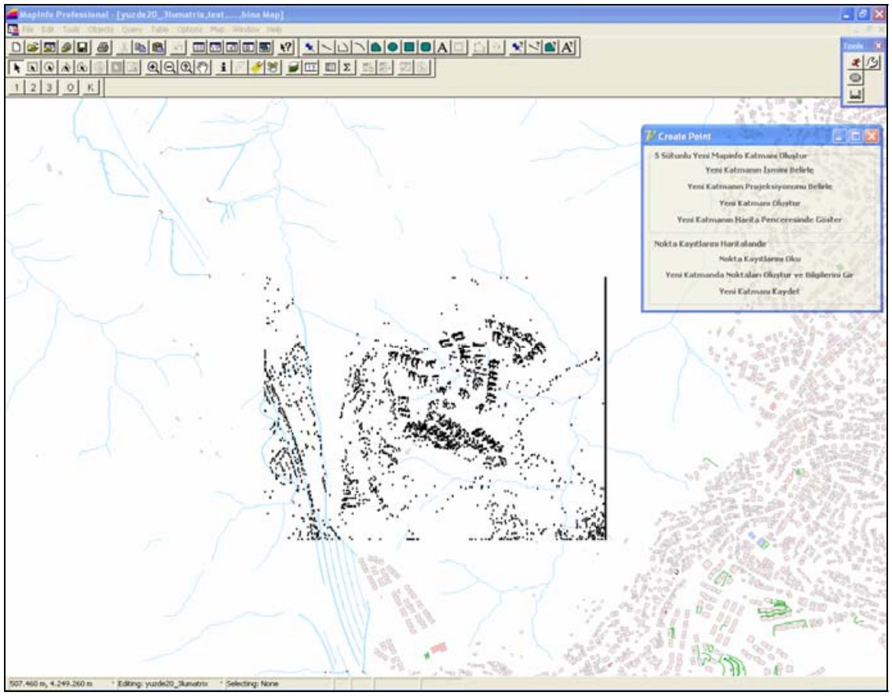


Figure 5.67. The result of the GIS connection

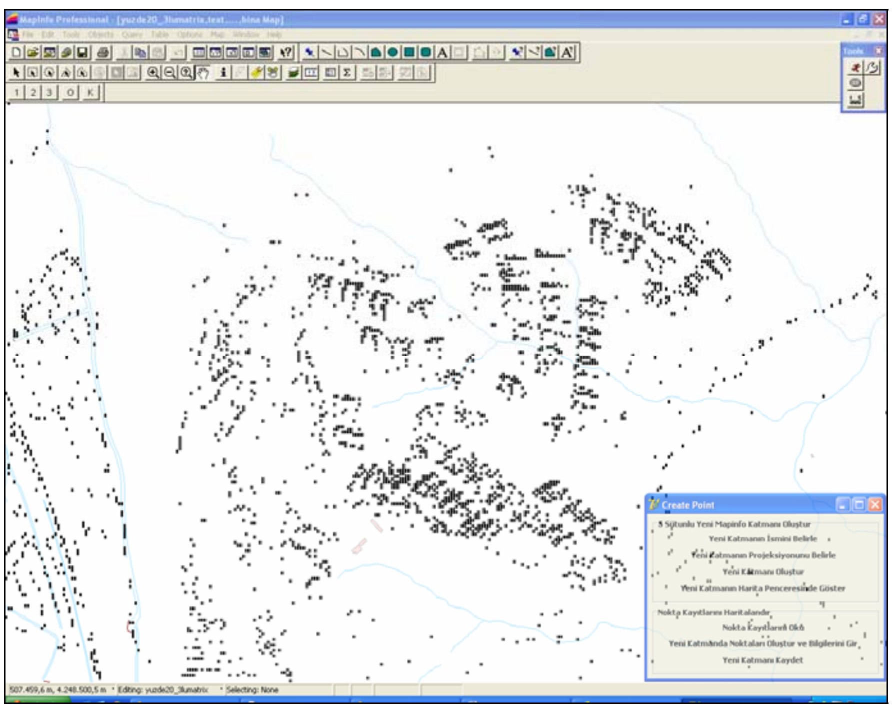


Figure 5.68. The result of the GIS connection - detail

5.4. General Evaluation of the Case

The change detection results are compared according to their pixel numbers in access and percentage and shown in Table 5.3 and Figure 5.69.

Table 5.3. Change detection pixels according to percentage and methodology

	Methodology			
Percentage	RGB ind.	RGB Total	Equal Matrix	Not Equal Matrix
70 %	14.404	26.001	0 (no change)	0 (no change)
50 %	32.071	7.535	0 (no change)	0 (no change)
20 %	103.965	43.564	30.426	171.525

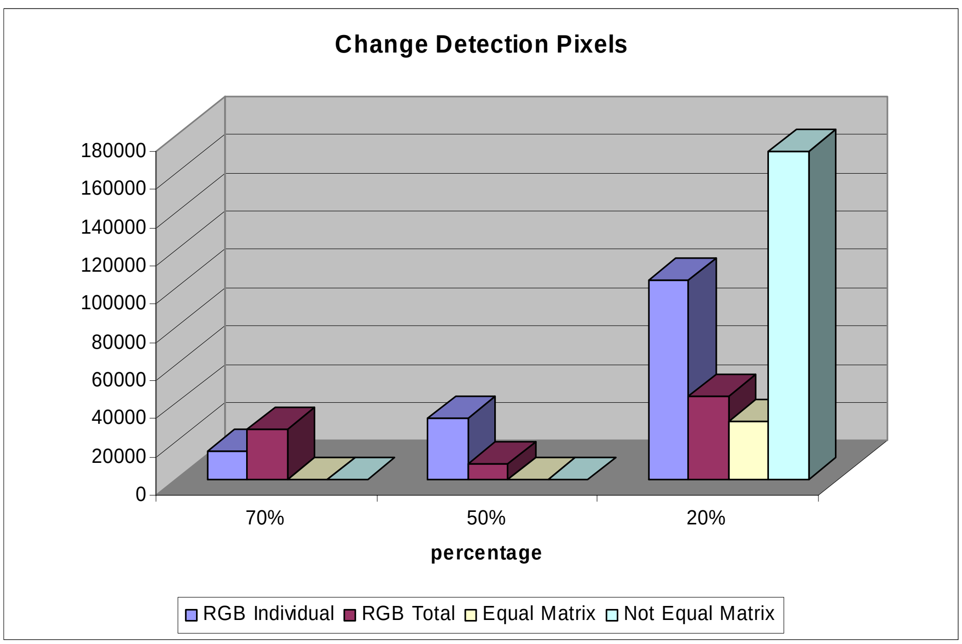


Figure 5.69. Change detection pixels' graphic

Additionally, the results are compared according to visual interpretation and shown their meanings in Table 5.4.

Table 5.4. Visual Interpretation

	Methodology			
Percentage	**RGB ind.**	**RGB Total**	**Equal Matrix**	Not Equal Matrix
70 %	Good	Good	No change	No change
50 %	Noisy	Insufficient	Insufficient	No change
20 %	Noisy	Noisy	Good	Good

According to the digital data and the graphic above, the case which has a settlement features defaults could have been detected as follows:

- RGB individual method is successful for high level change detection.
- RGB total method is successful for high level change detection, however, for middle level change detection, there needs to be used different image enhancement algorithms. Additionally, the resolution decrease affects the result's understandability.
- The Equal Matrix is successful to be found lower level settlement change detection. High level is affected geometric shifts.
- The not equal matrix is also successful with lower level settlement change detection. For middle level studies, there the images need to be improved in order to be reduced noisy areas.

CHAPTER 6

CONCLUSION

6.1. Results of the Thesis

The technological advances and social changes that are characteristic of late twentieth-century urban centers have created the need for new strategies of urban planning. Urban planners have responded by developing supportive tools such as geographic information systems (GIS), remote sensing (RS) and so on. These technologies automate data handling, reduce planning time, and increase the opportunity for public participation. The important questions here were:

- What could RS & GIS do for planning?
- What could do planning for RS & GIS?
- How could RS & GIS and planning improve understanding of human - environment interactions?

From this starting point, the hypothesis of the thesis is that change detection; a RS based process, could be realized in the GIS environment efficiently and overlaid the results with digitized data in the same environment. Because of this, the thesis has been developed a new model how RS and GIS technologies could work with in urban planning discipline.

The thesis examined the use of very high resolution images for changed detection. Various available techniques for change detection and feature extraction have been reviewed. It has been realized from the literature review that no automated method is available for change detection where GIS and RS have been used together. A new graphical user interface (GUI) has been developed for this task.

In order to understand urban planning and information technologies relationship, first, this was examined in Chapter 2. At the end of the chapter, it has been realized that, there is only one direction relation between RS & GIS which is to be used remotely sensed data for updating process. However, today, remotely sensed data is an indispensable part of GIS-based studies. They are used to enhance each other's results.

The discussion in Chapter 3 was the change detection classification techniques. As a result of literature survey, it has been realized there are 3 classification techniques for using change detection especially at urban scale which are pixel-based, feature-based and object-based classification techniques. Pixel-based classification is widely used in land use studies, but the limitations are clear and widely accepted. The basic idea of object-based classification is to classify not single pixels but groups of pixels that represent already existing objects in a GIS databases. Feature-based studies have been accepted as optimum technique in order to get the high accuracy. The thesis contains all of them, at different levels. For example, feature-based classification will be used to detect land changes. The object-based classification will be used to detect the building changes. The pixel-based classification will be used to adjust the results and increase the accuracy of the study.

Then, the focus was given to the change detection concept. Different change detection techniques were discussed. The most common methods using for change detection are listed as image differencing, image rationing, principal component analysis and change vector analysis. The selected existing methods were classified as "image to GIS change detection" and "image to image change detection", after that their application results were compared for the case area. Traditional change detection methods such as the post supervised classification and the PCA technique have been implemented. At the end of the comparison, the supervised classification method is found unsuitable for change detection of man-made objects such as buildings. The PCA technique is very accurate for change detection but only provides information about the overall changes in the images. The PCA method can not suggest any direct information about the changes in the buildings. Also, the PCA method can not discriminate changes that occur due to missing objects from changes that occur due to the appearance of new objects.

The existing studies show that to select GIS or RS software may not be enough to detect the changes. There is no special GUI created by the study owners. At this point, this study differs from the others because; it is expected to be created a GUI for change detection process. The important point here is to provide a connection between spatial and non-spatial data. At the end of the study, it has reached an effective information technology based system to monitor urban squatter settlement.

Another discussion was methodological issues of problems and algorithms used for application and fuzzy inference concept. The methodology was composed of four different methods as pixel by pixel, total bands difference, equal matrix and not equal matrix. Algorithms were classified as spectral, spatial and radiometric image enhancement. This thesis is also an example of the fuzzy inference system.Fuzzy inference was described the relationship of the application. These algorithms are classified according to literature survey results. Especially, fuzzy inference capability makes the GUI a functional tool because; urban areas have not the same feature and density. The fuzzy tool obtains to be performed different queries according to different change percentage with using different image enhancement techniques. In other words, there are memberships functions such as algorithms, methodology and difference percentage. “And” and “Or” are used as logical operators. Then, the results are formed according to If-Then rules.

This thesis also discussed potential contributions of RS and GIS to planning discipline, and proposed a prototype, which would help the users to offer optimum service to the citizens. The need for accurate, easily replicable, geospatial data of the landscape in growing metropolitan regions around the world is increasing. Planners and managers find themselves in constant need of updated geospatial data layers. Of particular interest to local and central managers is land use change detection and urban growth estimation. Such information can help inform decisions concerning the effective balance human needs and natural resource management. However, land uses are not easy to classify and measure, even small areas. Fortunately, RS and GIS with their capabilities for managing and manipulating large amount spatial data have made the task of land use and land cover survey easier. This thesis explored land cover and land use change detection in a part of İzmir using an integrated RS and GIS based change detection methodology.

For this reason, in Chapter 5, new change detection tool, GUI, and GIS integration was presented. This chapter also discussed characteristics, components and system realization of the thesis.

The system realization has been mentioned in three parts called high, middle and low change percentage cases. In other words, the difference percentages have been 70, 50 and 20 %. As image enhancement algorithms, all of the images have been applied “histogram equalization”, “smooth” and “edge detection-weak” algorithms once. For all of them four methods have been used:

(i) the RGB individual,
(ii) the RGB total,
(iii) the equal matrix and
(iv) the not equal matrix.

Both the PAN and MS images have been compared. According to their results, the PAN images should be used for change detection process for building monitoring, because, its resolution is suitable to perform this process. On the other hand, the MS images should be used for regional change detection processes. The 4 times resolution difference between the PAN and the MS affects the correction percentage of the change detection process. Because of this, the RGB individual, the equal matrix and the not equal matrix are used for PAN images; besides, the RGB total has been used only the MS images. While the difference pixels have been found, the results have been saved, and transferred to Access. Additionally, without using Access, the results can be linked to GIS environment with a command. With this feature, the result changed area can be easily represented on the digital maps. In this way, the combination between RS & GIS data has been ensured.

At the end of this part of the case, it is clearly observed, there is no default option to find the environmental detection specifically. It depends on such as needs, objectives, user knowledge level, thresholds, and what the environmental features are. Because of this, this GUI makes different types of detection possible.

The change detection results are compared according to their pixel numbers in access and percentage. According to the digital data, the case which has a settlement features defaults could have been detected as follows:

- RGB individual method is successful for high level change detection.
- RGB total method is successful for high level change detection, however, for middle level change detection, there needs to be used different image enhancement algorithms. Additionally, the resolution decrease affects the result's understandability.
- The Equal Matrix is successful to be found lower level settlement change detection. High level is affected geometric shifts.
- The not equal matrix is also successful with lower level settlement change detection. For middle level studies, there the images need to be improved in order to be reduced noisy areas.

As mentioned in the introduction, there have problems about RS & GIS based change detection applications in Turkey. The thesis can answer and solve some of them. Firstly, to buy different software for RS and GIS based studies is very expensive, in addition to it, each municipality has not enough financial support for them. Therefore, this GIS-based GUI provides the users performing change detection process just using GIS software. Another problem is the lack of specialized staff. The created GIS based GUI is not as complex as the other image processing or RS software. Because of this, the user can perform change detection process easily. The next problem was data loss while converting process. This GUI runs in GIS software, as a part of that software, because of this, the losses are minimized. Additionally, there was a coordinate disharmony problem between the raster and vector data. When the raster data process in GIS software, the loss data risk is minimized. The most important solution of the thesis is to combine the change detection results and GIS based analyze and queries. Without this GUI, to perform these processes take more time, money and manpower.

6.2. Recommendations and Future Expectations for Further Studies

The selection of image acquisition dates is very important for urban monitoring studies. In this thesis, the satellite images belonging to 2001 and 2004 have been chosen because, there were just those two as achieve for the case area. Especially, seasonal differences between these IKONOS images caused several problems in detecting changes. Color variation due to the changes in green areas, also, the color confusion between concrete roads and concrete roofs led to difficulties in the process. Additionally, to perform urban monitoring with 3 year difference is not an efficient way. The time interval should be close anniversary. Therefore, the land cover dynamics control regularly on time.

The case study in this thesis is an example of 1/1000 scale planning studies. Because of IKONOS high resolution, the images let detect buildings on the area. However, urban monitoring should also be applied different scales as 1/25000 and 1/5000. In this way, an urban can easily be monitored from regional development to building differences. In Turkey, 1/25000 and 1/5000 are the most widely used scales in planning studies. Thus, further studies should be conducted using satellite images having different resolutions to see whether they provide the information for planning.

To perform change detection process with different types of remotely sensed data should be developed as further studies. For example, IKONS's and Quickbird's image resolutions are so close to each other. They can be used together as after and before images for change detection studies.

For further studies, existing land use maps should be updated from remotely sensed data. For instance, visual analysis can be performed to monitor urban developments for short time intervals in the area. Thereby, it can be clearly observed whether the planning decisions have been implemented as they were supposed to be. This would provide the responsible local and central governments with the possibility of timely monitoring and the control of developments in the area.

The basic problem in planning studies is the lack of base maps showing the existing situation of the case area and on which plan decisions will be developed. If the planners do not have up-to-date data, plan decisions could be wrong and irrelevant. The remotely sensed data provides up-to-date screen of existing situation with exact coordinates. Especially, map production from them is quicker, cheaper and easier than classical ways. It is therefore pointed out that to detect change areas and update digital maps are the basic needs for any scale planning studies.

At this point, future expectation of this thesis is important because this change detection model is not a standard change detection model. In other words, the system can be adopted by different public organizations to their requirements. This user group may be local governments, central governments and also “Tapu Kadastro Genel Müdürlüğü” or “Bayındırlık ve İskan Bakanlığı”.

In fact, all these organizations have the same basis: i.e., as-is map-based and remotely sensed data based information system. In other words, all public organizations, local and central governments may use the same basis. This creates an advantage because if a common base is established, each organization can create its database management system that best suits its requirements and enrich their systems by using different maps, satellite data and visual data. This would also help to save money, time and manpower.

As a result, the next steps of study should be

- For the small areas, improving the building extraction methods from remotely sensed data.
- For the large areas, developing new change detection techniques.
- An organization integrated environmental change monitoring.

When planning strategies for sustainable management of environment, it is essential to be linked different types of data and analyzed in an effective manner. It is obvious that GIS and remote sensing play an important (potential) role in this process, as illustrated in the case, in particular for detection and monitoring. In this context, "Detection of Environmental and Urban Change Using Remote Sensing and GIS" has an important place as a system using RS and GIS based information system technology. However, as mentioned before, this is not a standard change detection program; because, its form, database structure, algorithms and capabilities need to be enlarged in time according to organizations and usage purposes.

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APPENDIX A

İmar kirliliğine neden olma

MADDE 184. - (1) Yapı ruhsatiyesi alınmadan veya ruhsata aykırı olarak bina yapan veya yaptıran kişi, bir yıldan beş yıla kadar hapis cezası ile cezalandırılır.

(2) Yapı ruhsatiyesi olmadan başlatılan inşaatlar dolayısıyla kurulan şantiyelere elektrik, su veya telefon bağlantısı yapılmasına müsaade eden kişi, yukarıdaki fıkra hükmüne göre cezalandırılır.

(3) Yapı kullanma izni alınmamış binalarda herhangi bir sınai faaliyetin icrasına müsaade eden kişi iki yıldan beş yıla kadar hapis cezası ile cezalandırılır.

(4) Üçüncü fıkra hariç, bu madde hükümleri ancak belediye sınırları içinde veya özel imar rejimine tabi yerlerde uygulanır.

(5) Kişinin, ruhsatsız ya da ruhsata aykırı olarak yaptığı veya yaptırdığı binayı imar planına ve ruhsatına uygun hale getirmesi halinde, bir ve ikinci fıkra hükümleri gereğince kamu davası açılmaz, açılmış olan kamu davası düşer, mahkum olunan ceza bütün sonuçlarıyla ortadan kalkar.

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