ISTANBUL TECHNICAL UNIVERSITY ★ INFORMATICS INSTITUTE

ANALYSIS OF LAND COVER/USE CHANGES USING LANDSAT 5 TM DATA AND INDICES

M.Sc. THESIS

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Department of Communication Systems

Satellite Communication and Remote Sensing Programme

JANUARY 2015

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İSTANBUL TEKNİK ÜNİVERSİTESİ ★ BİLİŞİM ENSTİTÜSÜ

ARAZİ ÖRTÜSÜ/KULLANİMİNİN LANDSAT 5 TM VERİLERİ VE İNDİSLER YARDIMIYLA ANALİZİ

YÜKSEK LİSANS TEZİ

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İletişim Sistemleri Anabilim Dalı

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Paria Ettehadi Osgouei , a **M.Sc.** student of ITU Informatics Institute student ID **705111023**, successfully defended the **thesis** entitled "**ANALYSIS OF LAND COVER/USE CHANGES USING LANDSAT 5 TM DATA AND INDICES**", which she prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

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Date of Submission : 22 February 2015
Date of Defense : 22 January 2015

To my dearest family,

FOREWORD

I would like to extend my special thanks to my supervisor Dr. Şinasi kaya for giving me valuable advice and support always when needed.

In addition, special thanks to my family for their endless love and support throughout my life.

February 2015

Paria Ettehadi Osgouei
Information Technology engineer

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ABBREVIATIONS

ANN : Artificial Neural Network
AWEI : Automated Water Extraction Index
BU : Built-Up
DN : Digital Number
DVI : Difference Vegetation Index
ER : Electromagnetic Radiation
EROS : Earth Resources Observation and Since
ETM : Enhanced Thematic Mapper
GDVI : Generalized Difference Vegetation Index
MNDWI : Modified Normalized Difference Water Index
MTVI : Modified Transformed Vegetation Index
MTVI2 : Modified Transformed Vegetation Index 2
NASA : National Aeronautics and Space Administration
NDBI : Normalized Difference Built-up Index
NDMI : Normalized Difference Moisture Index
NDVI : Normalized Difference Vegetation Index
NDWI : Normalized Difference Water Index
NDWI : Normalized Difference Water Index
NIR : Near Infrared
PVI : Perpendicular Vegetation Index
RDVI : Renormalized Difference Vegetation Index
RVI : Ratio Vegetation Index
SAVI : Soil Adjusted Vegetation Index
SVI : Soil and Vegetation Index
SVI : Soil and Vegetation Index
TM : Thematic Mapper
TNDVI : Transformed Normalize Difference Vegetation Index
TOA : Top of a Atmosphere
TVI : Transformed Vegetation Index
TVI : Transformed Vegetation Index
USGS : U.S. Geological Survey
VI : Vegetation Index
VIS : Visible
WRI : Water Ratio Index

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ANALYSIS OF LAND COVER/USE CHANGES USING LANDSAT 5 TM DATA AND INDICES

SUMMARY

Land cover and land use of earth has significantly been changed by natural and non-natural reasons throughout time and the amount of this change, which has increased by the passing years, were determined by various studies. The areas most affected by this change are countries and the metropolitan cities, which are under pressures due to an unprecedented increase in population growth and developments as the result of urbanization and industrialization. There are several studies about the change of land cover in big cities through the years and different methodologies for detecting these change were performed. Istanbul is among the cities that have undergone a large amount of land cover changes because of various factors specifically urbanization and population growth. Urbanization phenomena with all its advantages for people, causes the large portion of land cover and land use change in big cities such as in Istanbul. Besides the urbanization, there are so many other factors, which should be considered and controlled carefully. Vegetation reduction in the areas, which occurred due to the development of city and new constructions, is one of the consequences of the global land surface change in highly urbanized countries and cities.

Remotely sensed images and especially Landsat images with their long-term archive are the main sources in analyzing the changes happening both in the urban areas and vegetation covers. Classification of Landsat images are the mostly used and simple methodology for detecting the changes and checking the amounts of increase and decrease in the urban and vegetation classes.

Vegetation indices are commonly applied intermediates for emphasizing the specific feature on the land cover such as vegetation, urban areas and soil environment. In this study, temporal changes occurred in the vegetation cover and built-up areas in mega city of Istanbul were determined by using the potential of the remotely sensed data and utilizing Normalized Difference Vegetation Index (NDVI), Soil Adjusted Vegetation Index (SAVI) and Built-up area Index (BU). Benefiting by pre-determined changed areas, in 150 changed areas (points) the relation between indices values were analyzed. Landsat 5 TM data images of Istanbul in June of 1984, 2002, 2007, 2009 and 2011 were used in this study. Land cover/use changes through the entire metropolitan area were determined. According to analysis in the built –up area between 1984 and 2011, the vegetation cover of the completed infrastructural residential areas increased considerably in last two years, 2009 and 2011, compared to 2007. This can be because of the reorganization of the vegetation cover with built-up areas. As the result of study, it can be asserted that indices generated by utilizing the multispectral feature of Landsat 5TM, which has the long-term archive of satellite images, can be used for determining the land cover/use changes. In addition, it is shown that various analyses can be done by exploring the relation between indices.

ARAZİ ÖRTÜSÜ/KULLANİMİNİN LANDSAT 5 TM VERİLERİ VE İNDİSLER YARDIMIYLA ANALİZİ

ÖZET

Uzun yıllar boyunca yeryüzü örtüsü ve kullanımı doğal ve doğal olmayan nedenlerle bir çok değişiklikle yüz yüze kalmıştır ve zamanla bu değişikliklerin arttığı yapılan bir çok çalışma ile belirlenmiştir. Bu değişimden en çok etkilenen alanlar yüksek nüfus artışı hızı ve kentleşme ve sanayileşme vb. nedeniyle gelişmiş ülkeler ve metropoller olmuştur. Büyük şehirlerin zamanla değişimi ile ilgili çeşitli çalışmalar yapılmıştır ve bu çalışmalarda değişik metodolojiler kullanılmıştır. İstanbul hızlı nüfus artışı nedeni ile hızlı kentleşmeden kaynaklanan bariz bir değişim geçirmiştir. Kentleşme kavramı çeşitli avantajları yanı sıra İstanbul gibi büyük şehirlerde, şehirörtüsü/kullanımı değişmesinde en cok etkisi olan bir nedendir. Kentleşme kavramı yanı sıra, kontrol edilmesi gereken bir cok farklı neden vardir. Gelişmiş ülkeler ve şehirlerde inşaat ve yapı sektörünün etkisiyle şehir örtüsü/kullanımı değişmiştir ve bunun en bariz göstergesi bitki örtüsünün azalmasıdır.

Uzaktan algılanmış görüntüler ve özellikle uzun zaman arşivi olması nedeni ile Landsat uydu görüntü verileri, kentsel değişim ve bitki örtüsü tahribini analiz etmek için en önemli veri kaynaklardan biridir. Landsat uydu görüntü verilerinin sınıflandırılması ile arazi örtüsü ve arazi kullanımı değişikliklerinin analiz edilmesi ve bitki örtüsü-yerleşim oranını değişiminin belirlenmesi diğer yöntemlere göre daha kolay olmaktadır.

Bitki indeksleri, arazi örtüsünün belirli özelliğini örneğin bitki örtüsü, kentsel alanlarda ve toprak ortamını vurgulamak için yaygın olarak kullanılan uygulamalardır. Bu çalışmada, Istanbul il sınırlarında Landsat 5 TM uydu görüntü verileri ve bitki örtüsü indisi, toprak bitki örtüsü indisi ve yerleşim (kentsel) indisi kullanarak zamansal değişimler belirlenmiş ve bu değişim alanlardan faydalanılarak 150 değişen alanda (noktada) indisler arasındaki ilişki analiz edilmiştir.

İstanbul İl sınırlarını kaplayan 1984, 2002, 2007,2009 ve 2011 yılları Temmuz ayına ait Landsat 5 TM uydu görüntü verileri çalışmada kullanılmıştır. Metropolitan alanının tamamında arazi örtüsü/kullanımı değişimleri belirlenmiştir. Yapılan analizler sonucu bitki örtüsü değişimleri azalırken toprak sınıflarının arttığı belirlenmiş ve zaman içinde bu toprak sınıflarının yerleşim alanlarına dönüştüğü belirlenmiştir. 1984 yılından beri analiz edilen İstanbul metropolitan alanında yerleşim alt yapısını tamamlamış bölgelerde bitki örtüsü oranının arttığı belirlenmiştir. Bunun nedeni olarak yerleşim alanlarının bitki örtüsü ile yeniden düzenlenmesi gösterilebilir. Çalışma sonucunda, uzun bir döneme ait arşiv verisine sahip Landsat 5 TM uydu verilerinin multi-spektral özelliklerinden yararlanılarak oluşturulan indislerin arazi örtüsü/kullanımı belirlenmesinde kullanılabileceği ve indisler arasında ilişkilerden bir çok analiz yapılabileceği belirlenmiştir.

1. INTRODUCTION

Planet earth's environment has always been altered by human being throughout the several million years they have inhabited it. The first change of land goes back to centuries ago when people on the globe altered land cover by the invention of agriculture (Wolman 1993). Industrial revolution is the next main step in the chang of the land cover. In order to provide workforce for industries in the urban areas there were a need for labor which also fulfilled from rural areas. This situation became a motivation for people, individuals or households of the rural areas to move to cities (Duranton 2014). They had an opportunity of having better jobs with higher anticipated incomes in the urban areas. In addition, living in the urban area provided facilities such as health care, transportation system, electricity, pipe borne water, housing conditions and educational opportunities (Moore et al. 2003). There also were other groups of people who decided to migrate spontaneously. In the result of natural catastrophe, such as flood, drought, earthquake, insect and pests or because of political instability, people may come to the migration decision. Apart from the rural-urban migration, which is the form of internal migration, countries and metropolitan cities, may face the intercontinental migration too. Education is one of the reasons for international migration, as students pursue their studies abroad. Population growth and urbanization development are the next factors of land cover change. These changes have been ongoing, and evidently will continue in coming years.

Vegetation cover and forest areas are the two main land use/cover types, which in most cases affected negatively by the urbanization developing process. Changes of the vegetation canopies and destruction of such areas put the future generation life in real peril. The essential role of the vegetation and bare soil environment in the future life should be considered besides utilizing the advantages of living in cities.

Istanbul is the largest city in Turkey, and it also is the largest in Europe; and because of its superiority in historic, cultural and specifically economic aspects, it has always had a huge population within the city limits, and this has been a pressuring factor for rapid urbanization. This urbanization development and population growth resulted in drastic changes in the land cover/use of Istanbul through centuries (Sanli et al. 2008). Istanbul has always confronted the illegal housing problem to no avail, and besides this moot point, planned urbanization itself means the change in the land cover and somehow damages to the natural environment (Leitmann & Baharoğlu 1999). It is obvious that there is no cessation for urbanization operations and therefore land cover change is inevitable; so the land managers and people liable for the consequences of changes in land cover of the city should develop new methods and practical techniques for lessening negative effects caused by urbanization as much as possible. Vegetation cover decrease and its aftereffects, caused problems related to climate change and increasing of impervious lands are some of adverse impacts of urbanization and land cover change processes. For monitoring spatial changes that occurred through years and planning to solve problems of land cover changings, the trend of change in previous years should be analyzed and the future planning should be done considering this trend of change. Today remotely sensed data by satellites are among the most used data for such kind of studies. Image data files of Landsat TM are reliable data for detecting and studying changes through years because of availability of long-term image archive.

Urban change detection in Istanbul is one of the topics, which was studied by researchers previously ((Kaya & Curran 2006), (Musaoglu et al. 2006), (Geymen & Baz 2008)). For detecting the changes, there are some methods. Classification of the multi temporal images of the specific area and detecting the changes by comparing the classified images is the method, which is used in most cases ((Van Niel 1995), (Yuan et al. 2005), (Coban et al. 2010)). In this method, the classes are separated and the size of each class is determined and by comparing the size of definite class through years, increasing and decreasing of the selected target can be recognized. Another method is using the vegetation, soil and built-up indices which are graphical indicators used to detect the target such as vegetation and its magnitude and intensity ((R.D & Huete 1991), (Jung et al. 2005), (Hadjimitsis et al. 2010), (Villa 2012), (Benkouider et al. 2013)) By comparing the index images, changes can be detected.

In the framework of this study, changes of land cover, vegetation cover and built-up areas in Istanbul were analyzed using multi temporal Landsat 5 Thematic Mapper(TM) data images of Istanbul city in 1984, 2002, 2007, 2009 and 2011. The data specifically selected from the same month of the year (June) for emitting the changes caused by season variations. Different indices values such as NDVI, SAVI and BU were extracted from the Landsat images.

After overlaying the index images, land cover and land use changes were illustrated by different colors in the resulted layerstack images, were analyzed precisely. The relationship between the change of urbanized areas and the change of vegetation areas were checked by evaluating the index values in the changed area and different analysis were done by exploring the relation between various indices. In other words, effects of the urbanization and land use/cover changes on the vegetation cover of the area were studied by analyzing the NDVI, SAVI and BU index values and their relation.

2. LAND USE CHANGE AND DRIVERS

This chapter presents the general view of literature that compiles information on the topic of land use change, urbanization and their impacts on environment. It discusses the reasons for land cover change and urbanization consequences as one main cause of change. The chapter concludes by review of studies from the scientific research in the domain to link the studies of land use change and the urbanization phenomenon.

2.1 Land Cover and Land Use Change

Land-cover designates the surface cover over land, including vegetation, bare soil, hard surfaces, bodies of water and human-modified surfaces such as buildings. Land-cover is a characteristic of the land that can be observed physically by remote sensing technology (Townshend 1992). Land cover change refers to the change in the physical form of the land surface, such as nature of the surface.

Land use is referred to the processes in which humans use the biophysical or ecological properties of land for agricultural, residential, industrial, recreational, or other purposes. Changes in the area which occurred by these type of developments are marked as the land use change (Briassoulis 2009).

According to time and space there are various mixed factors that cause land use changes, which are specific for human-environment case. Beside effects of biophysical drivers of land cover change, such as droughts induced by climate change, loss of soil fertility by erosion or earthquakes; there are human drivers which includes economic and policy (Lambin & Geist 2006). Some major causes of land use change in classes are basically; natural variability, economic and technological factors, demographic factors, cultural factors and globalization. In the following sub-sections, there are brief explanations of five factors and an example for each factor.

2.1.1 Natural variability

These changes that happen in natural environment, prompt human being to make some alterations on land cover. Climatic changes due to variable ecosystem conditions, such as dry to sub-humid climatic status, results as search of human being for new land resources causing more change in land cover. Different soil and climate condition of natural environment results in various possible decisions for land use (Khan et al. 2014). Cultivation in favorable soil, climate and livestock grazing in dry lands are some drivers of these decisions. Therefore, any wrong decision made in response to climatic change in area can cause land use change, which may have negative consequences, such as land degradation in the case of wrong livestock management.

2.1.2 Demographic factors

Local population, as the one of demographic factors, can change the land cover of the region by both increasing and decreasing. Population growth increases the demand from global agricultural systems; push them to their very limits. Dietary preference of these number of population change the area to lands proper for livestock farming in response to the high amount of demand for meat and dairy consumption. There are some factors associated with regional land use change such as soaring tendency of living in urban areas and though urban-rural population distribution and rapid urban development. Migration and urbanization are impressive demographic factors. Migration causes rapid land-use changes, and it can change consumption patterns, economic integration, and globalization by interacting with government policies. The effect of migration is overlooked in the studies of land cover change. It causes land use changes in two ways. It changes the land, which is abandoned and affects the condition of the land parts that is inhabited. In the study by Lopez E. et al.(2006), as a consequences of population and migration increase which is because of poverty, wars, economic reasons, environmental degradation and etc. through the targeted area, there is an increase in the new settlements or denser populations in new lands that are inhabited. Also there is an expansion of scrubland areas at the expense of rain-fed agricultural land associated with the abandonment of agricultural land with poor soils (López et al. 2006).

2.1.3 Economic and technological factors

Decisions about the status of land use are affected by the economic factors. Altering prices and taxes, changing the costs of production and transportation or making, various plans about the investments are among these economic factors. It is obvious that technologies, which are used in various land use management purposes, play important role in the changes of land use and land cover. These technologies are unequally distributed between regions and households, which ends in different layouts of land use changes. Mechanized large-scale agriculture is one of the most impressive technologies.

The influence of these factors can simply be explained by following example. According to different economic and technological factors, the building roads has facilitated access to new markets ensuring the possibility of global sales as well as local. With better investing plans farmers will naturally be encouraged to change the forestlands to new croplands, utilizing the new technologies in the agriculture industry.

2.1.4 Globalization

With the advent of globalization, the processes has resulted in adaptation new forms and standards such as removal of borders for the international expansion of markets, increase of the interdependency among people and between nations, providing more freedom of trade between countries, and etc. . This new developments can affect the other factors of land use change. Globalization has increases the worldwide interconnectedness of places and people through markets, information and capital flows, human migrations, and social and political institutions. In other words, globalization being not in itself a driver of land cover change, acts as an underlying process for other driving forces. For example, increase in demand for global food, as the result of association of globalization and other socioeconomic factors, can cause deforestation in areas suitable for modern agriculture. Study of a group in Stanford university (Rueda & Lambin 2013) reveals that market trends are becoming prominent forces of shaping local landscapes. As an example the increasing demand for high quality and sustainable coffees is driving land-use decision among Colombian farmers.

2.1.5 Climate change

The climatic change also can be added to the aforementioned drivers of land use and land cover change that are sorted by Lambin (2013). In an absolute sense, land-use change has probably been a stronger driver of changes in twentieth century in wild plants and animals than of the climate change (Parmesan & Yohe 2003). However, in respond to a question of whether there is sufficient evidence to implicate climate change as a common force affecting natural systems on a global scale, it can be mentioned that from a biological view, however, finding any significant climate signal amidst noisy biological data is unexpected in the absence of real climate drivers. Such small, persistent forces are inherently important in that they can alter species interactions, de-stabilize communities and drive major biome shifts (Parmesan & Yohe 2003).

A report written by the Union of Concerned Scientists (UCS), about the impacts of the global warming and climate change on ecosystem and specifically on land, mentioned the migration of plants and animals to higher altitudes and latitudes.

Alpine region became the new habitat for animals and plants, which already live in extreme habitats. These species are threatened with extinction because of the lack of proper space, which they can inhabit due to the encroachment of shrubs and boreal trees on the warming tundra. Plant-hardiness zones are shifting as formerly low-latitude plants survive at higher latitude.

In a study of Gehrig F. et al.(2007) for checking the drivers of tree line shifts in the Swiss Alps, two factors were introduced and discussed which were climate change and the land abandonment. Results reveal that land abandonment is the most dominant driver for both forest ingrowth and a majority of the upward shifts in the Swiss Alps near the tree line. The relatively small effect of climate change was attributed to anthropogenic suppression of the current tree line and the short time frame of only 12 year between the two surveys (1979-1985 and 1992-1997). It is therefore assumed that in the long run, climatic effects will become more obvious as forests rise towards their climatic potential.

In the study by Theurilla J-P et al. (2011), according to conclusions drawn from general climatic impact assessment in mountain regions, the review synthesizes results relevant to the European Alps, published mainly from 1994 onward in the fields of population genetics, eco-physiology, phenology, phytogeography, modeling, paleoecology and vegetation dynamics.

They conclude that global warming will shift, in a more or less regular pattern, the climatic ranges of species or even whole vegetation belts upward along altitudinal, thermally defined gradients. Although a shift of a whole vegetation belt is hardly likely, one can nevertheless project an initial estimate of the potential range of change that is to be expected (Theurillat & Guisan 2001). For Switzerland, an increase of 3.3 K in mean air temperature, corresponding to an altitudinal shift of 600 m, would reduce on average the area of the alpine vegetation belt by 63%. Interestingly, the Colline and Montane vegetation belts would be reduced on average by only 20%, and the sub-alpine vegetation belt by even less (–9%) (Theurillat & Guisan 2001).

Given the inertia of vegetation belts, an increase of 1–2 K in mean annual temperature may not shift the present forest limit upwards by much more than 100-200 m. However, it is inconceivable that the inertia of the temperature-related forest limit, either climatic or edaphic, will withstand a 3–4 K increase, which is equal to the temperature range of an entire vegetation belt. If a temperature increase of more than 2 K persists for several centuries, it is possible that forests could develop at even higher elevations than those observed since the last glaciation.

Shifting the forest limit is occurred by persistent process through years. Theurilla J-P et al.(2011) explained the example procedure that causes the limit shifting. They mentioned that warming would modify competitive relationships between plants functional types. For instance, at the lowest elevations, Sclerophyllous, i.e., having tough, persistent leaves or Laurophyllous Phanerophytes in the understory may overrun the deciduous tree layer. In the sub-alpine belt, deciduous trees may overrun coniferous ones. And finally, in the alpine belt, Chamaephytes (i.e., plants which have surviving organs lying close to the ground up to 50 cm) may overrun Hemicryptophytes (i.e., plant which have surviving organs lying at the soil surface), and low shrubs may overrun Chamaephytes in subalpine-alpine heaths (Theurillat & Guisan 2001).

By reviewing all these studies it can be concluded that climate change as small, systematic trends that may become important in the longer term, should not be underestimated because such underlying trends would be confounded by strong forces such as habitat loss in the near future (Parmesan & Yohe 2003).

2.2 Urbanization and land cover change

Large numbers of people congregate, try to find an area with more opportunities and settle there. For this reason, social institutions such as government are developed for supporting purposes. Today, more than half of world’s population resides in urban areas. It is obvious that in the following years large extent of society tend to live in urban lands. Urbanization will continue as long as people from communities move from one place to another, domicile in sites where new friend, old families and good job opportunities can be found. Whether it will tend to improve the condition of humankind, or detract from it (Orum 2004).

“The population division of the department of economic and social affairs of the united nation” which has been issuing, since 1988, every two years revises estimates and projections, at all countries in the world and of their major urban agglomerations showing the percentage of urban areas through the whole world by in years 1970, 1990, 2014 and 2030. As illustrated in **Figure 2.1** there is great increasing through years in percentage of urban areas.

2.3 Urbanization impacts

It is conspicuous that urbanization itself has many advantages, for the one wants to progress, have better occasion, and benefit from high standards of living. However, one should not forget to consider and confront the side effects and disadvantages as well. Urbanization development should take place within well-thought-out rules and predetermined provisions. Most of this growth will not occur in the largest cities but in smaller secondary cities and towns where poverty rates are higher and where existing coverage of basic public service is far from comprehensive. The other most important concern of this dramatic growth in urbanization is the unfavorable effects on the environment and climate. It is crucial to focus and analyze the ecosystem responses to urbanization for debarment of the unwanted effects. Pauchard et al.(2006) survey includes multiple effects of urbanization on the biodiversity of developing countries.

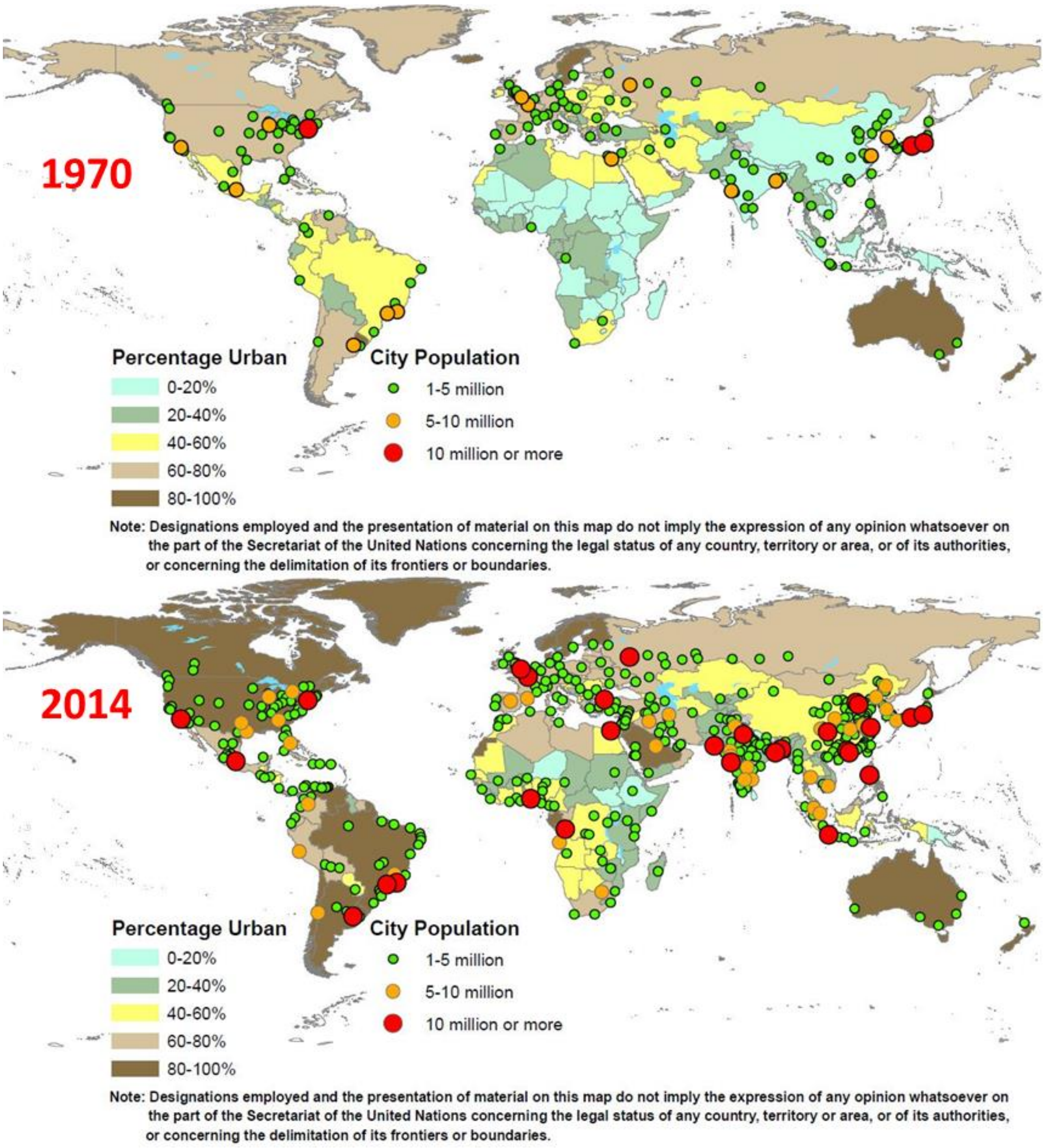

Figure 2.1: Percentage of urban and urban agglomerations by size class 1970 and 2014.http://esa.un.org/unpd/wup/Maps/CityDistribution/CityPopulation/CityPop.aspx, date retrieved 9/21/2014.

With the knowledge that there is difference between the effects of urban sprawl on biodiversity in the metropolitan area of conception from the worldwide situation, results show that native ecosystem are replaced by pavements and buildings and what is left of the natural soil is covered with green areas, which are dominated by non-native ornamental species. Wetland and other peri-urban ecosystems have been destroyed, fragmented or invaded by non-native species over the course of centuries. These are some of spatial effects of urbanization on the selected area of study which can be generalized to sizeable scales. Side effect of urbanization on climate has been one of the topics, which is exclusively considered and studied in big cities.

Urbanization results in big changes in land cover and land use. These changes play key role in creating an urban-heat island, which lead to the warming over land. Cites tend to have higher air and temperature than their rural surrounding especially at night. Urban heat island affects not only local and regional climate, but water resources, air quality, human health, biodiversity and ecosystem functioning as well (Grimm et al. 2008). Eugenia Kalnay et al.(2003) checked the impacts of urbanization and land-use change on climate, by using the difference between trends in observed surface temperature in the continental Unites States and corresponding trends in a reconstruction of surface temperature determined from a reanalysis of global weather over the past years, which is insensitive to surface observations. Results suggest that half of the observed decrease in diurnal temperature range is due to urban and other land-use changes. Moreover, their estimates of 0.27°C mean surface warming per century due to land-use change is at least twice as high as previous estimates based on urbanization alone.

Urbanization and its consequences on the vegetation cover and soil is the other cause of concern in developing cities. Deforestation because of the urban growth is one of the main reasons of vegetation cover reduction. Soil is the other victim of urbanization development. Municipal polluted water, industrial waste gas, waste gas of automobiles and garbage can change the physical and chemical nature of soil.

Soil erosion is the other impacts of urbanization on surroundings. Erosion has experienced intensive impact by human activities. Urban areas witness a quick economic growth and have more construction projects than rural area and have more intensive changes of environment during a short period of time or add some new elements to the erosion system (Hu et al. 2001).

It is noticeable that urbanization growth and increasing in the number of settlement and constructions will end in downtrend in vegetation cover. The amount of vegetation change should be considered and analyzed in order to make the proper decisions for preventing and solving the probable troubles. It can be discussed that by urbanization expansion, the number of newly constructed parks and other vegetation canopies increases. But it should be studied if these parks and greensward areas near the buildings are able to take the place of natural forests and play its role in confronting the air pollution, caused by urbanization, or not. Other than the global decrease of vegetation cover, there are some other effects of urbanization on the vegetation phenology. According to the group studying major cities in Yangtze river delta region about the impacts of urbanization in vegetation phenology, the urbanization of the cities has caused the vegetation in the urban area having an earlier start of growing season, longer growing season length and smaller difference of maximal and minimal normalized difference index(NDVI) in a year. These changes were more obvious in buffer zones if they were closer to urban area (Han et al. 2008). It is plain to see that planted areas in cities in accordance to their ecological capability are not equal to those in rural environment. On the authority of a study, performed by a group, on the effects of urban on vegetation in a less built-up city, it is revealed that just the half of the vegetation could behave as a natural living being and the other half was under stress (Jung et al. 2005).

3. INDICES

In this chapter, Indices that were used for interpretation of the remotely sensed images are described, later various types of indices that were used for different cases according to the characteristics of objects are mentioned, and their arithmetic formula are explained.

3.1 Index

In order to monitor the changes which have occurred in land surface and specifically measure and map the density of green vegetation over the Earth, scientist have always been probing for methods in order to predict and model the surface process.

There are four stages in the gradual advance of these indices. The first indices were those developed from simple band ratios and used for inferring the spectral properties of vegetation through its growing period. Second stage is referred to development of indices which were designed to reduce the impacts of the background such as soil response. The third stage indices were developed to compensate for the effects of atmospheric distortion. The development of new spectral indices for applications other than vegetation health is the final stage of this procedure. Indices that are used for burned area assessment and fire severity are in the last developed group of indices.

By applying the spectral indices on remotely sensed data, the sensitivity of certain surface (e.g. plant biophysical) properties is maximized. Such responses change linearly to allow both ease of scaling and use over a wide range of surface conditions. In addition, such indices are capable of normalizing or reducing effects of sun angle, viewing angle, the atmosphere, topography, instrument noise, etc., making consistent spatial and temporal comparisons possible. Spectral indices can be linked to specific and measurable surface processes (e.g. biophysical parameter such as LAI, biomass, etc.) (Jenson (RSE Book, 2000).

Vegetation analysis by spectral measurements is performed in order to reduce the spectral data dimension of different vegetation canopies to a single number. Such analysis reflect the physical characteristics of vegetation, including leaf area, biomass, photosynthetic activity, productivity and percent cover and minimize the consequences of internal factors, such as canopy geometry and soil properties and external factors, such as the noises caused by sun angle and atmosphere on the spectral data(Van Niel 1995).

3.2 Vegetation Index

By using the output of each spectral band that is dependent on the reflected energy, vegetation indices are designed as arithmetic relations of bands and provide information about the spectral characteristics of vegetation. The major usage of vegetation indices is in vegetation classification and biophysical inference of the radiometric and structural parameters of vegetation (Huete 1988).

Vegetation characteristic at a specific wavelength is defined by the amount of absorption and reflection of a solar radiation. Vegetation indices as combination of surface reflectance at two or more wavelengths are intermediates that feature a specific character of vegetation. Water, pigments, nitrogen, and carbon parameters are each expressed in the reflected optical spectrum from 400 nm to 2500 nm, with often overlap but are spectrally distinct, reflectance behaviors. The known spectral signatures allow scientists to combine reflectance measurements at different wavelengths to enhance specific vegetation characteristics. In scientific literature, several vegetation indices have been produced but there are few among these indices which are based on fundamental biophysical characteristics and have been tested methodically.

The units of the input variables form indices. The use of different vegetation indices will result in more successful results provided that all these units are considered and studied thoroughly. In addition, the external environment and the architectural features of the vegetation canopies, influence and change the index value, and should carefully be investigated in order to get better results from these indices. (R.D & Huete, 1991).

The Normalized Difference Vegetation Index (NDVI) is the most commonly used vegetation index and because of its ratio properties, it is an operational vegetation index, which reduces most of the noise caused by changing sun angles, topography, clouds or shadow, and atmospheric conditions. It is defined as the ratio of the difference between near-infrared reflectance and red visible reflectance to their sum, which is an indicator of vegetation productivity. Written mathematically, the formula is:

$$NDVI = (NIR - VISred)/(NIR + VISred) \tag{3.1}$$

Where VIS and NIR stand for the spectral reflectance measurements acquired in the visible (red) and near-infrared regions, respectively. Calculations of NDVI for a given pixel always result in a number that ranges from minus one (-1) to plus one (+1); however, no green leaves gives a value close to zero. A zero means no vegetation and close to +1 (0.8 - 0.9) indicates the highest possible density of green leaves.

There are some other indices with a range of complexities. Indices are chosen depending on their application. The simplest vegetation index is the Ratio Vegetation Index (RVI). A more complex index is the Perpendicular Vegetation Index (PVI) that takes into account the soil emissivity (one of the major limitations of NDVI). The simplest vegetation index is the RVI, which takes the ratio of the near infrared (NIR) and red (R) radiances.

$$RVI = NIR / R \tag{3.2}$$

It has been found that there is a linear relationship between Red and NIR reflectance from bare soils. This was tested for several different soil types, including sand, pebbles and clay. It was even true when the roughness and moisture of the soil varied. This relationship is called the soil line and is given by

$$NIR_{soil} = aR_{soil} + b \quad NIR_{soil} = aR_{soil} + b \tag{3.3}$$

In calculating the PVI of a surface with vegetation, the reflectance in the red and NIR ranges are measured and plotted on a graph. An example graph is shown in **Figure 3.1**. The PVI is the perpendicular distance of the measured point from the soil line, defined as follows:

$$PVI = \frac{NIR - aR + b}{\sqrt{a^2 + 1}} \tag{3.4}$$

Where a and b are the slope and gradient of the soil line respectively. In this way, the PVI measures the changes from the bare soil reflectance caused by the vegetation. In addition, it gives an indication of vegetative cover independent of the effects of the soil.

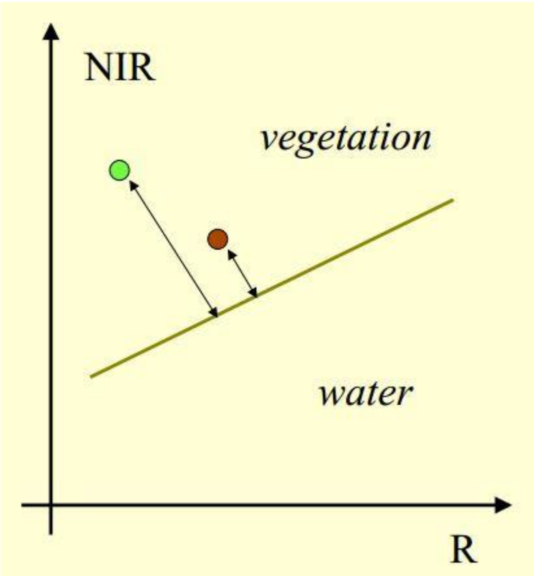

Figure 3.1: The circles represent the measured red and infrared reflectances. The green line is the soil line.

In the study of (Wu 2014) about the vegetation indices, by taking into account the limitation which was observed while applying VIs in research in dry areas due to their low sensitivity to low vegetation cover, the Generalized difference vegetation index (GDVI) is proposed. The formula is:

$$GDVI^n = \frac{\mathrm{NIR}^n - VIS^n}{\mathrm{NIR}^n + VIS^n} \quad \textbf{(3.5)}$$

Where **n** is power, an integer of the values of 1, 2, 3, 4... n. The global dynamic range of GDVI is the same as NDVI, from −1 to 1; and when n = 1, GDVI is equal to NDVI. GDVI has its uniqueness such as higher sensitivity and dynamic range in the low vegetation biomass in spite of its disadvantages and limitations (e.g., low sensitivity and saturation) in densely vegetated areas.

There are some other indices that were tested in the case of study, including: Improved Modified Triangular Vegetation Index (MTVI2), Red Edge Normalized Difference Vegetation Index (NDVI705), Transformed Normalized Difference Vegetation Index (TNDVI), Re-normalized Difference Vegetation Index (RDVI), Ratio vegetation Index (RVI), Difference Vegetation Index (DVI) and etc. After checking all these indices on images, results reveal that using NDVI index is giving better and more reliable outcomes for detecting the vegetation cover in the study area. In **Figure 3.2** NDVI image of Istanbul province in years 1984, 2002, 2007, 2009 and 2011 are shown. Highly vegetated areas such as forest that have the high values of NDVI are separated by bright white colors. Pixels get darker by the decrease in NDVI value. In highly urbanized areas, pixels are in dark black color.

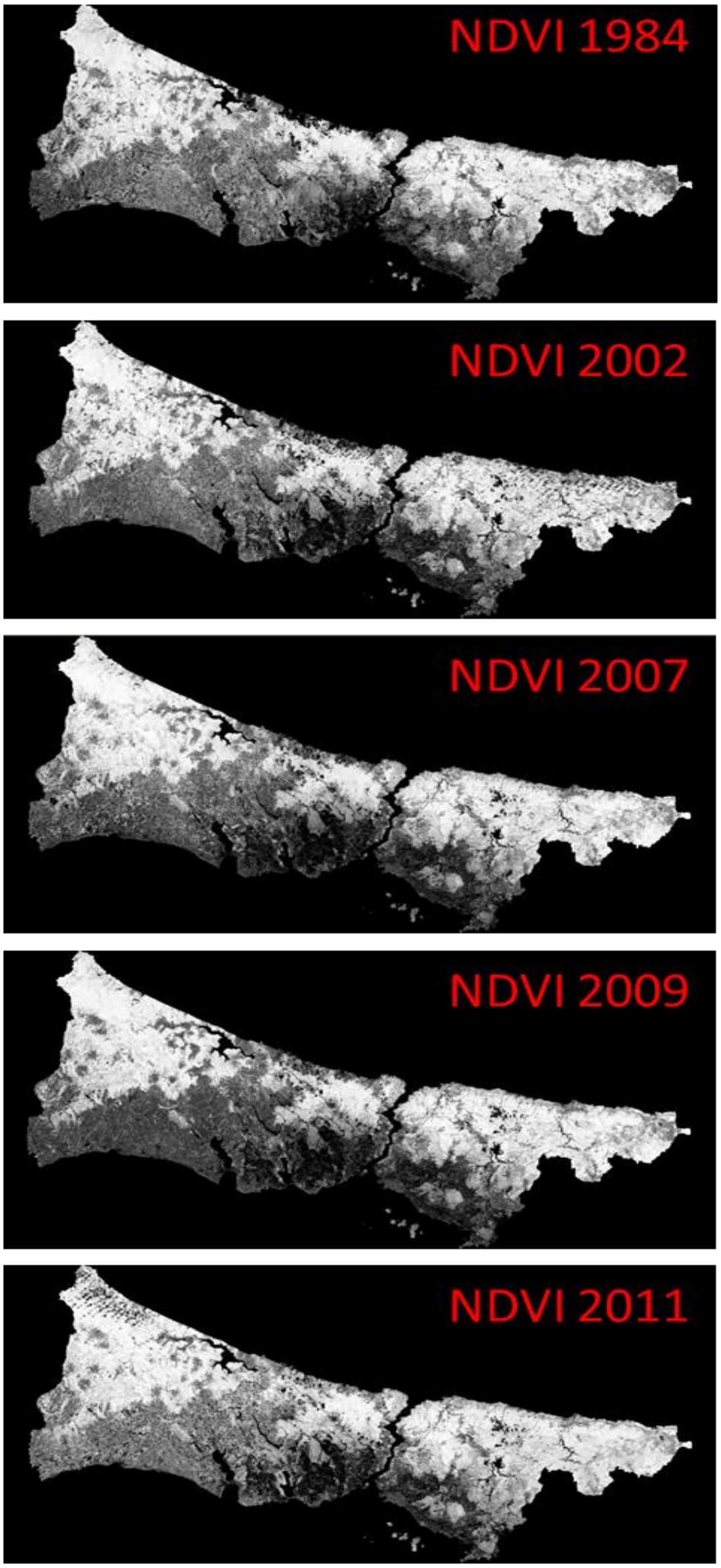

Figure 3.2 : NDVI images of Istanbul province in years 1984, 2002, 2007, 2009 and 2011.

3.3 Soil Adjusted Vegetation index

As same as the normalized difference vegetation index, red and near-infrared canopies reflectance or radiances are utilized for producing the new index named Soil Adjusted Vegetation Index (SAVI) which is designed for minimizing soil brightness effects from spectral vegetation indices. The vegetation canopy spectrum is significantly affected by the condition of soil background. Therefore, the background soil plays a crucial role in the calculated vegetation indices. Different vegetation indices give various results due to the condition of the background soil. For example for a given amount of vegetation NDVI and Ratio Vegetation Index (RVI), we have higher values in darker soil while for the Perpendicular Vegetation Index (PVI), brighter soils resulted in higher index values (Huete, 1988).

Background soil is mostly effective in vegetation indices in the case of intermediate levels of vegetation on area. In highly vegetated areas, there are no significant soil signals coming out of vegetation canopy while there is not enough vegetation for separating the canopy scattered and soil reflected signals on lowly vegetated region (Huete, 1988).

The SAVI is structured similar to the NDVI but with the addition of a soil brightness correction factor,

$$SAVI = \frac{\mathrm{NIR} - \mathrm{VIS}}{\mathrm{NIR} + \mathrm{VIS} + \mathrm{L}} \times (1 + \mathrm{L}) \qquad \textbf{(3.6)}$$

Where NIR is the reflectance value of the near infrared band, RED is reflectance of the red band, and L is the soil brightness correction factor. The value of L varies by the amount or cover of green vegetation: in very high vegetation regions, L=0; and in areas with no green vegetation, L=1. Generally, an L=0.5 works well in most situations and is the default value used. When L=0, then SAVI = NDVI. **Figure 3.3** shows SAVI images of Istanbul province in years 1984, 2002, 2007, 2009 and 2011.

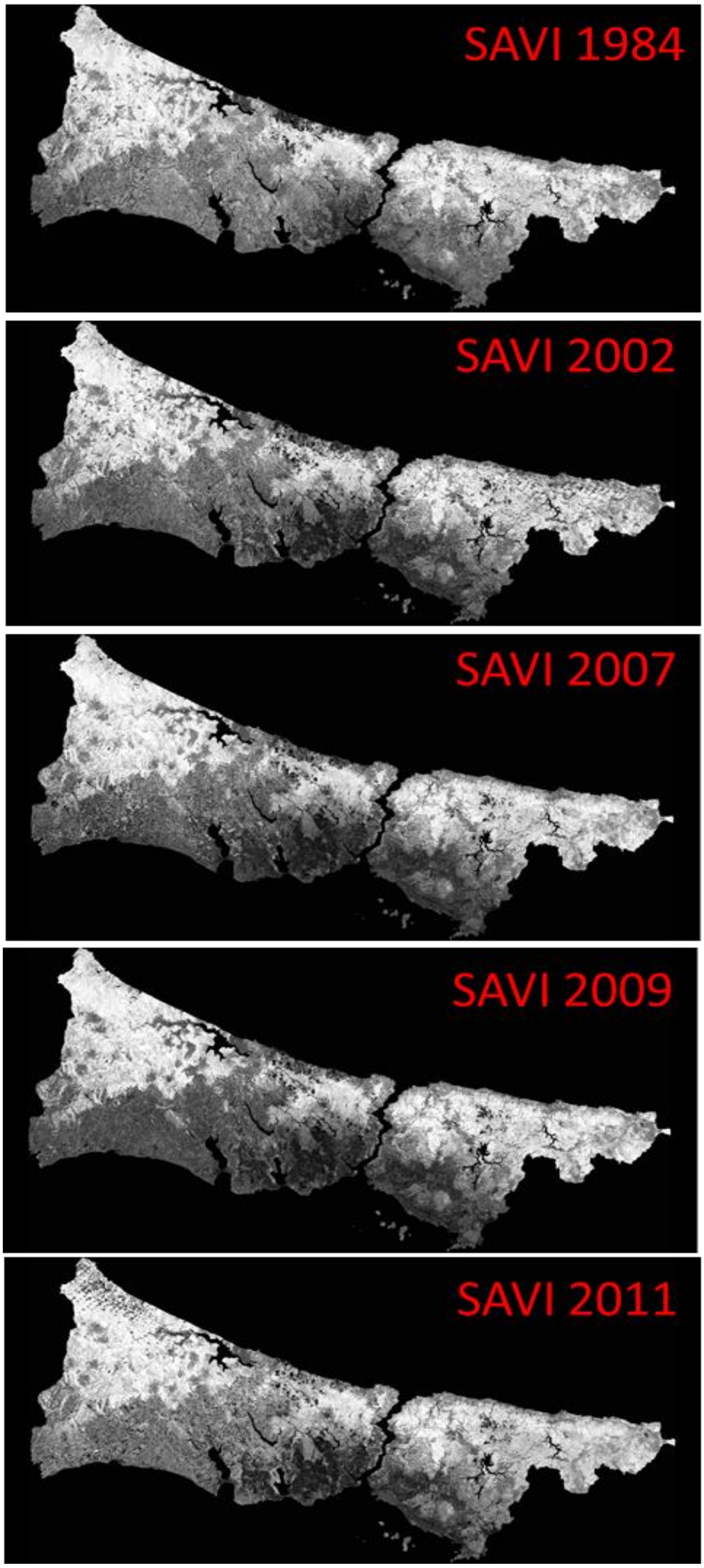

Figure 3.3 : SAVI images of Istanbul province in years 1984, 2002, 2007, 2009 and 2011.

3.4 Built-up Index

In this study, I used the BU index for extracting urban built-up land features, which has been firstly used by Lu, et al. (Lu et al. 2014). In their study, they categorized the land surface types as; built-up and non-urbanized areas according to the difference of their spectral features.

The built up index is produced using the NDVI and the NDBI by Zha et al. (2003) with the following equation:

$$\mathrm{NDBI} = \frac{\mathrm{MIR} - \mathrm{NIR}}{\mathrm{MIR} + \mathrm{NIR}} \qquad \textbf{(3.7)}$$

Where MIR stands for the spectral reflectance measurements acquired in the Mid-infrared region. The assumption underlying the NDBI method is the spectral reflectance of urban areas in band 5 exceeding that in band 4. This method will generate valid results so long as this assumption is not violated (Zha et al. 2003).

BU index is measured by extracting the NDVI value from the NDBI value as shown in the following equation:

$$\mathrm{BU} = \mathrm{NDBI} - \mathrm{NDVI} \qquad \textbf{(3.8)}$$

There are BU images that are referred to built-up areas of 1984, 2002, 2007, 2009 and 2011 in Istanbul in **Figure 3.4** and the graphical model of BU index, a combination of graphical models of NDBI and NDVI, constructed using Erdas Imagine model maker is shown in **Figure 3.5**. In this model, firstly, the NDVI value was calculated by using the relation between band 4 and band 3 and then the NDBI was calculated by evaluating band 5 and band 4 data. The BU index was computed by subtracting the NDVI value from NDBI value. After computing BU values, resulting data were stretched to 8-bit (0-255) data range. As it is observable in BU images, urbanized regions with higher BU values are shown by brighter colors while the surfaces with high amount of vegetation are shown by darker color.

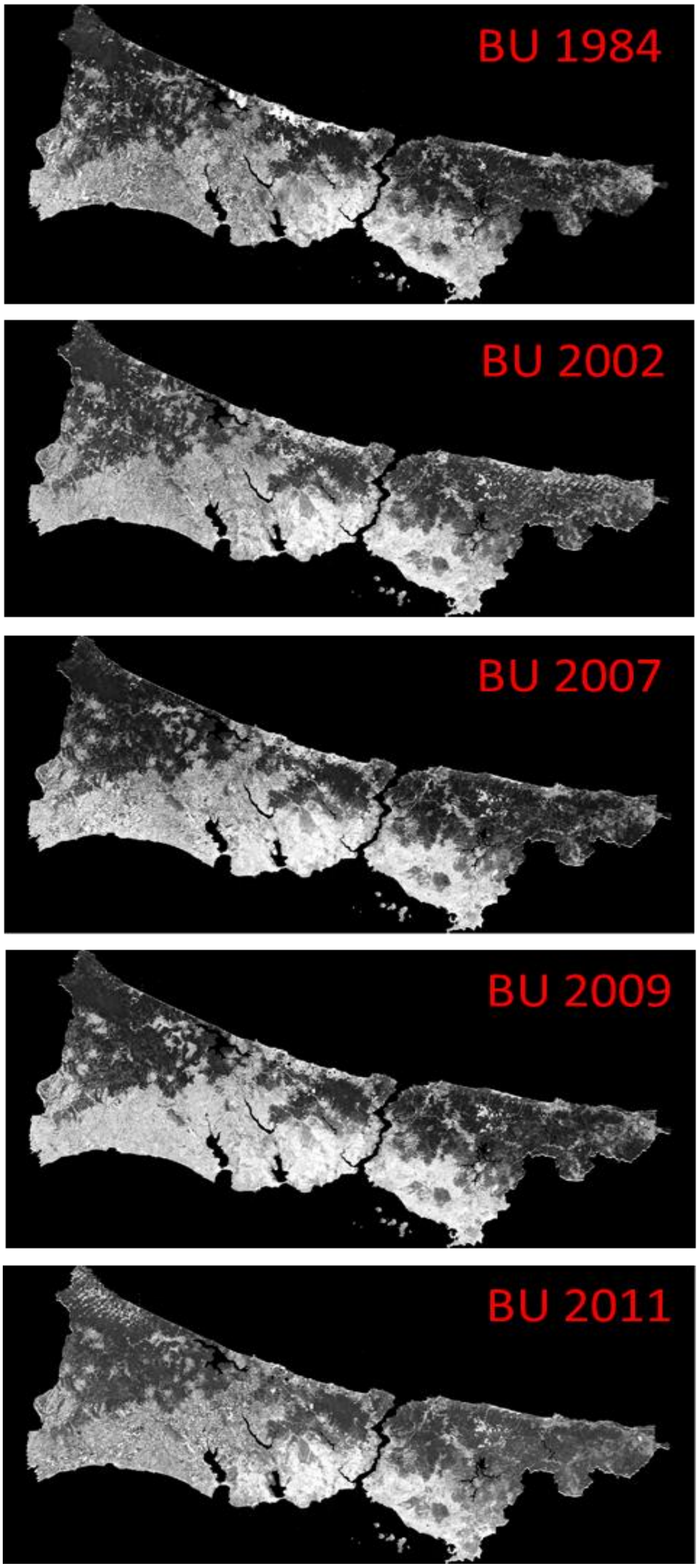

Figure 3.4 : BU images of Istanbul province in years 1984, 2002, 2007, 2009 and 2011.

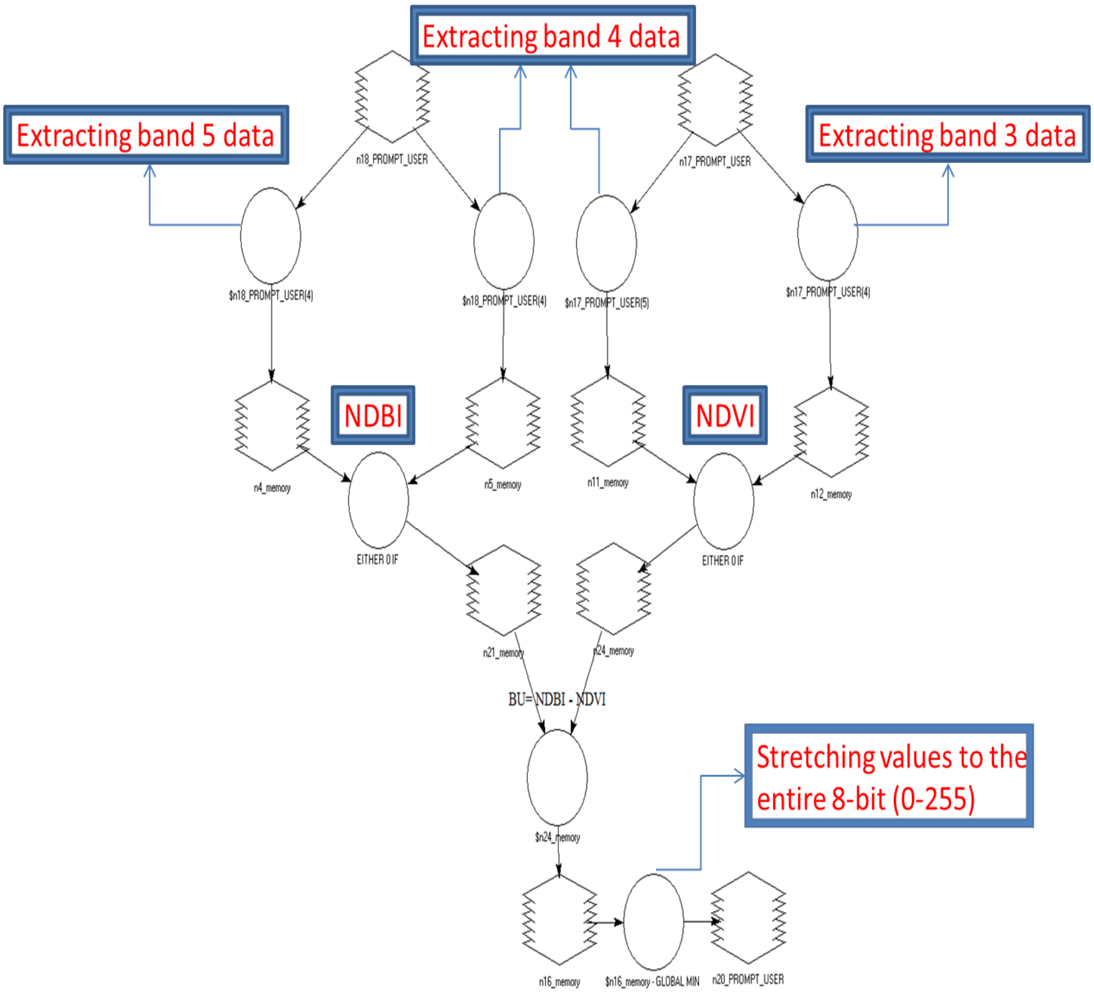

Figure 3.5 : Graphical model of BU Index.

4. LITRETURE REVIEW

Monitoring changes occurred in land cover and probing for the causes of these changes and making a connection between the various causes have been the topics for survey since centuries ago. Remotely sensed images are the main data sources for searching about the changes through years because of availability of the extensive datasets of large spatial and temporal coverage. Comparing and differencing the images is one of the ways for detecting the changes with various methods and applications. Environmental changes has always been in the center of attention of scientists and researchers for the obvious vital role environment plays in current and future life of human being and all other beings.

Hutchinson et al(2000) surveyed the primary hypothesis for vegetation change in the southeastern Arizona by use of repeated aerial photography covering a period of 50 years (Hutchinson et al. 2000). They considered two main causes: climate and land use. According to their study, land use is more responsible for regional vegetation change than climate. Due to intense reliance on local supplies of wood for human livelihood and the use of it for mine shoring and steam engines, there is significant decrease in woody land in the early 1900s. By the decline in demand for woody vegetation, due to other economical alternatives becoming available and assigning stricter roles for assessing the forest resources, a noticeable increase happened in years between 1930s and 1980s.

After digitally scanning imageries and assigning a threshold for detecting the shrub lands in the study region, considering total canopy area and segmented canopy area comparisons, they concluded that there was a general increase in tree and shrub cover over almost 50 years (Hutchinson et al. 2000).

There is a wide usage of vegetation indices in the studies related to changes which occurred through a period in various regions. NDVI is one of the most used vegetation index, showing the best results for studies concerning alternations in vegetation canopies. There also is a study which analyses the dynamics of terrestrial biosphere by the help of satellite observations and satellite-derived Normalized Difference

Vegetation Index (NDVI) (Piao 2003). They studied the climate change and human activity as the effective element in inter-annual variation of monthly and seasonal NDVI in china; during years between 1982 and 1999. Results indicate that temperature and precipitation as climate variables, play a critical role in NDVI variations. It is revealed that increased temperature and precipitation could cause increase in NDVI in most areas generally but also under specific situation, the increase in variables could lead to decrease in NDVI value, such as increased temperature and precipitation in summer time. About the impacts of human activity, this study declared that spatiotemporal patterns of NDVI largely affected by such activities. Although irrigation has probably increased plant growth, Sharp decrease happened in NDVI in the most urbanized part of region of study because of urbanization developments(Piao 2003).

As it is known, different materials and various types of vegetation have specific spectral feature. For example, at certain wavelengths, sand reflects more energy than green vegetation while at other wavelengths it absorbs more (reflects less) energy. In addition, urban areas have various physical characteristic comparing to other human modified and undeveloped land surfaces which results in different spectral features. Hyperspectral remote sensing by using the hyperspectral imaging sensors, which combines imaging and spectroscopy in a single system, is also being used for identification of minerals, vegetation and man-made materials. Detecting the urban effects on vegetation cover by analyzing digital airborne imaging spectrometer images (DAIS) is the subject of study of Jung A. et al (Jung et al. 2005). They calculated normalized difference vegetation index modified for hyperspectral imaging (hNDVI). In addition, they produced a map of partial long wave radiation for detecting the cooling effect of vegetation surrounded by urban area and at last, they calculated urban stress effect on vegetated surfaces. After classifying the source images, all resulted maps and images are compared for final interpretation. Results show that vegetation cover surrounded by urban area is under stress and just half of the vegetation could behave as a natural living being. It is obvious that in growing cities this should be considered for ceasing the probable ecological problems.

Landsat thematic mapper data is one of the most reliable data sources for identification and detection of changes occurred in urban area and vegetation cover. Yuan F. et al (2005) tried analyzing the change by classifying the multi temporal images of the Twin cities, one of the metropolitan areas that witness significant growth in population and large urbanization development (Yuan et al. 2005). After classification and assessing a reliable accuracy of classification, classified images are differenced for detecting changes. They used the “from-to” change detection method. After classifying, they defined the type of change by using several samples. For example, agriculture to urban is one of these types. It reveals that urban areas and developed land increased while the significant decrease happened in rural cover types of agriculture, forest and wetland during years between 1986 and 2002 (Yuan et al. 2005).

As previously mentioned, there is a wide range of NDVI usage in the studies related to changes through years. One of the advantages, which could be mentioned about NDVI, is the accountability of NDVI for variation in the shadows due to sun elevation, and its resistance for topographic changes. However, the disadvantages of the NDVI should also be considered. As (Morawitz et al. 2006) mentioned in the study, NDVI is significantly affected by the rainfall. Especially urban vegetation types were more likely to be influenced by dry and wet years than was native forests. So it would be a considerable advantage to use other GIS data in such studies. Morawitz D.F.et al(2006) tried to assess the vegetative land cover change in central Puget Sound. They studied change in vegetation at three spatial scales and at two temporal scales: a 15 year period and three 5 year time blocks. Through their study they assess the both negative and positive changes of vegetation through different time periods and various scales. The negative change is generally happened due to human activities such as structure or pavement development that has replaced the forestland and this means the loss of greenness despite the addition of lawns and landscaping.

The span of years which are chosen to study upon can significantly affect the results. For instance in the study of Morawitz D.F. et al(2006), in the time interval of 1986 to 1991, the area witnesses the largest volumes of timber harvest of the last century, which resulted in negative change of NDVI. And in the following years, regrowth of clear cuts resulted in positive change. It should be considered that losses of vegetation due to anthropogenic activity were long term, while increases in vegetation were transient.

One of the points, which should also be considered about the NDVI, is the feebleness of NDVI in distinguishing between vegetation types. According to this fact, positive change of NDVI is not always good. For example some of the changes which were green-up after disturbing in a relatively short time span, does not necessarily represent changes that are ecologically beneficial in managing rainwater flow and maintaining native wildlife habitats. Despite all these facts about the NDVI, their results indicate that NDVI value is capable of detecting the varying patterns and processes at multiple scales (Morawitz et al. 2006).

The best method for detecting change depends on the spatial characteristics of the area, which is chosen to study. Coban H.O et al (2010) tested different method for detecting the changes in complex vegetation coverage using multi temporal Landsat data images of Western Black sea region (Coban et al. 2010). Additional to Landsat 5 TM image of 1987 and Landsat 7 ETM^+ image of 2000 and forest inventory plans for these two dates, they used ground measurement of sample points, infrared aerial photos and topographical raster and vector maps. After geometric and atmospheric correction steps, images were classified using a maximum likelihood algorithm and new thematic images were obtained.

Classified images were compared using the post-classification method, matrix process, using ERDAS software. They also checked three other comparison methods using the threshold determined by a change matrix: NDVI differencing, image rationing and band differencing.

After checking the results of all the methods, the final result shows that the post classification method is the most appropriate for the forestry activities, due to the diversity of vegetation, topographical characteristics, atmospheric conditions and other environmental factors related to the study area. Considering the fact that in case of the need for instantaneous detection of change, other methods could also be used which might give the result faster and without the need for time consuming classification processes.

Countries and cities, which have experienced remarkable urbanization and population growth, are more in the danger of urban vegetation deterioration. Developing cities should be more cautious about the changes that have occurred in the vegetation cover and soil environment by the developing of urban areas. China has encountered the world's most substantial urbanization since 1980. Sun J. et al (2011), monitoring the changes of vegetation cover in china's metropolises, declared that current urbanization has generally reduced vegetation greenness in China, despite the increasing in vegetation productivity in most areas (Sun et al. 2011). They used average urban area NDVI ($NDVI_{u)}$ and the surrounding rural area vegetation cover ($NDVI_{b).}$ $NDVI_u$ calculated by using the percentage of urban area for each pixel (p_i) of the NDVI map and the growing season NDVI for that pixel ($NDVI_i$) using the following equation:

$$NDVI_u = \frac{\sum(\text{NDVIi} \times \text{pi})}{\sum \text{pi}} \tag{4.1}$$

$NDVI_b$ was calculated by averaging growing season NDVI for pixels within five pixels outside the edge of urban pixels. They analyses the temporal trends in $NDVI_u$ and the difference between $NDVI_u$ and $NDVI_b$. Both $NDVI_u$ and the difference between $NDVI_u$ and $NDVI_b$ are negatively correlated with urban built-up area. As result of increased population, emigration from rural areas to urban areas decreased the human disturbance in these areas causing the increase in NDVI of the surrounding rural areas. Generally, this study suggests the strong influence of urbanization processes on vegetation cover.

Urbanization as the most impressive factor of changing land cover, vegetation canopy and soil environment, should be considered and managed for monitoring its impacts such as on runoff, air quality, climate change and etc. . There are so many methodologies which can be used for monitoring the urban growth and realizing the impacts of it. A methodology which is developed by Villa P.(Villa 2012) by improving the Soil and vegetation index (SVI), by threshold ratios of SVI, has been used to map the urban growth in Milan city. SVI showed a high degree of reparability between impervious and non-impervious surfaces and therefore the strongest capabilities in discriminating urban from non-urban features. By analyzing the multi-temporal SVI maps, the change in impervious surfaces and therefore calculating the urban growth is possible. By detecting the area of change, the changes and impacts, which have happened to vegetation covers can be detected and analyzed.

There are so many vegetation indices, suitable for different vegetation cover. Indices are used for indicating the vegetation behavior. Detecting the changes of vegetation and probing for the causes of negative and positive changes is possible with applying indices on available multi-date satellite images. In the study of Benkouider F. et al (2013), three vegetation indices are tested for the semi-arid area in Algeria (Benkouider et al. 2013). Results of three indices including: NDVI, Soil vegetation index (SAVI) and Transformed Vegetation Index (TVI), show a better description of the vegetation by SAVI index in semi-arid zone because of the spreading-out of the spectrum of the vegetation of the SAVI, compared the two other indices. They classified thematic images by assigning different colors for SAVI image of three dates and superposition of three layer. Changes happened to vegetation cover, including positive and negative, can be detected by the resulting image.

According to study of Yuan L. et al.(2014) about the detection of vegetation disease named "powdery mildew" in winter wheat by using the high resolution satellite images Spot 6, it is shown that applying vegetation indices and classifying the satellite images can be effective in detecting healthy and diseased vegetation(Yuan et al. 2014). Vegetation indices are generally sensitive to the disease at significant stages but among them NDVI and TVI were reserved for subsequent analysis by the Yuan et al. During their study, they used three methods of classification of 6 band image; including four original bands, NDVI and TVI: artificial neural network, Mahalanobis distance and maximum likelihood classifier and they revealed that although all three method show good results and higher accuracy according to in situ measurements, but the ANN surpassed the two other methods with higher accuracy. Considering the availability and reduced cost of high-resolution remote sensing data, it is obvious that remotely sensed data have become one of best sources of data for mapping vegetation covers. Furthermore, such applications for detecting disease are among the most needed applications for growers all over the world.

5. STUDY AREA

In this chapter the specifications of the study area such as physical characteristics and land cover, vegetation cover and socio-economic characteristics of city are explained; at the end, the upcoming land cover of Istanbul resulted by ongoing development of mega projects is demonstrated.

5.1 Phycsical Characteristics and the Land Cover in Istanbul

Geography of Istanbul is divided into four regions due to seas and lands. The strait of Bosphorus, once a community of few villages, now has enormous residential districts settled within, and with the old Istanbul rooted in the shores of Golden Horn (Halic). Inhabitants of Istanbul are placed along the shores of Marmara Sea, which is known as one of the smallest seas in the world. The Old City is spread over seven hills of the triangular peninsula surrounded by 22 km of city walls (Burak et al. 2004).

Having been the center of the old world, Istanbul is an important mega city with its historical monuments and wonderful natural scenery. It was established where Asian and European Continents were split with a narrow strait; built on two continents, it is the only city that the sea goes through. With its history of over 2500 years, Istanbul became an important commerce center because of its establishment in this strategic location where land meets sea. Historical city of Istanbul is located on a peninsula, surrounded by Marmara Sea, Bosphorus Straits and Golden Horn.

Istanbul is located in the coordinates of 28°56′58″ East longitudes and 41°00′49″ North latitudes. While joining Black Sea and Marmara Sea, Istanbul Straits divides Asian and European Continent as well as Istanbul City. The province is surrounded by high summits of Kocaeli Mountain Ranges in the East, by Marmara Sea in the South and waterline of Ergene Basin in the West.

Being in the junction where all the roads reach sea, ideal climate, rich and generous nature, strategic location of being in the center of world are all fortunes of Istanbul. Istanbul has been of much significance throughout history because of being in the joining point of two continents, being the gateway to the hot climates and oceans and being outer reach of Silk Road extending to Europe. **Figure 5.1** indicates the study area.

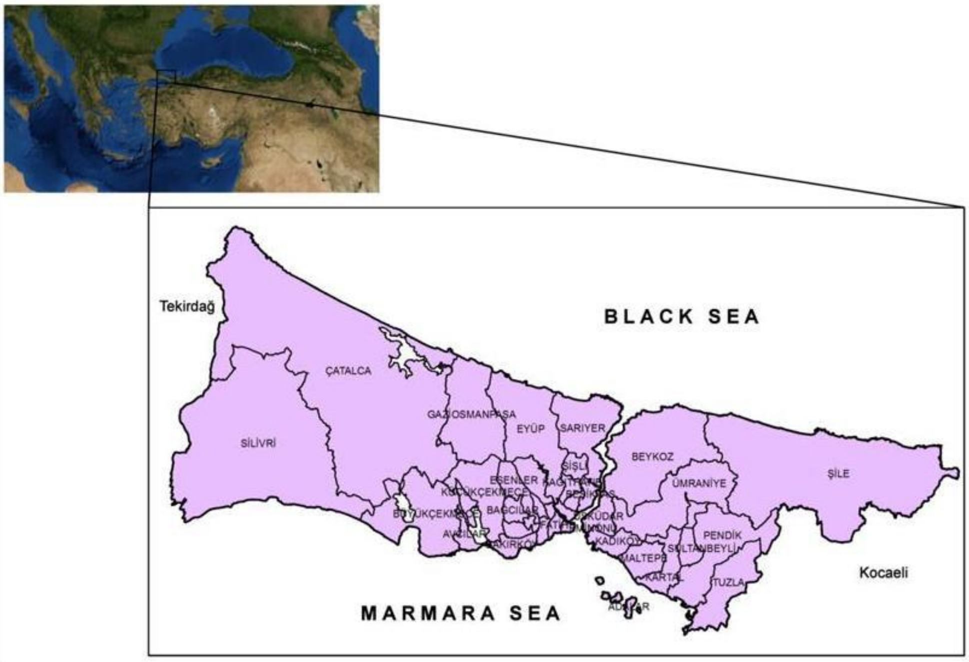

Figure 5.1: Location of the city and its topographic map, http://www.ibb.gov.tr/sites/airqualistanbul/documents/eng/istanbul.htm, date retrieved 10/5/2014

5.2 Vegetattion Cover of Istanbul

Istanbul city is surrounded by forests on the north and by water on the south. The tiny parks and groves within the city are the oxygen suppliers of this metropolis. The Marmara region is characterized by a transitional climate, midway between that of the Mediterranean and the Black Sea. Istanbul is one of the provinces that best illustrate this aspect of the Marmara. In terms of Istanbul's plant geography, its true plant type is the forest. It is possible to see examples of pristine forest on both shores of the Bosphorus today. The Alemdag forests on the Anatolian side and the Belgrade forest on the European, are damp, mixed-leaf forests. Three species of the oak, their dominant tree species, including: English oak, sessile or durmast oak, and Hungarian oak are spreading over a wide area. Oriental beech is seen in areas near the Black Sea coast. Other species entering into the mix in these damp forests include hornbeam, Anatolian chestnut, quaking aspen, alder, common hazel, hedge maple, beech-maple, smooth elm, field elm, broad leaf linden, goat willow and grey willow. The importance of Istanbul’s forests is not limited to their flora; they are interesting for their wild life as well. Despite all of today’s threats, deer, roe deer, wild cats, foxes, jackals, wild boar, otters, badgers and a very small number of wolves continue to inhabit the city’s forests. With a region around 5500 hectares, the Belgrade Forest is one of Istanbul’s most important forested areas with several historical reservoirs lying within. A recreational facility of the Belgrade forest is most significant besides its water supplying property today. Similar in structure, the Catalca, Kanlica and Alemdag forests continue to produce firewood and lumber (wikipedia 2014).

The Istanbul forests are not limited only to these natural forests. Since the 1960’s especially, various units of the forestry service have been experimenting with different types of reforestation with fast-growing exotic (foreign) species in the city’s vast vacant areas. Reforestation with the maritime pine (Pinus pinaster), known throughout the world as a fast-growing industrial tree, has however unfortunately failed to produce the desired results (Tokcan, 2007).

Therefore, Istanbul vegetation zones can be classified into two groups. Scrub and forest as natural vegetation, grove, park and housing gardens made by human efforts, Scrubs that occur because of destruction of forests are generally found together with forest; and formations of Scrub are found in the southwest part of Istanbul too.

5.3 Socio-economic Characteristics of Istanbul

Istanbul has always been the center of the country’s economic life because of it being located at an international junction of land and sea trade routes. Turkey’s major manufacturing factories are settled in the city(Göktürk et al. 2010). Food processing, textile production, oil products, rubber, metal ware, leather, chemicals, electronics, glass, machinery, paper and paper products and alcoholic drinks are among the major industrial products. The city also has plants that assemble automobiles and trucks (wikipedia 2014).

The economy of Istanbul stands solid on two columns: nationally it dominates the trade and it has international significance as well. As the only sea route between the oil-rich Black Sea and the Mediterranean, the Bosphorus is one of the busiest waterways in the world; more than 200 million tons of oil pass through the strait each year, and the traffic on the Bosphorus is three times that of the Suez Canal. As a result, there have been proposals to build a canal, known as Canal Istanbul, parallel to the strait, on the European side of the city. Istanbul has three major shipping ports, the Port of Haydarpasa, the Port of Ambarlı, and the Port of Zeytinburnu, as well as several smaller ports and oil terminals along the Bosphorus and the Sea of Marmara. Haydarpasa, situated at the southeastern end of the Bosphorus, was Istanbul's largest port until the early 2000s. Shifts in operations to Ambarlı since then, have left Haydarpasa running under its capacity and with plans to decommission the port. In 2007, Ambarlı, on the western edge of the urban center, had an annual capacity of 1.5 million TEUs, making it the fourth-largest cargo terminal in the Mediterranean basin(Zeybek et al. 2008). The Port of Zeytinburnu is advantaged by its proximity to motorways and Ataturk International Airport, and long-term plans for the city call for greater connectivity between all terminals and the road and rail networks.

Istanbul is an increasingly popular tourist destination; whereas just 2.4 million foreigners visited the city in 2000, it welcomed 11.6 million foreign tourists in 2012, making it the world's fifth most-visited city (Hedrick-Wong et al. 2013). Istanbul is Turkey's second-largest international gateway, after Antalya, receiving a quarter of the nation's foreign tourists. Istanbul's tourist industry is concentrated in the European side, with 90 percent of the city's hotels located there. Low- and mid-range hotels tend to be located on the Sarayburnu, while higher-end hotels are primarily located in the entertainment and financial centers north of the Golden Horn. Istanbul's seventy museums, the most visited of which are the Topkapı Palace Museum and the Hagia Sophia, bring in 30 million in revenue each year. The city's environmental master plan also notes that there are 17 palaces, 64 mosques, and 49 churches of historical significance in Istanbul.

Overall, the metropolis Istanbul is the economical capital of Turkey and therefore one of the biggest cities in Europe. A problem for the city administration is the irregular and illegal urbanization, increasing rapidly day by day, leaving the greater Istanbul municipality with not much time to search for solutions.

5.4 Drivers of Land Cover and Land Use Change in Istanbul

Like other mega cities in the world, land cover of Istanbul has been affected through years by multiple factors. Urbanization and immigration are two of the factors, which are more responsible for changes. They are sorted as two main elements of demographic factors of land use change, interacting with other factors in other classes as well. Urban development and population increase has resulted in rapid economic growth and industrialization, causing mass immigrations from countryside to major urban centers. It is obvious that under this situation Istanbul was forced to develop and expand in order to house these excess amounts of immigrants. Urgent need to renew urban infrastructure of Istanbul resulted in large-scale urban operations. These operations induced construction of a new road network for car traffics.

Istanbul continued to expand around urban areas, along major roads and Marmara shorelines. Opening of Bosphorus bridge (1973) and Fatih Sultan bridge (1988) was largely contributed to spread of the city(Akbulut et al. 2012). In the opinion of Inceoglu A., this was the first major growth period in Istanbul. The second major period is related to the liberalization of Turkish economy (Institutional factor) and in the last decade, Istanbul experienced another major growth period, and this time propelled by the integration of Turkish economy to the global market (globalization) (Inceoglu et al. 2011). All these factors caused drastic changes in land cover that should be considered by land managers in order to be ready for related consequences and complications.

Urbanization as the most effective factor of global land cover in Istanbul should be mentioned and considered thoroughly. With a population of 14.16 million (Wikipedia, 2013), Istanbul forms the largest urban agglomeration in Europe, second largest in the Middle East and the fifth-largest city in the world by population within city limits. Its commercial and historical center lies in Europe, while a third of its population lives in Asia. In the second half of the 20th century, during which turkey experienced rapid industrialization and urbanization, Istanbul has been the destination of influx of large scale rural to urban migrants. Between 1950 and 2000, the city has grown up by an average of 4.5% annually (Geymen & Baz 2008).

Many groups have worked on different areas of Istanbul city in order to understand the urban dynamics, and provide reliable information on current and temporal urban land use and land cover characteristics and changes by using remotely sensed data. According to a survey on Gaziosmanpasa (an urbanized district of Istanbul with its population having been almost doubled between the years 1990 and 2000), the rapid conversion of the forest areas and bare lands to urban areas has happened due to the proximity of the district to down-town Istanbul, well established transportation networks, and proximity to a receiving body of water (Musaoglu et al. 2006). In another similar study, results showed that Istanbul has been under the pressure of rapid and unplanned urbanization; and the continuing of this urbanization process means a decreasing amount of green areas and degradation of barren lands. Monitoring urban growth and land cover change will enable the greater Istanbul metropolitan municipality for a better management of this complex urban area (Geymen & Baz 2008).

5.5 Impacts of Land Cover/use Change in Istanbul

The Land cover change, occurred in Istanbul, affects environment in some main fields: Impacts on forest areas and natural grassland, on the water reservoir storage, on soil surfaces, on coastal areas and on the climate. There are many studies concerning the impacts of land cover change in different sites of Istanbul and they have come up with certain results. As an example, Beykoz province, located on the Asian side of the Bosphorous extending toward the hills near the Black Sea coast, is one of the most pleasant and peaceful districts of Istanbul with much greenery still unaffected by land cover change. According to a study in this region by Musaoglu N. et al (2005), there is a decline of forest areas resulting from establishment of new residential areas within the forest areas (Musaoglu et al. 2005). The illegal building is happening in the forests further back from the sea, particularly in the areas of Cavusbasi and Elmali. This countryside is scattered with little villages, all of which are expanding now and consequently causing for more roads being put through. The forest areas in part of the Elmali Reservoir Watershed have already diminished by one-half between 1984 and 2001, whereas the urbanized areas increased almost tenfold. The distribution of barren land in the city center and in the watershed, presented significant 12-fold and 8-fold increases, respectively, reflecting the tendency toward urbanization (Musaoglu et al. 2005).

This merely is one of the forest areas in Istanbul that has been damaged due to the land cover change. In other alike survey about the land cover change in Silivri coastal zone by Yilmaz R, results show that the land use and land cover in the study area experienced significant changes over the 13-year period (1987-2000). Artificial surfaces increased while agricultural areas, forest area, and natural grasslands decreased (yilmaz R 2010). The structure of natural grasslands was completely replaced by urban fabric, industrial, commercial, and transport areas. Changes of forest into artificial surfaces were the second most extended ones. This type of change is the result of the anthropogenic impact (yilmaz R 2010).

As we know, forests provide many important goods, such as timber and paper. They also supply essential services, for example, they filter water, control water runoff, protect soil, regulate climate, cycle and store nutrients, and provide habitat for countless animal species and space for recreation (Adams 2012). The decreasing forest cover has its impact on human and environment; impacts such as rising of the water level, size and floods from heavy rain because there are less trees to absorb the force of water, Loss of plant and animal life, Lack of oxygen, Greenhouse effect, Ozone layer deterioration and increase in temperature.

One of the main processes of land cover change is the open mining in Istanbul; forest areas and sand dunes were destroyed by open mining activities performed in on the Black Sea coast of the European part. As a result of dumping materials extracted from open mining areas into the sea, the ecosystem and topographic structure were damaged (Kaya et al. 2008). In this region, natural land cover changes also occurred as a result of coastal erosion (Sertel et al. 2011).

Climate is another factor affected by land cover change. A study was done by Sertel E. and Ormeci C. in the Marmara Region, a region which has experienced significant land cover changes because of rapid industrialization and population increase especially after 1980s. Study reveals that anthropogenic land cover change has impacted several aspects of the regional climate of the Marmara Region, including warming of 2 m air temperatures and changes in the strength and orientation of the sea breezes (Sertel et al. 2011). Urbanization increase in Istanbul resulted in urban heat island effect over this city. Climate change adversely affect animal, human, agriculture and ecosystems.

5.6 Mega Projects to Change the Land Cover of Istanbul

Sixteen scientists have composed a report for the “Turkish Foundation for Combating Soil Erosion, for Reforestation and the Protection of Natural Habitats” (TEMA) filled with warnings on the third bridge, the third airport and Canal Istanbul. The report underscores that Istanbul is at great risk from these large projects. The author thinks that these are projects to kill the nature and environment.

In the TEMA report, it is noted that the intersections between Kinali-Gebze will provide greater access to the northern regions of Istanbul, which have the facilities such as water resources, agricultural areas, forested areas and pastoral land. The way to these land will be cleared and changed to residential area. This will cause the northwards development in Istanbul (Savgi 2014).

The TEMA report talks about the risks presented by the third bridge, the third airport and the Canal Istanbul project. These projects all threaten the pastoral land located in Buykcekmece, Kucukcekmece, the Terkos Lakes, the Omerli Basin and the pastoral land of western Istanbul. The sand in Kilyos and Agacli on the shores of the Black Sea, the Alibeykoy Dam area, the pastoral land of western Istanbul, the Terkos Basin, the Bosphorus, the Sile coastline, the Omerli Basin and the Pendik Valley; these are all important ecosystems in their own right and will all be negatively affected. The area of forested land, set to be cut down for the third airport and the third bridge, will be as much as 8,715 hectares. This means somewhere around 8,000 football fields. (Savgi 2014).

As well as the devastation of natural forested land, caused by the development of airport buildings and its runways and various bases, there would be many large and small lakes affected negatively as well. Agricultural areas and pasturelands, the rivers and streams that feed into the very important Terkos are the most affected by this unpleasant situation. In other words, the lives of precious wildlife, faces a substantial risk. The risk of plane accidents will also be increased. Changes taking place environmentally because of these projects, would immediately affect the local and subsequently the wider regional climate. Not only this, but a situation of local city heat islands will be created due to changes in the distribution of local heat and moisture streams, and these changes will affect the cloud and evaporation patterns. (Savgi 2014).

Finally the Canal Istanbul, the Turkish name for an artificial sea-level waterway project, connecting the Black Sea to the Sea of Marmara and hence to the Aegean and Mediterranean Seas, is in opinion of Savgi G. a serious threat to Istanbul, which already is faced with limited amounts of water. Canal Istanbul will damage the vital underground water basins in Silivri, Catalca and Buyukcekmece, which have great potentials of helping with agricultural irrigation. Canal Istanbul will also trigger intense new construction in the area. By disrupting the balance of the Marmara Sea, Canal Istanbul will essentially turn the area around Istanbul into an unlivable region (Savgi 2014).

That these new projects play a crucial role in easing the life for people living in urban area is an undeniable fact. Had people realized the significance of nature and environment for their future life, they would have deliberated on these kinds of projects much more meticulously. Some people and managers strongly believe though, that such kinds of projects' advantages outnumber their disadvantages.

6. DATA AND METHODOLOGY

This chapter is mainly devoted to provide the overall research approach and data analysis details that underpin this study. After providing briefs on data sources and the data quality issues, processes that were applied on images before performing the indices on images and later on interpretation procedures, are explained in the subsection named Preprocessing. Thereinafter it describes the research methodology adopted to attain the objective of the study and explain the details of data analysis and processing on the main phases of the research progress.

6.1 Data Source and Quality

The data used during the course of this study are data images of Landsat-5 Thematic Mapper (TM) that were collected and distributed by the US Geologic survey's Center for Earth Resources Observation and Science (EROS). Landsat-5 as the longest-operating earth-observing satellite mission in history, was a low Earth orbit satellite launched on March 1, 1984 to collect imagery of the surface of the Earth. In a continuation of the Landsat Program, Landsat 5 was jointly managed by the U.S. Geological Survey (USGS) and the National Aeronautics and Space Administration (NASA).

As it shown in **Table 6.1**, Landsat TM 5 images consist of seven spectral bands with a spatial resolution of 30 meters for Bands 1 to 5 and 7. Spatial resolution for Band 6 (thermal infrared) is 120 meters, but is resampled to 30-meter pixels. TM Band 6 was acquired at 120-meter resolution, but products processed before February 25, 2010 are resampled to 60-meter pixels. Products processed after February 25, 2010 are resampled to 30-meter pixels. Approximate scene size is 170 km north-south by 183 km east-west.

Table 6.1: Landsat TM bands

Landsat 4-5	Wavelength (micrometers)	Band	Resolution (meters)
Band 1	0.45-0.52	Blue	30
Band 2	0.52-0.60	Green	30
Band 3	0.63-0.69	Red	30
Band 4	0.76-0.90	Near IR	30
Band 5	1.55-1.75	Short-wave IR	30
Band 6	10.40-12.50	Thermal	120(30)
Band 7	2.08-2.35	Short-wave IR	30

Data set include five Landsat imageries of years 1984, 2002, 2007, 2009 and 2011 shown in **Table 6.2**. The data specifically selected from the same month of the year (June) for emitting the changes caused by seasonal variations. Erdas imagine 2013 and Envi are the softwares used in this study. After Mosaicking two frames, containing the Istanbul city limits, the Istanbul province border was subsetted from mosaicked images.

Table 6.2 : Dates of Landsat TM acquisition

year	Day Month
1984	12 June
2002	14 June
2007	12 June
2009	17 June
2011	2 June

6.2 Preprocess

Before applying the indices and going to the next step of interpretation and evaluating the index images and index values, some corrections should be applied on the raw images for improving the results. Preprocessing though is very important and should be done intently because it can affect the conclusion thoroughly.

6.2.1 Radiometric Correction

Remotely sensed image is a two-dimensional array of pixels. Each pixel has an intensity value represented by a digital number (DN) and a location address, referenced by its row and column numbers. Digital sensors record the intensity of electromagnetic radiation (ER) from each spot viewed on the Earth's surface as a DN for each spectral band.

The exact range of DN that a sensor utilizes depends on its radiometric resolution. For example, a sensor such as Landsat MSS, measures radiation on a 0-63 DN scale whilst Landsat TM measures it on a 0-255 scale. DN values recorded by a sensor are proportional to upwelling ER (radiance). DN value is commonly used to describe pixel values that have not yet been calibrated into physically meaningful units.

Spectral radiance is a precise scientific term used to describe the power density of radiation; it has a unit of $W\ m^{-2} sr^{-1} \mu m^{-1}$ (i.e. watts per unit source area, per unit solid angle, and per unit wavelength). DN is scaled from Radiance measured by sensors. Reflectance calibration is applied by deriving the reflectance value from the DN and calculating the top of atmosphere reflectance or TOA reflectance, which is the reflectance measured by a space-based sensor flying higher than the earth's atmosphere including contributions from clouds and atmospheric aerosols and gases.

By this brief introduction on the principles of remotely sensed images, it should be mentioned why the reflectance calibration is important in this study. In the simplest case, where a single image is being analyzed and it is not necessary to generalize the results to other sensors, other times or other places, it is feasible to analyze remotely sensed data as raw DN values, with no conversion to any physically meaningful units. For example, when classifying a single satellite image it is not crucial to change the DN values but as it was mentioned before, prior to using Landsat data as input to any of the common indices and processing the multi-temporal images, it is essential to use the reflectance values because of certain reasons. For monitoring the changes that has happened on the land cover and land use, it is important to detect the real changes and using the reflectance value is essential and useful because it largely removes variations between images due to sensor differences, earth-sun distance and solar zenith angle caused by different scene dates, overpass time and latitude differences.

Reflectance calibration is done in two steps, which are followed by the atmospheric correction that is not essential in this study. At first step, the DN values are converting to spectral radiance at the sensor using gain and bias values, which are all supplied by metadata of Landsat data. The formula is:

$$L_{\lambda} = Gain \times DN + Bias \qquad (6.1)$$

Where:

L_{λ} is the cell value as radiance

DN is the cell value digital number

Gain is the gain value for a specific band

Bias is the bias value for a specific band

As it is shown in **Figure 6.1** gain represents the gradient of the calibration. Bias defines the spectral radiance of the sensor for a DN of zero.

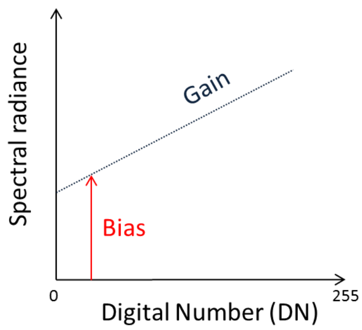

Figure 6.1 : Calibration of 8-bit satellite data.

The second step involved calculating top of atmosphere (TOA) reflectance for each band as per Equation (6.2), which corrected for illumination variations (sun angle and Earth-sun distance) within and between scenes. The correction was applied on a pixel by pixel basis for each scene in each era and the output reflectance values scaled to an 8-bit data range. Some of the parameters for the conversion are available in the image header files, while the exo-atmospheric irradiance values for Landsat 5 are available from Markham and Barker (1987) and for Landsat 7 from NASA's (National Aeronautics and Space Administration) Landsat 7 Science Data Users Handbook (2003).

$$\rho_\lambda = \frac{\pi\, d^2 L_\lambda}{\mathrm{ESUN}_\lambda \cos \theta} \tag{6.2}$$

Where:

ρ_λ = reflectance as a function of bandwidth

d = Earth-sun distance correction

L_λ = radiance as a function of bandwidth

$ESUN_\lambda$ = exo-atmospheric irradiance

θ_s = solar zenith angle

Reflectance values were extracted by using the reflectance calibration provided by ENVI program on all images using their metadata that is provided in file with MTL extension and the resulted images were used as source images for the further steps.

6.2.2 Geometric Correction

Geographic data should be aligned to a known coordinate system to become ready to be viewed and analyzed with other geographic data. Geo-referencing may involve shifting, rotating, scaling, skewing, and in some cases warping, rubber sheeting, or orthorectifying the data. In some cases, the requirements may call for one satellite image to be transformed to the geometry of another. Accurate georeference allows you to overlay a spatial object correctly with all your other project materials.

For interpolating the new cells values of a raster image during georefrencing, in other words resampling, there are so many methods through a variety of software. Bilinear filtering, cubic convolution and nearest neighbor are three of common resampling methods. Nearest neighbor method, which is known as simple method and has the advantage of preserving original values in the unchanged scene, assigns a value to each corrected pixel from the nearest uncorrected pixel. As the disadvantages for this method, noticeable position errors can be mentioned, especially along linear features where the realignment of pixels is obvious.

Here, in order to check the changes of vegetation cover, urban area and soil environment, all five index images, NDVI images, SAVI images and BU images, were stacked on each other, so it is required to properly georeference the source images, for getting the better results related to the change of each pixel. All images were georeferenced using the polynomial geometric model, to the image of year 2011 which is nearly cloud free and has high resolution; using Erdas Imagine, testing about 25 ground control points, with the RMS error lesser than 10 meter and were resampled by using the nearest neighbor method.

6.2.3 Water Body Masking

The increases in the size of water bodies are detected as changes when index images are overlaid in the index layerstack images. Although it is referred to change of land cover, considering the role of surface water as the one of irreplaceable strategic resource for human survival and social development, and its essentiality for food crops and ecosystem (Ridd & Liu 1998), this kind of change, change of land cover to water body, has not been considered in this study.

Water feature extraction from satellite data has been an interesting topics and there are many techniques introduced for this purpose. There are some indices that are used for water body detection. Some of them are: NDVI, Normalized Difference Moisture Index (NDMI), Modified Normalized Difference Water index (MNDWI), Water Ratio Index (WRI), Automated water extraction Index (AWEI). The near infrared band is usually chosen for water body interpretation because of the specific features of the water bodies. Water features strongly absorb the NIR where the terrestrial vegetation and dry soil strongly reflect it (Sun et al. 2011). There also are other methods which are referred to the specific spectral characteristics of different types of waters such as clear or green waters and the amount of reflectance in different bands, for instance, the pixel based method introduced by Sun et al. (Sun et al. 2011). In this study the Normalized Difference Water Index(NDWI) was used which is known as one of the best indices for water extraction and it shows improved result than the other tested indices (Rokni et al. 2014). NDWI is also resulted from the noticeable amount of reflectance in band 2(green) and absorption of near infrared band as defined in following equation.

$$\mathrm{NDWI}=\frac{\mathrm{Green\ -\ NIR}}{\mathrm{Green + NIR}} \qquad (6.3)$$

There are a considerable number of dams, constructed through the years in Istanbul; such as Alibey dam (1975-1983), Darlik dam (1986-1988), Omerli dam (1968-1973) and Sazlidere dam (1992-1996). They form the water bodies that are being detected as change in land cover when comparing the multi-temporal images. Therefor the image of year 2011 was used for masking in order to cover almost all the water bodies until 2011.

The NDWI image of 2011 was categorized in two classes, water bodies and non-water classes, and the classified image was applied to all images as water mask. The resulted images were the Landsat images of Istanbul land cover excluding the water bodies. In **Figure 6.2**, there are Landsat images of Istanbul in 1984 before and after water masking.

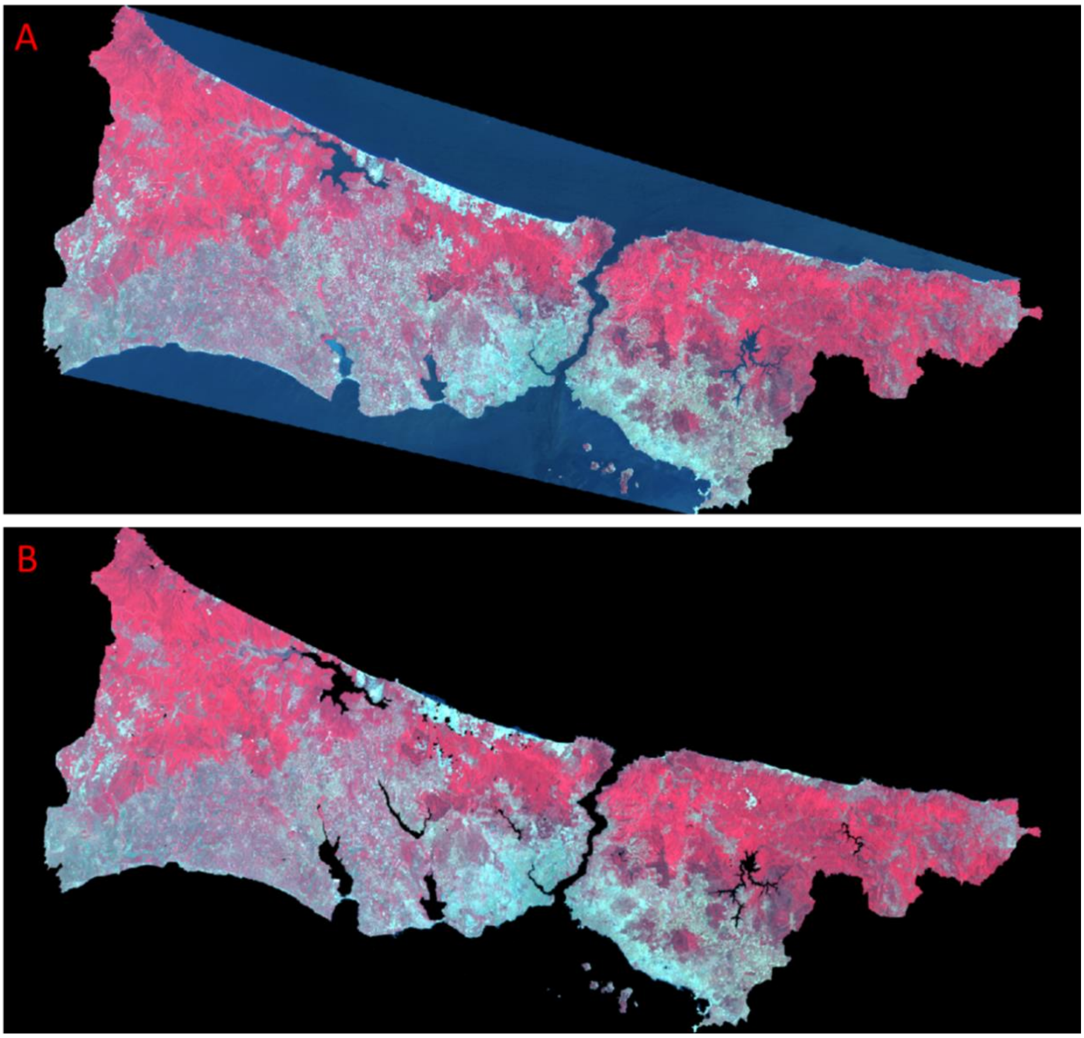

Figure 6.2 : Sample of water masked image **a)** Istanbul 1984 image before water masking and **b)** after water masking.

6.3 Analyzing and Quantifying the land cover/use changes

It is aimed to show the changes happened through years by using the indices. There are studies that show the changes in land cover and land use by classifying the images ((Sertel et al. 2011), (Geymen & Baz 2008), (Kaya & Curran 2006), (Kaya et al. 2008), (Musaoglu et al. 2006), (Yener & Koç 2006)) and image differentiating ((Morawitz et al. 2006), (Maktav & Erbek 2005)). In this study however, changes happened in land cover/use areas were detected by overlaying the index images.

Three selected indices, NDVI, SAVI and BU were applied on five Landsat images of Istanbul in years 1984, 2002, 2007, 2009 and 2011 individually. NDVI images as SAVI and BU images were overlaid and three images were resulted which have five layers, each layer is index image of five surveyed years, 1984, 2002, 2007, 2009 and 2011. These images were named as NDVI layerstack, SAVI layerstack and BU layerstack.

SAVI images with SAVI layerstack image, NDVI images with NDVI layerstack image and BU images with BU layerstack image are displayed respectively in **Figure 6.3**, **Figure 6.4** and **Figure 6.5**. Land cover/use that have been changed through years are shown by red and cyan colors in layerstack images. Unchanged areas are separated by white color in NDVI and SAVI layerstack images. For example, vegetation cover of forests which were not changed significantly through years are in white color in the NDVI layerstack image. And in BU layerstack image it is obvious that previously urbanized areas which were remaining as urban areas in further years with insignificant changes, are highlighted by white color.

Besides the thorough looking of changes happened in Istanbul province in figures 6.3, 6.4 and 6.5, it is beneficial to study the significant land cover changes happened in specific regions between 1984 and 2011 much more scrupulously. The detailed views of some examples of alterations are illustrated in **Figure 6.6**.

The changes shown in **Figure 6.6** are related to areas that are changed by constructing the new settlements in different regions of Istanbul. Some examples of changes that had occurred in Rumelifeneri Koyu (Koc University), Goztepe zone, Alemdag-Sile road, Avcilar region and Bagcilar region are respectively shown in the **Figure 6.6**. These new constructions caused drastic reduction of vegetation cover and increase in built up area. In other words increase in BU index and decrease in NDVI index. The changed area were detected by NDVI, SAVI and BU layerstack. The increase of BU index shown by brighter cyan color in the BU layerstack image and decrease in SAVI and NDVI are shown by red color in NDVI layerstack image and SAVI layerstack image. All changes that are shown by these images have happened through 1984 and 2011 period. There are also satellite images which show the status of specific regions in 2014 which were obtained from Google Map.

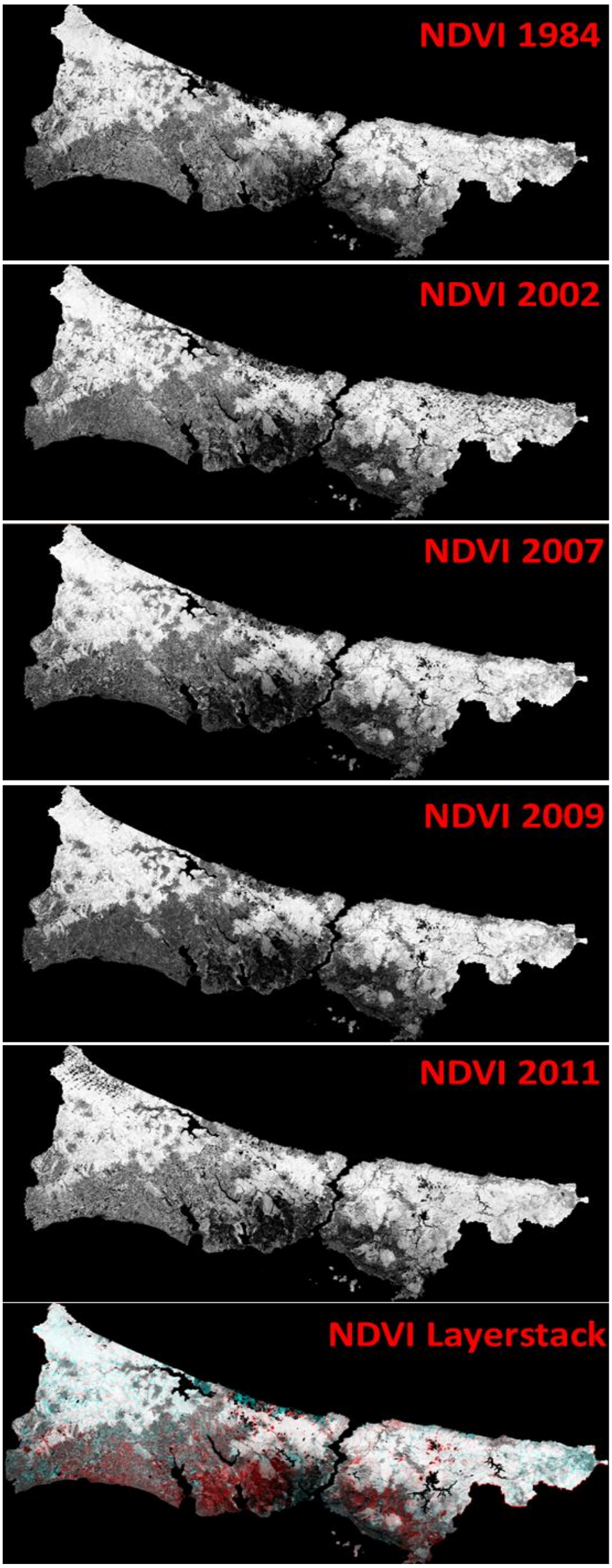

Figure 6.3 : NDVI images of Istanbul province in 1984, 2002, 2007, 2009 and 2011 and NDVI Layerstack

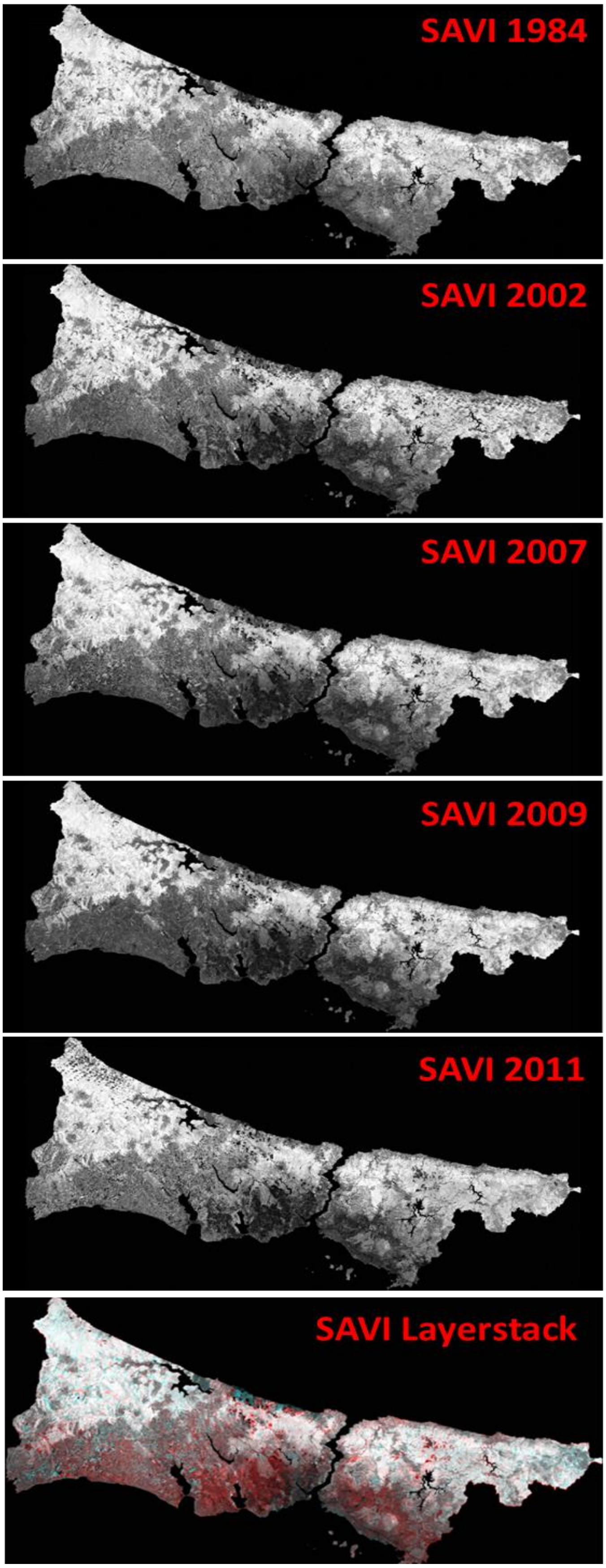

Figure 6.4: SAVI images of Istanbul province in 1984, 2002, 2007, 2009 and 2011 and SAVI Layerstack

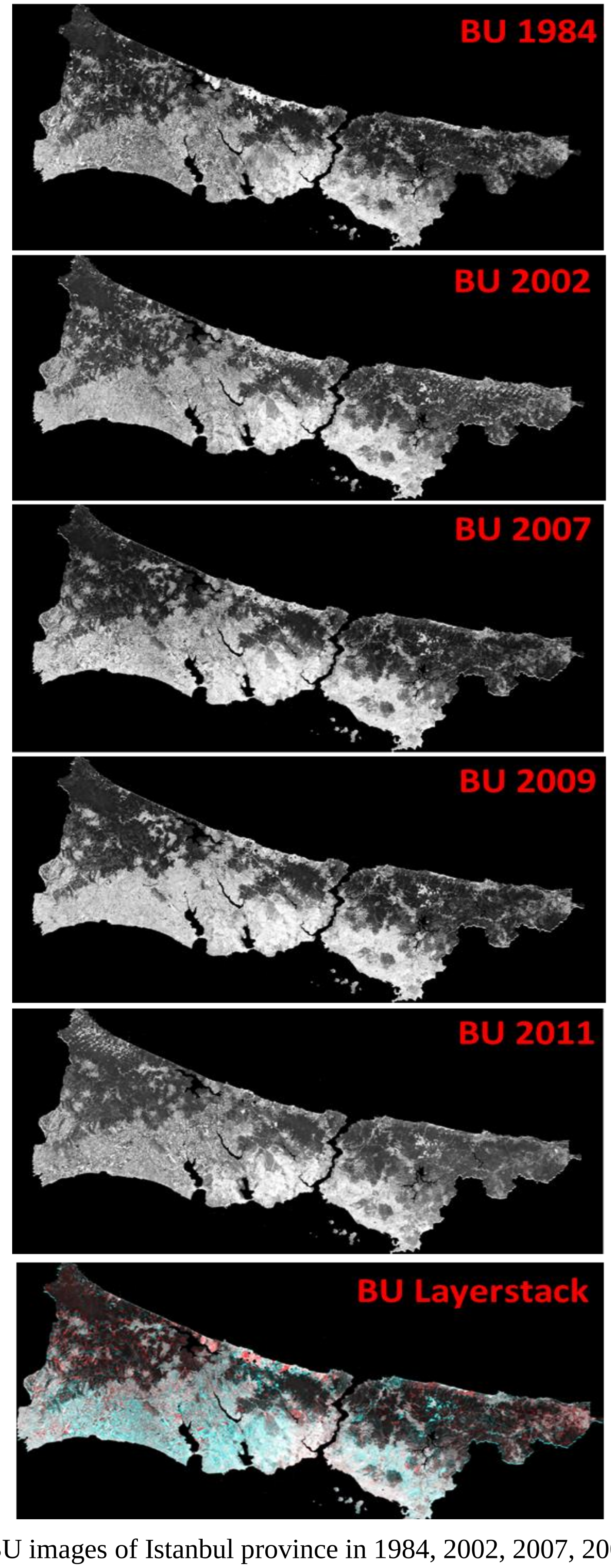

Figure 6.5 : BU images of Istanbul province in 1984, 2002, 2007, 2009 and 2011 and BU Layerstack

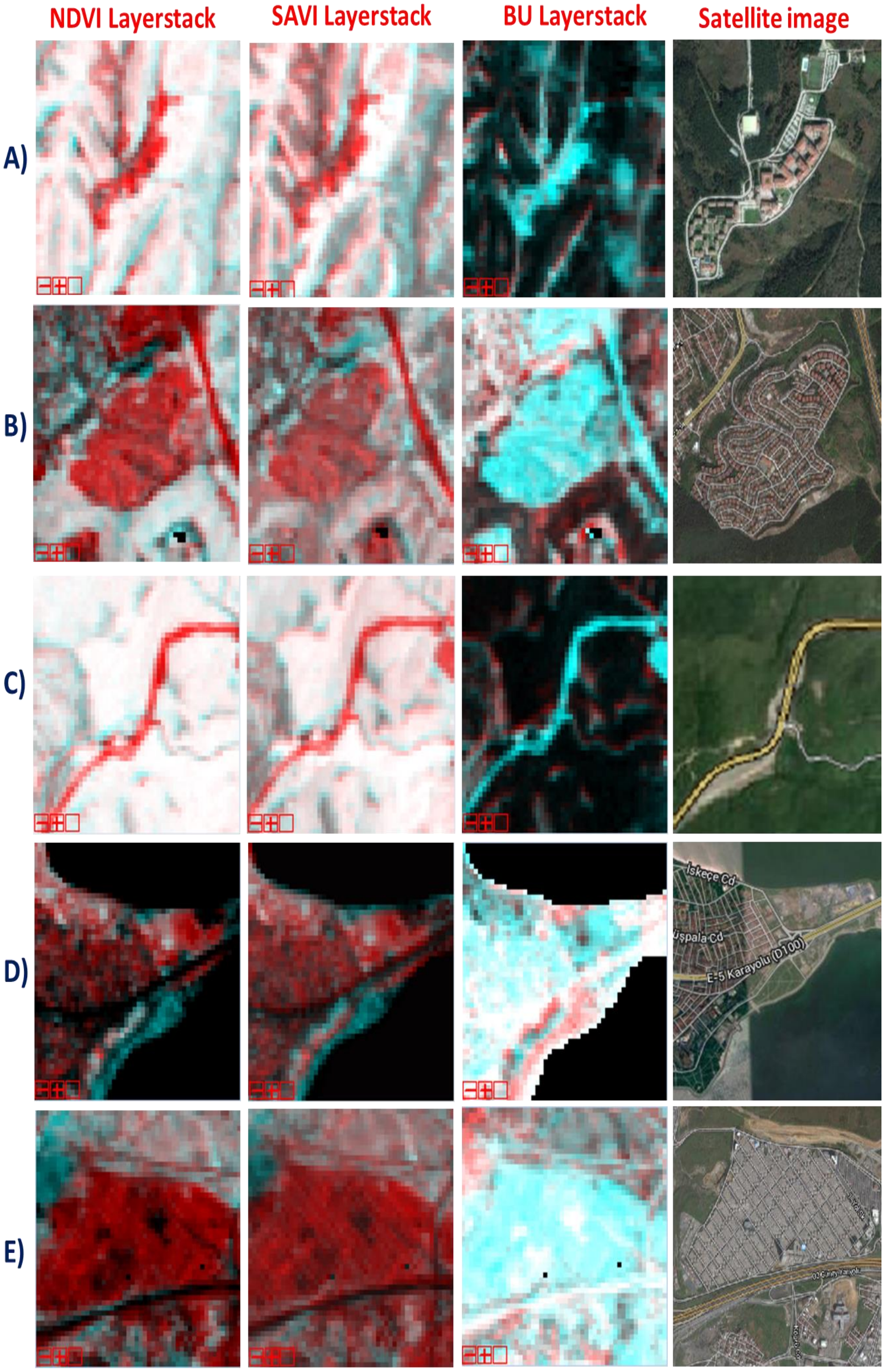

Figure 6.6 : BU, SAVI, NDVI Layerstack images and satellite image of Istanbul showing the changes of land cover in a)the KOC university district b)Goztepe region c)alemdag-sile road d)Avcilar region e)Bagcilar region.

By checking the changes happened through four time intervals between 1984 and 2011 including 1984-2002, 2002-2007, 2007-2009 and 2009-2011 time intervals in the specific region, it is observable that large extent of change in the specified area had happened between years 1984 and 2002. **Figure 6.7** shows the stages of land cover change by constructing the settlements in KOC university district in five intervals. Changes are shown by red and cyan colors in index images. In the last three time intervals, 2002-2007, 2007-2009, 2009.2011, there were slight changes within the Koc university limits and few changes happening in the borders of the university.

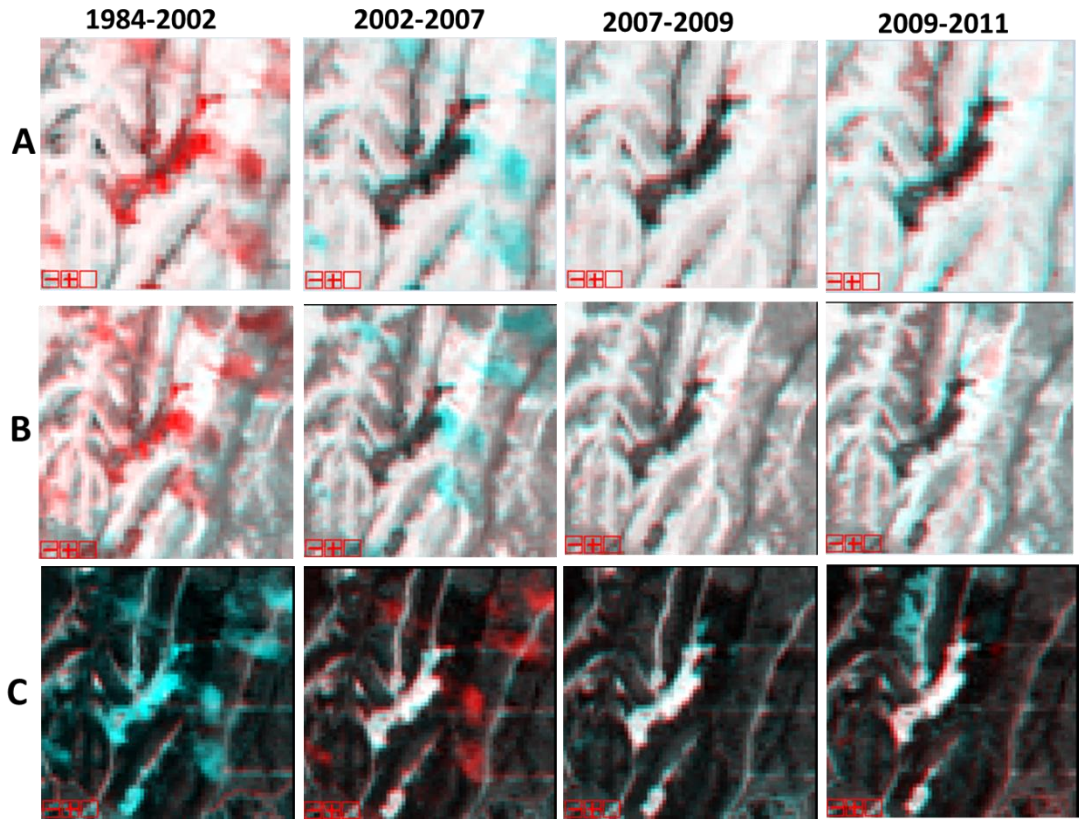

Figure 6.7 : a) NDVI b) SAVI and c) BU Layerstack images in four time interval displaying the changes after the development of Koc University.

There is another example in **Figure 6.8** displaying the phases of land cover change happened in Acarkent span in Istanbul between five time intervals. The satellite image of the targeted area in 2014 is shown in **Figure 6.9**, acquired from Google Map. In series of index images in four time intervals including 1984-2002, 2002-2007, 2007-2009 and 2009-2011, the land cover change and reduction of vegetation cover by developing the new constructions in the area covered by new settlements is clear. As it can be seen, most of the changes happened through the 1984 and 2002 and in the following time intervals there were changes happening within the Acarkent limits, also in the 2002-2007 interval there was a change happened by developing a new settlement added to Acarkent span while there was not significant change in 2007-2009 and 2009-2011. As it is obvious in figures, the changes of BU and NDVI are highly correlated with each other. Increase in the BU Index, which means the developing built-up area causes the decrease in vegetation canopy, which means the decrease in NDVI value.

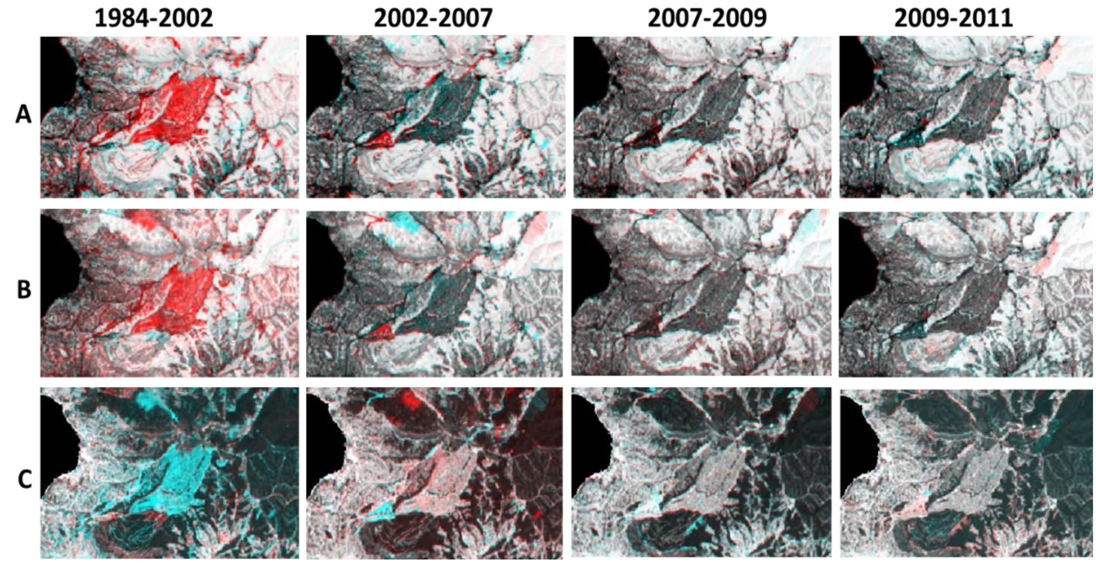

Figure 6.8 : change of land cover in Acarkent span in four time intervals between 1984 and 2011 detected by overlaying a) NDVI, b)SAVI and c)BU images.

Figure 6.9 : Satellite image of Acarkent span (2014).

6.4 Interpretation and Evaluating the Index Values

6.4.1 Exploring Index Values and Index Images

There are methods, used in this study for interpretation of the change. The first method is determining the value of some points on NDVI layerstack, SAVI layerstack and BU layerstack, which were selected from changed and unchanged regions and then comparing the values and interacting the increase and decrease of values. In other words, the values of pixel in same coordinate in three layerstack images were compared. Each pixel's value in layerstack image shows the value of index through five years. Each layer represents for the index image of one year in the five layer layerstack images. So the decrease and increase of the amount of vegetation, built up area can be detected by analyzing the value of index for points on layerstack images. The next step was comparing and connecting the increase or decrease in one index to other index

Points were chosen from both changed and unchanged parts, which were detected from overlaying the index images, and changed areas were separated from unchanged ones by displaying the changed areas by distinguishable colors. There are 150 point, chosen from the changed areas detected by layer-stacking the index images showed in **Figure 6.10**.

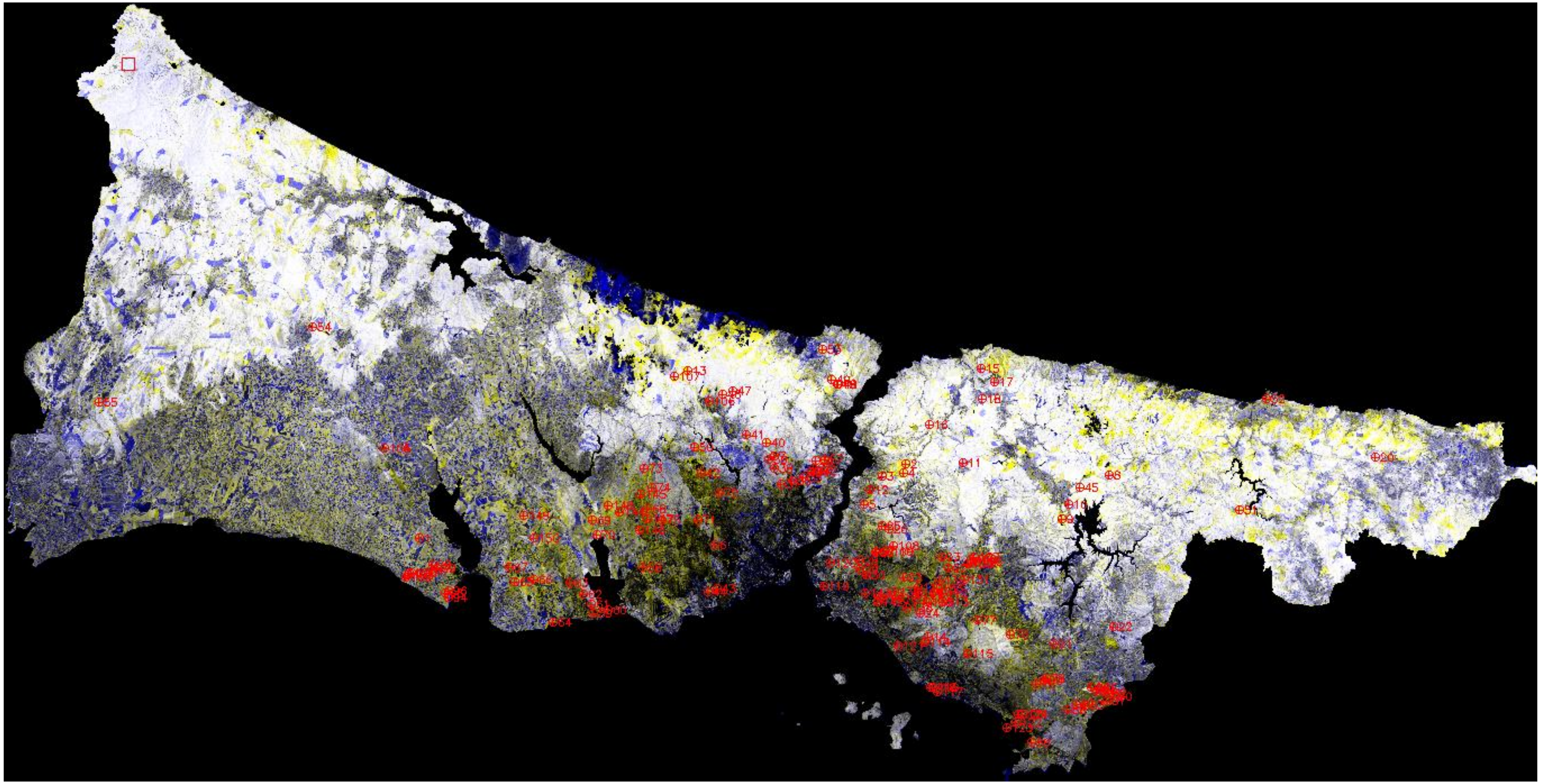

Figure 6.10 : Points on NDVI layerstack image selected from changed area.

There are some examples of analyzing the process of the land cover changes through years by exploring the values of indices, examining the index images and comparing them. For example in the sample point with the NDVI, SAVI and BU index values listed in **Table 6.3**, considering the NDVI and SAVI values related to 1984, it can be concluded that the amount of vegetation cover is less. Moreover, by analyzing the value of BU index it can be understood that the area is referred to built-up area. In 2002, BU value decreased. It indicates the possible reconstruction in the area, which continues to increase in the next years. A slight increase in the vegetation cover in the last years can be explained by the green infrastructure around the settlements, which was still much more less than the 1984 year's NDVI value. There are the Landsat images, NDVI, SAVI and BU images of 1984, 2002, 2007, 2009 and 2011 showing the changes of the pixel in **Figure 6.11**, confirming the result about the pixel situation by analyzing the index values.

As it can be seen in the Landsat and index images in **Figure 6.11**, the selected area was a built-up area, which had continuously been developed since year 2002. In 1984, it can be seen that area, from which the targeted pixel has been selected, was the sparsely vegetated area with a few constructions. In 2002 the most parts of the land went under construction and it remained as the built-up area until 2011. As it was mentioned later, SAVI index shows better results in semi-arid areas with lower vegetation. In this area SAVI shows better results in displaying the condition of land cover. According to BU images, it can be understood that in the last two years, there were some new darker pixels within the built-up area, which was referred to newly constructed green covers such as parks and etc. near the settlements, that explains the decrease of BU index in two last years, 2009 and 2011. The decrease was because of the reorganization of the vegetation cover with residential cover.

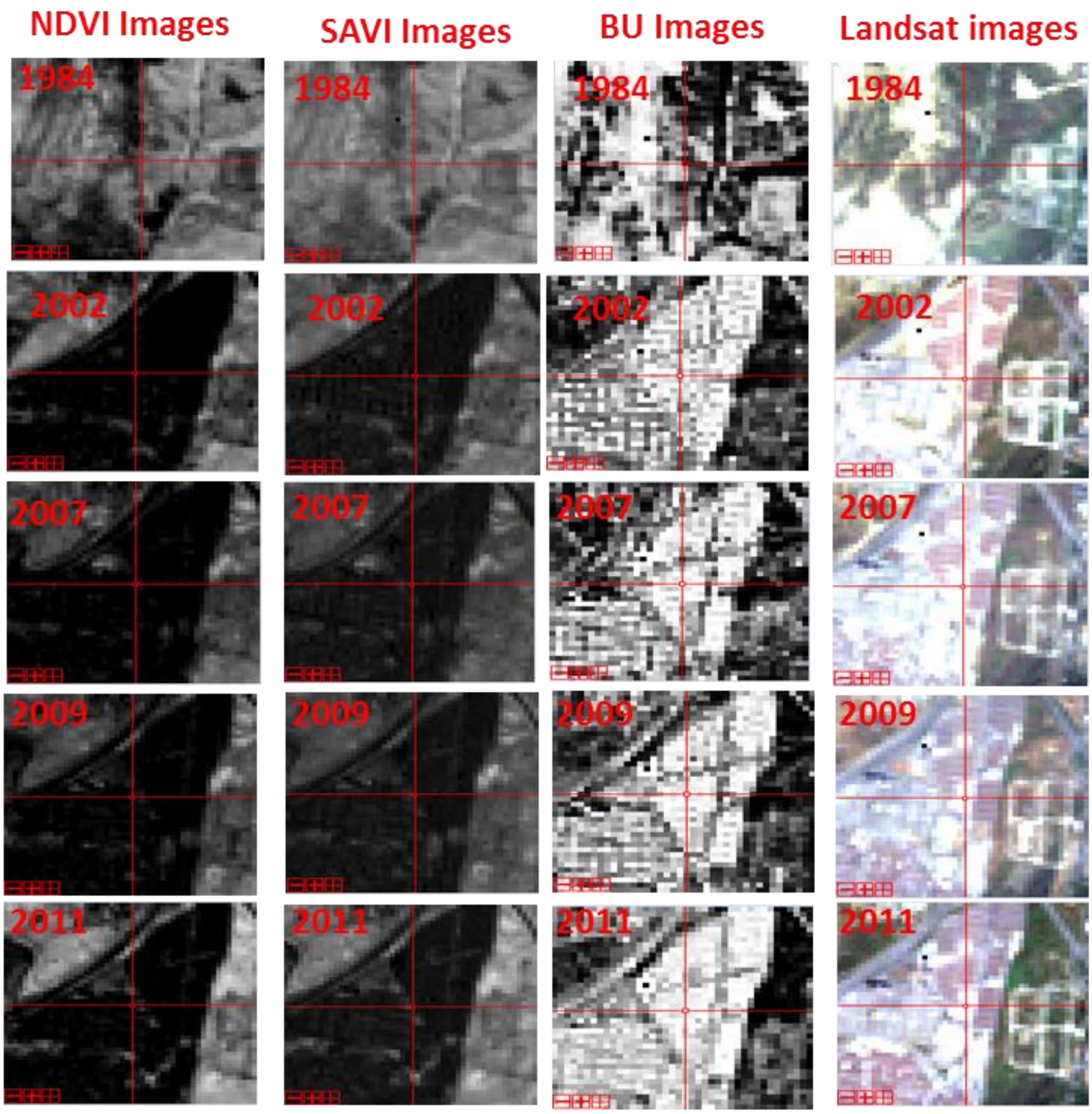

Figure 6.11 : NDVI, BU, SAVI and true color Landsat images of Istanbul of years 1984, 2002, 2007, 2009 and 2011 showing the sample point on are changed by developing new settlements.

Table 6.3 : Index values of a sample point on changed area by developing new settlements.

Year	SAVI	NDVI	Built-up
1984	0.256	0.404	130
2002	0.032	0.045	106
2007	0.038	0.058	181
2009	0.052	0.106	130
2011	0.076	0.132	102

There are two other examples of points that were selected from the changed areas in **Figure 6.12** and **Figure 6.13**. There are also the Landsat images of years 1984, 2002. 2007, 2009 and 2011, which show the land cover/use change of the area from which points had been selected from it. As it is shown in both figures most of the changes happened between 1984 and 2002, which the vegetation cover shifted to built-up area. **Figure 6.12** shows the land cover change in Sultangazi district in Istanbul. Land cover changed significantly because of the stone mining activities in the region. As it can be concluded from the index NDVI and SAVI values in 1984, which are listed in **Table 6.4** and the index images and Landsat images of 1984, the region was covered with vegetation canopies before quarrying stones in the specified land. Most of the changes happened between 1984 and 2002 but by the continuous mining activities in the region the area continually changed in the following years.

As another example, **Figure 6.13** displays the changes happening in urbanized area in Gaziosmanpasa region. In the indices and Landsat images of 1984, it can be seen that the selected area was covered with both vegetation canopies and built-up settlements. However, in the following years there was a significant agglomeration in the built-up area where the vegetation canopy decreased considerably. In the NDVI image of 2007 the vegetation detected by the index is negligible. There was a slight increase in vegetation canopies in 2009 and 2011. There is a sample point selected from the targeted area in Gaziosmanpasa district, and index values of the point are inscribed in **Table 6.5**.

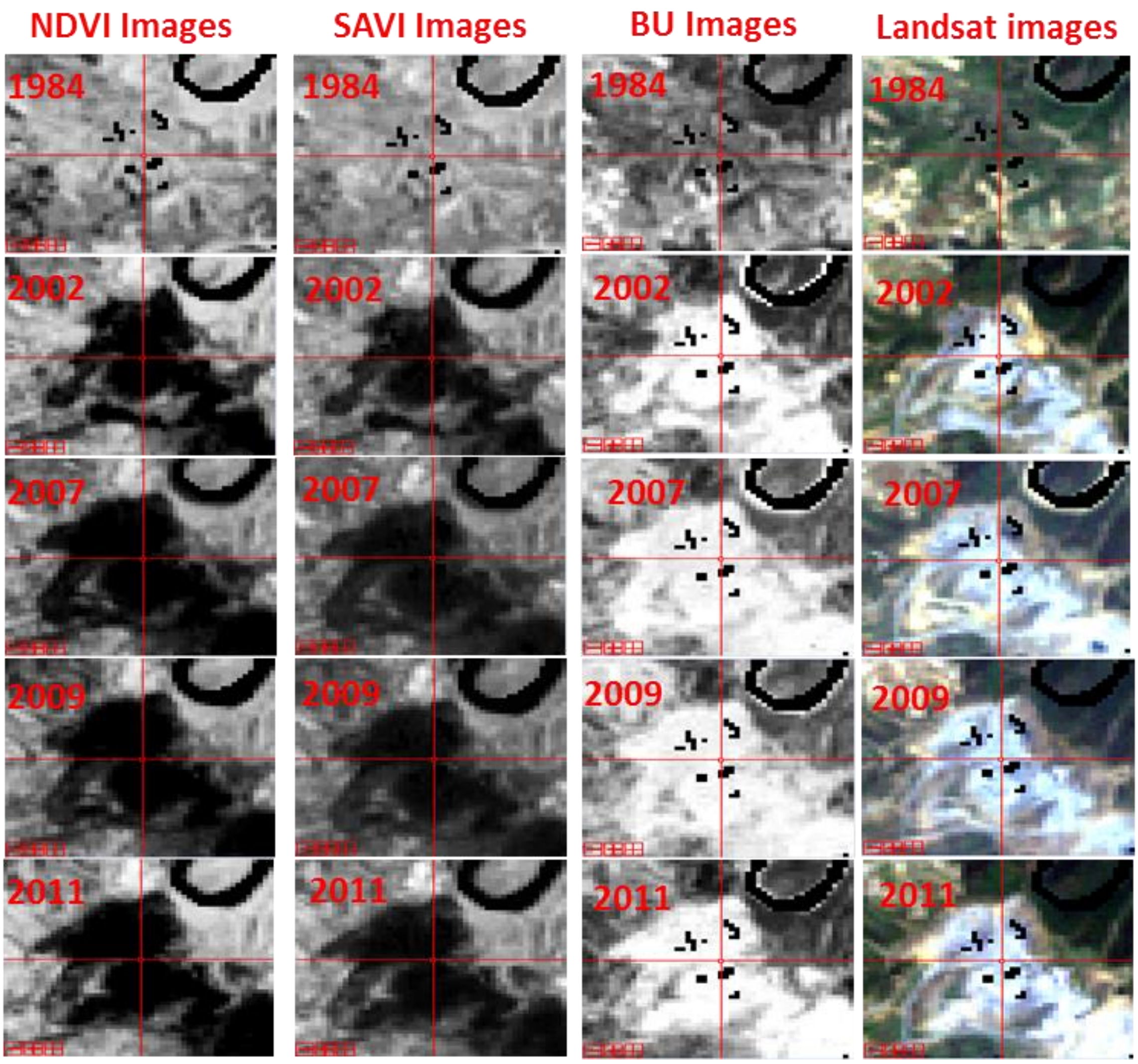

Figure 6.12 : NDVI, BU, SAVI and true color Landsat images of Istanbul of years 1984, 2002, 2007, 2009 and 2011 showing the sample point on area changed by the stone mining activities.

Table 6.4 : Index values of a sample point on stone mining region.

Year	NDVI	SAVI	Built-up
1984	0.54	0.35	79
2002	0.0	0.02	161
2007	0.05	0.0	168
2009	0.05	0.02	131
2011	0.06	0.03	101

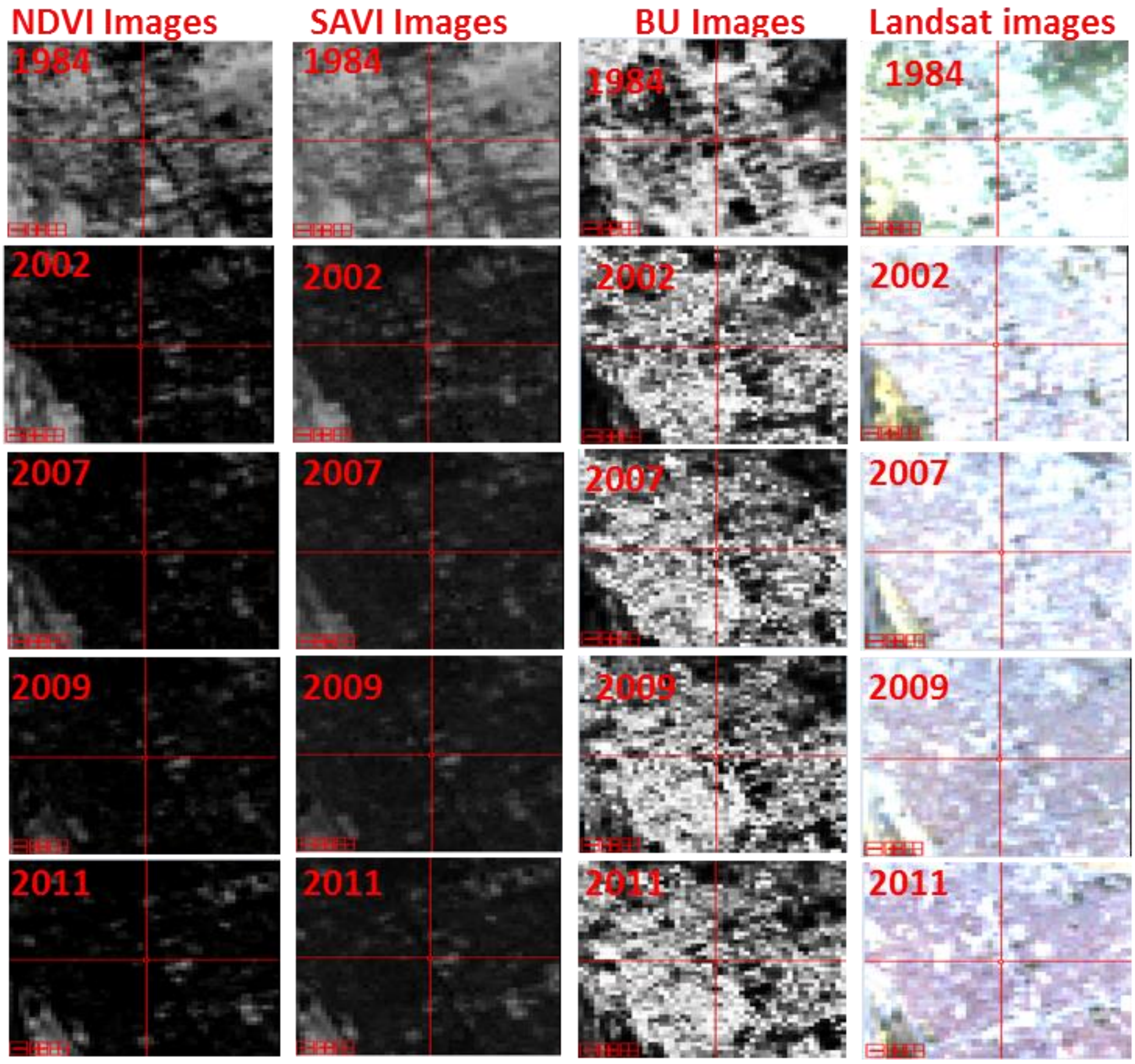

Figure 6.13 : NDVI, BU, SAVI and true color Landsat images of Istanbul of years 1984, 2002, 2007, 2009 and 2011 showing the sample point on area changed by the agglomeration in urbanized area.

Table 6.5 : Index values of sample point on agglomerated urban area.

YEAR	NDVI	SAVI	Built-up
1984	0.27	0.17	90
2002	0.06	0.11	176
2007	0.07	0.04	184
2009	0.03	0.03	150
2011	0.06	0.04	111

In almost all the changed areas, which were detected by overlaying the index images in layerstack images, the BU index value decreases in the last two years. As it was mentioned previously, this reduction is explainable. It is obvious that in the area totally covered with new settlement, including buildings, industrial instructions and etc., there are no more possible space for developing the built-up area, also the area possibly witnesses the increase in semi-vegetation cover around the residential areas. These two reasons describe the decrease in last two years, 2009 and 2011 to some extent.

The average values of points that were selected from changed areas were computed and analyzed. The average values show the same manner as each of the selected points. The average value of the SAVI and NDVI decreased significantly and there are remarkable differences between the SAVI and NDVI values of 1984 and 2011, which shows the main decrease of vegetation cover in the changed areas. The average value of the BU index increase notably in compared to its value in 1984.

The average of points values on NDVI, SAVI and BU images are displayed in **Table 6.6**. The trends of these average values are plotted in **Figure 6.14**.

Table 6.6 : Average of selected points on changed areas detected by indices.

Year	SAVI	NDVI	Built-up
1984	0.39843	0.587669	65.95972
2002	0.13643	0.198742	90.76565
2007	0.09898	0.14906	161.8791
2009	0.088143	0.143967	131.4848
2011	0.088437	0.134238	102.9771

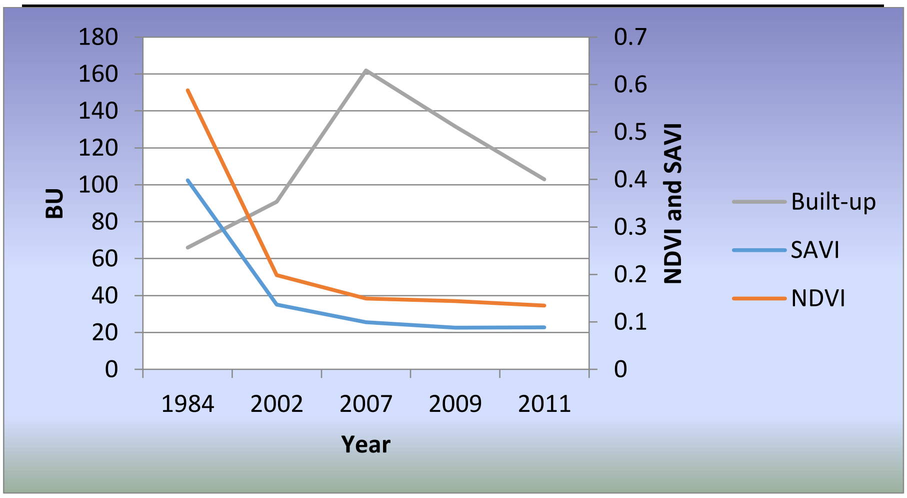

Figure 6.14 : Trend of changes of indices values of points on changed area.

As it can be understood from trends of changes in figure 6.14, there was general decrease in the NDVI and SAVI between 1984 and 2011. There was a sharp decrease in the NDVI and SAVI between 1984 and 2002. After 2007, there was no significant change in NDVI and SAVI. BU index increased between 1984 and 2007 but after 2007 it started to decrease because of the possible green infrastructure activities.

There is one moot point with used indices. In the Layerstack images, some land use changes detected which relates to the farmlands. These changes originate from the variations in the situation of farmlands. Specific farmlands can be totally vegetated in one year while it may not be cultivated the next year. The changes also can be related to the change in the type of crop, which grows in the farmland. The NDVI value of the crop type can be different and this difference was detected as change of land use by indices. In addition, Images can be acquired right after harvesting the land where the land is covered by bare soil. Non-photosynthesis vegetation and dry soils may have similar spectral responses as impervious surface thus detected as the built-up areas in index images.

These types of changes can be discovered and separated by considering the NDVI and BU values of the points in farmland areas. There are several fluctuations and variation in index values in farmland areas while at the points in the changed areas index values increase or decrease permanently in most cases, except the value of BU index in last two years, 2009 and 2011 that started to decrease after 2009, which was clarified previously.

There are index data of a sample point on farmland showed in **Table 6.7** and the related Landsat images and index images showing the condition of selected point on farmland through years in **Figure 6.15**. As it is seen in the figure in the specified farmland through years, land situation changed from plantation to the pillowed land that was covered totally with soil. It was detected that there was no newly constructed settlements in the region.

There is one more point related to farmlands that can be analyzed by use of the SAVI and NDVI index images. SAVI index gives better results in detecting the vegetation cover in the semi-arid areas. As it can be seen in the index images of farmlands, SAVI and NDVI indices give actually same results in densely vegetated areas such as fields. Therefore, it shows that these two indices can be used interchangeably specifically in fully vegetated lands.

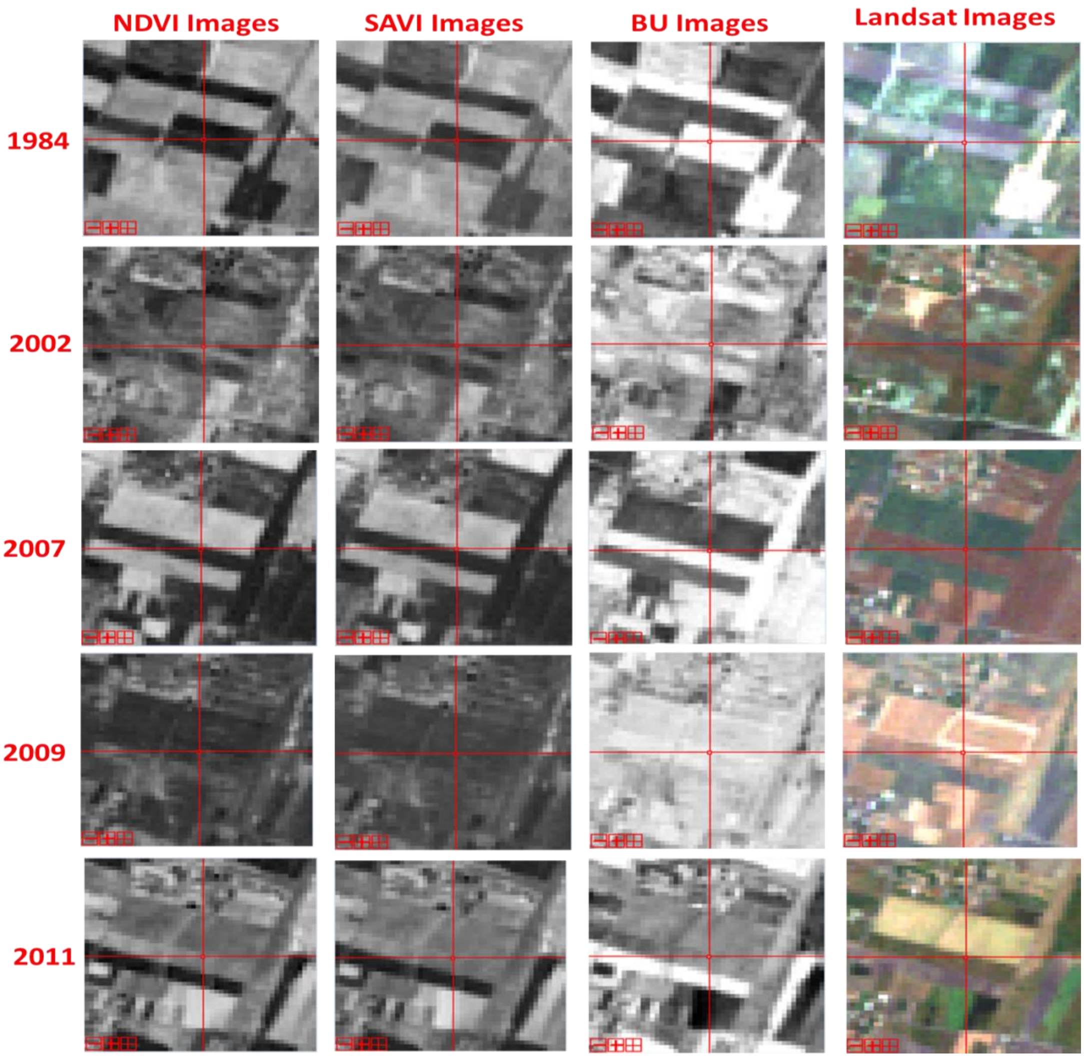

Figure 6.15 : NDVI, BU, SAVI and true color Landsat images of Istanbul of years 1984, 2002, 2007, 2009 and 2011 showing the sample point on farmland.

Table 6.7 : Index values of sample point on farmland

Year	SAVI	NDVI	Built-up
1984	0.12	0.22	158
2002	0.19	0.40	76
2007	0.24	0.18	114
2009	0.13	0.13	125
2011	0.26	0.26	71

Fifty points were selected randomly from farmlands and average index values were calculated which are shown in **Table** 6.8**.** Trends of the calculated average values are shown in **Figure 6.16**. When these trends are compared with the trends of changes of points on changed areas displayed previously, the difference is observable. Therefore, it can be said that, type of land cover change can be understood from the fluctuation of the index values in the trends.

Table 6.8 : Average of selected points on farmlands.

Year	SAVI	NDVI	Built-up
1984	0.2664	0.4144	102.6
2002	0.2316	0.201	67.92
2007	0.2184	0.354	116.76
2009	0.1556	0.2544	116.4
2011	0.1844	0.3104	86.96

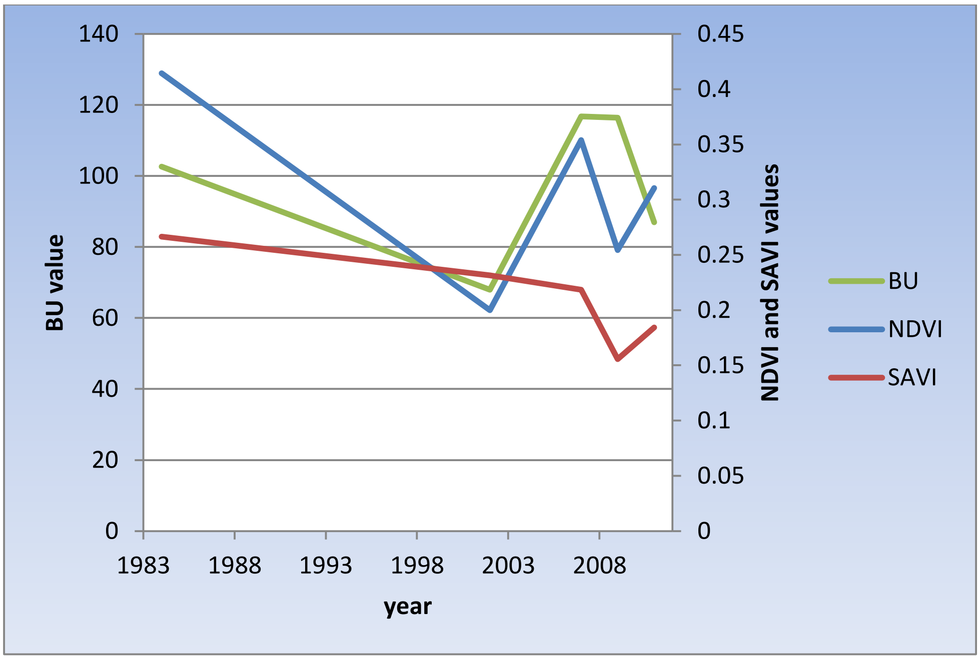

Figure 6.16 : Trend of changes of average indices values of points on farmlands.

6.4.2 Comparing Multitemporal Index Values of changed areas

Besides checking the sample point in the changed area and analyzing the type of change in the area by scrutinizing the index values of the targeted point, it is possible to detect the change of the region by looking over the cluster of index values of the specified area in multitemporal pixel data of index images metadata. Exploring the SAVI, NDVI and BU values of the changed area shows the amount of changes and limits of change in the changed region.

Figure 6.17 shows the land cover change and vegetation cover reduction in Koc university district. As it can be seen in the pixel data of NDVI images of 1984 and NDVI image of 2011 in the specified area, the index values decreased intensely within the Koc university district. In addition to the effects of newly developed settlements on the vegetation cover of the specific region, there are considerable impacts on the neighboring vegetation covers. It is possible to detect the limits of changed area by considering the decrease of index values in two different dates. A SAVI image and SAVI index values of 1984 and 2011 displayed in **Figure 6.18,** shows similar decrease in value in the targeted region. SAVI layerstack image shows better results in detecting the changes that happened in the surrounding of the Koc university district.

In **Figure 6.19**, BU Layerstack and BU images of 1984 and 2011 are displayed. The changes of the region by increasing the built-up area are obvious in BU layerstack. By comparing the BU index values of the two BU images of the two years, 1984 and 2011, in the specified region which is related to Koc university limits, It can be understood that the BU index values increased between 1984 and 2011 significantly by developing the new buildings in the Koc university district.

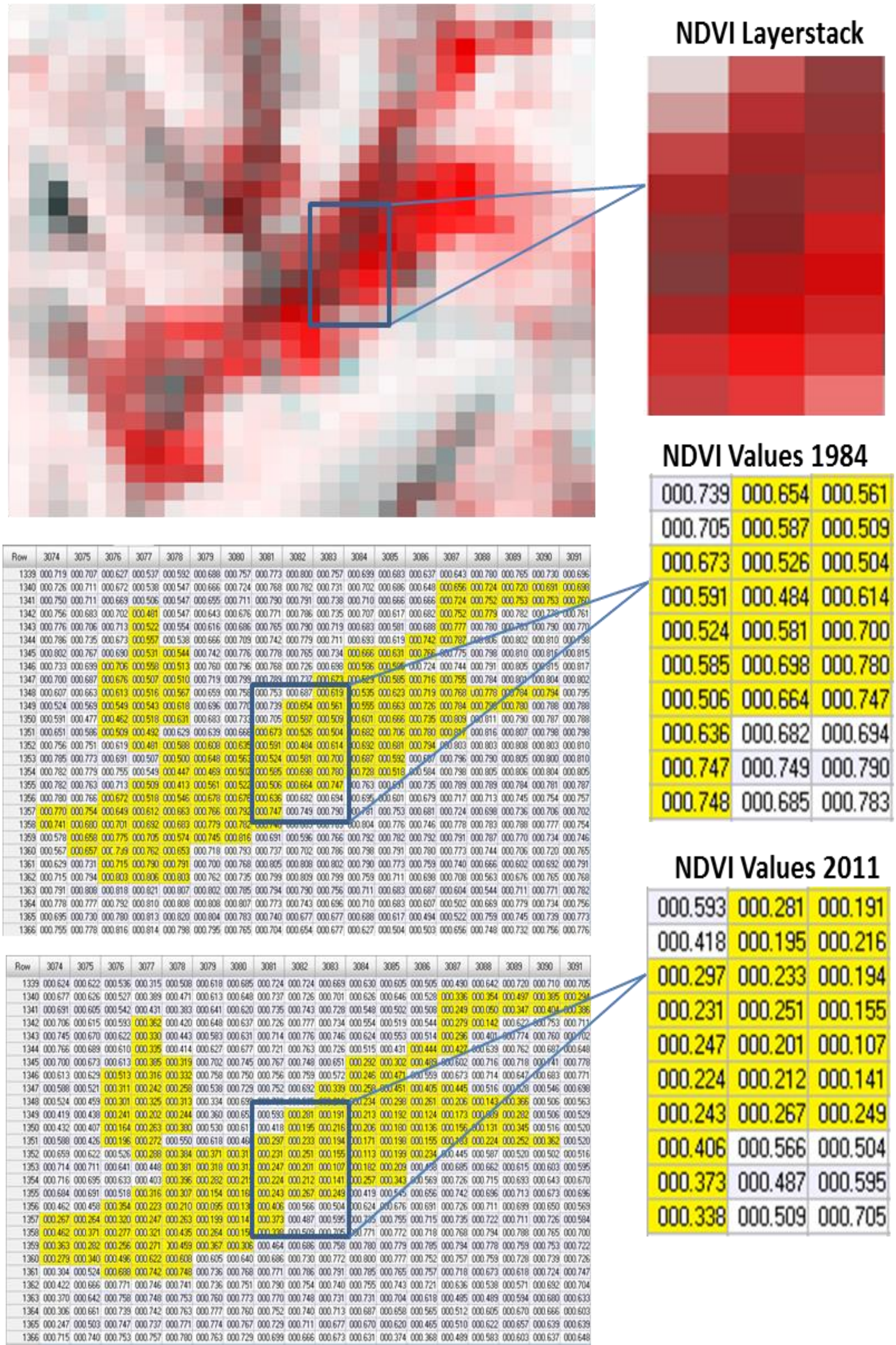

Figure 6.17 : NDVI Layerstack and clusters of pixel data of NDVI images in 1984 and 2011 showing the vegetation cover changes in Koc university district.

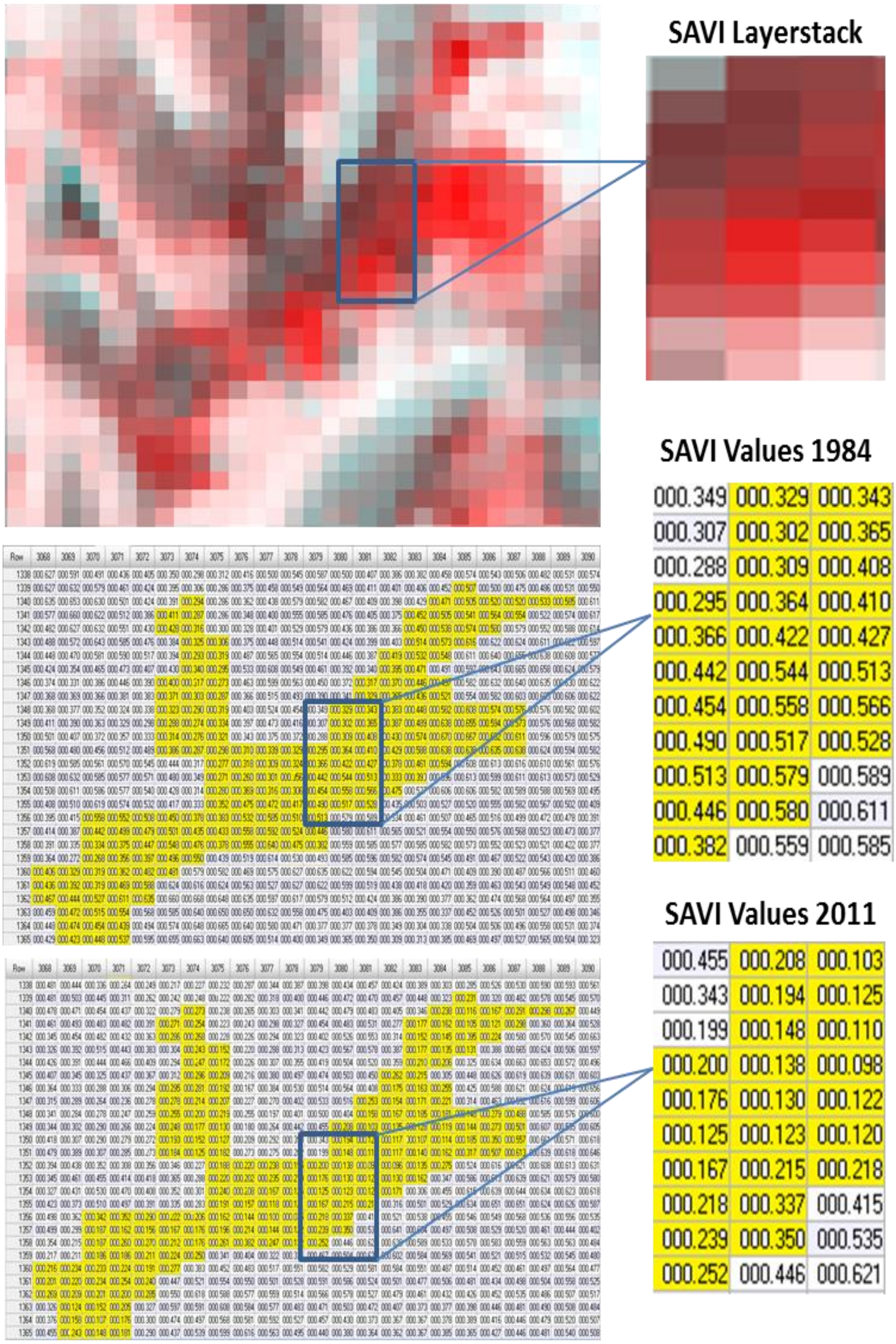

Figure 6.18 : SAVI Layerstack and clusters of pixel data of SAVI images in 1984 and 2011 showing the vegetation cover changes in Koc university district.

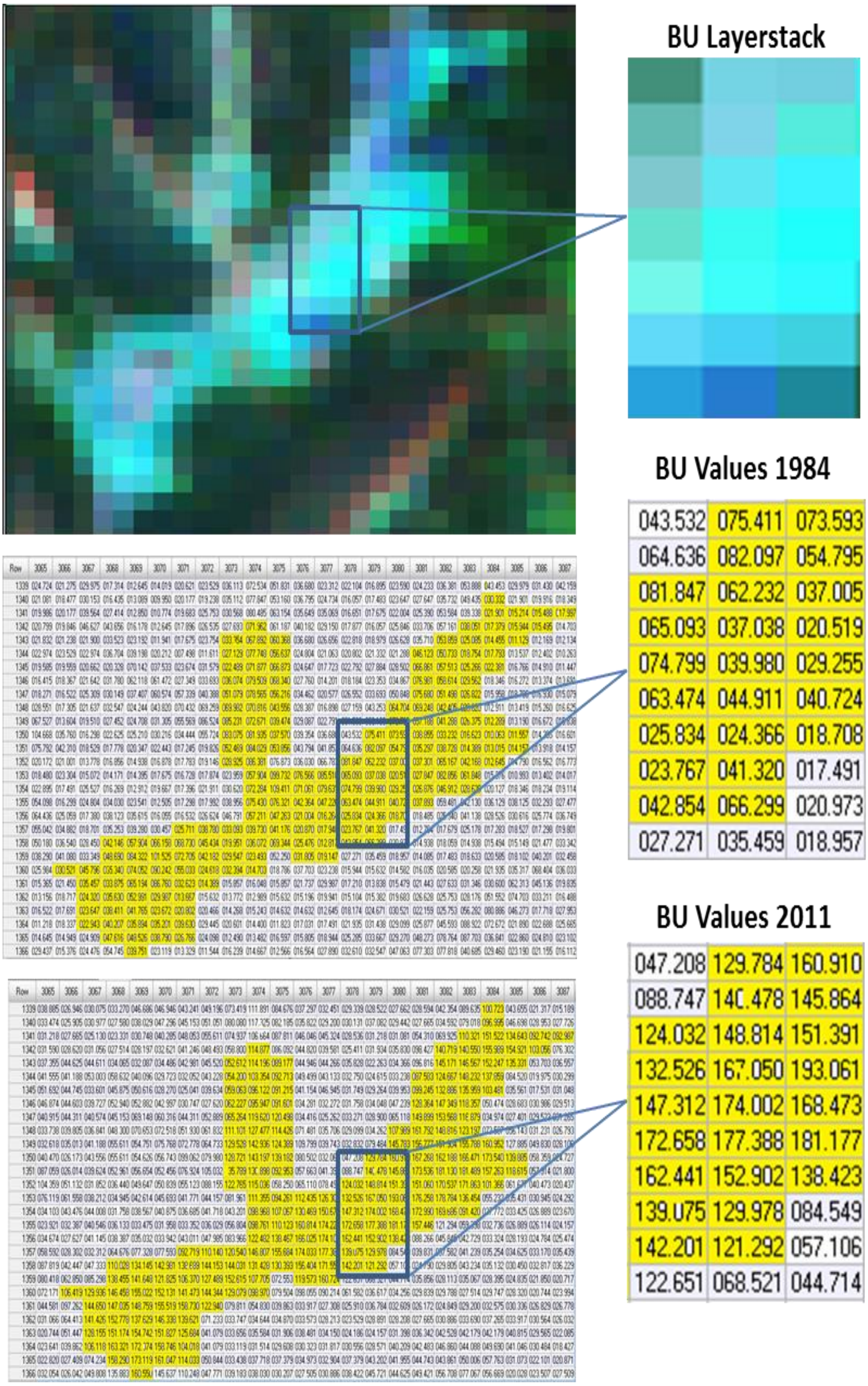

Figure 6.19 : BU Layerstack and clusters of pixel data of BU images in 1984 and 2011 showing the built-up changes in Koc university district.

6.4.3 Indices Relationship

Besides the describing of the land cover/use change process by probing the index values individually, it is also beneficial to look into the relation of indices with each other. SAVI, NDVI and BU values of the previously mentioned 150 points, which were selected from the changed areas, were compared for exploring the possible data in the relationship between different indices and the interrelation of each index in different years. As it was interpreted in previous parts and comparing the index values of sample points in the changed areas, it can be concluded that there is a relation between indices. There are both inverse and direct relations between indices. If we look at the relation of SAVI and NDVI in **Figure 6.20**, it can be seen that these two indices are in high correlation and have a direct relationship. Although the NDVI values are greater than SAVI values in most of the cases of exploring index values of points on changed areas, the index values of SAVI and NDVI increase and decrease coordinately. According to similar results of these two indices, it can be derived that NDVI and SAVI can be used interchangeably in detecting the vegetation cover but it should be mentioned that SAVI is more useful in semi-arid areas because SAVI index minimize soil brightness influences while there are advantages of using NDVI index in highly vegetated areas. The total decrease of vegetation cover in the areas, which were changed through years, is clear in the graphs related to the relation of SAVI and NDVI indices (**Figure 6.20**). In the graph related to 1984, SAVI and NDVI values of points are greater than their values in the following years. The group of indices values of points come close to zero in the last years.

Most of the changed areas from which points had been selected, are related to regions having been changed because of urbanization developments with low-level vegetation covers. In this sort of regions, employing SAVI index that gives better results in sparsely vegetated lands is more advantageous. SAVI index provide applicable results in relation with BU index.

According to the inverse relationship between the BU-SAVI in **Figure 6.21**, it can be concluded that by the increase of BU index, SAVI and NDVI indices have the decrease in value. It is so obvious that in the area under construction, there is a necessity to diminish the vegetation cover of the surface. The results of relationship between BU index and SAVI index in the changed area reflect this fact. As it was mentioned, there probably were some plans for the increasing of the green vegetated area in the built-up regions, like building parks and lawn in the last years, but it cannot replace the natural vegetation canopy, so the decrease of NDVI value in the built-up areas is definitive.

High correlation of SAVI and BU indices in 1984 with R^2 coefficient equal to 0.79 (**Figure 6.21**) points to the fact that the SAVI values are less in amount in the points where the BU index is high in value. In other words, in the pixel donated to built-up cover, vegetation cover is less in amount.

Increased correlation of SAVI and BU index in 2002 in comparison with 1984, (R^2=0.83) shows the increase in built-up areas and coordinated decrease of vegetation canopy levels. This increase continued until 2007. As it was shown previously, most of the land covers and land use changes happened between 1984 and 2002. There were some extend of change between 2002 and 2007 but after 2007 there was stability in the size of built-up area and a slight increase by some green activities around the built-up area so the pixel becomes a mixture of Built-up area and vegetation cover. This can explains the decrease of SAVI and BU correlation after 2007 (R^2 values of 0.87 in 2007, 0.76 in 2009 and 0.67 in 2011).

Exploring the BU values of the points, which were selected from the changed areas, shows the increase of built up area in the region through years. Helpful data has been derived by probing the relation of BU index of different years (**Figure 6.22**). In addition to total increase of built-up area that is clear in the graphs showing the relation of BU index in different years, low correlation between BU index values of 1984 and 2002, shows the dissimilarity of these two groups of values. It means that there is a big change happened between these two years. It was mentioned previously that the most of the changes happened through 1984 and 2002, which was truly described by the relation of BU index of 1984 and BU index of 2002. There is also low correlation between BU index values of 2002 and 2007 (R^2 = 0.06) which shows the significant difference of index values in 2002 and 2007. Increased correlation of BU index values of 2007-2009 and 2009-2011 shows the stability of built-up area after 2007 and mixture of built-up are with newly added semi-vegetation covers.

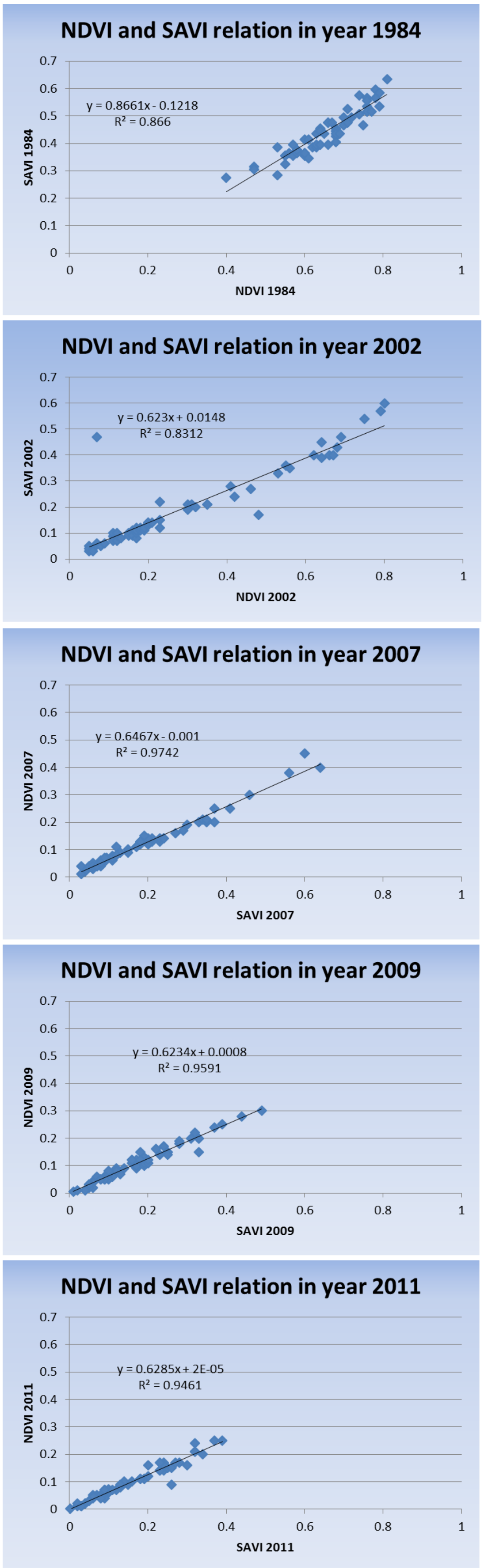

Figure 6.20 : NDVI and SAVI indices relation in 1984, 2002, 2007, 2009 and 2011.

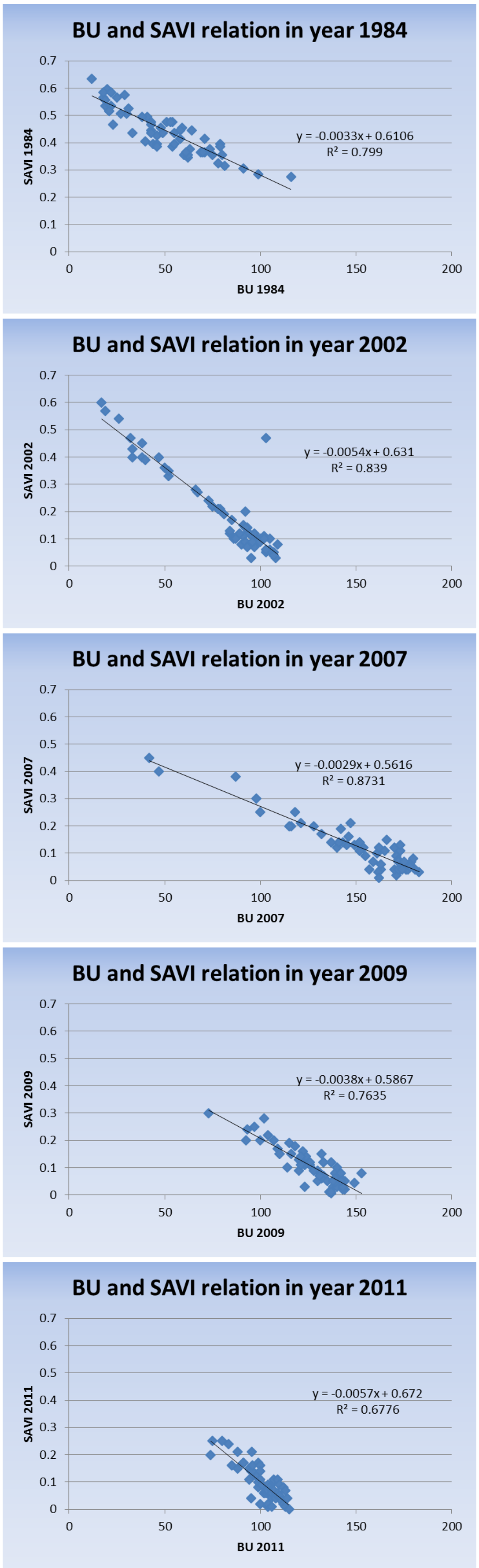

Figure 6.21 : SAVI and BU indices relation in 1984, 2002,2007,2009 and 2011.

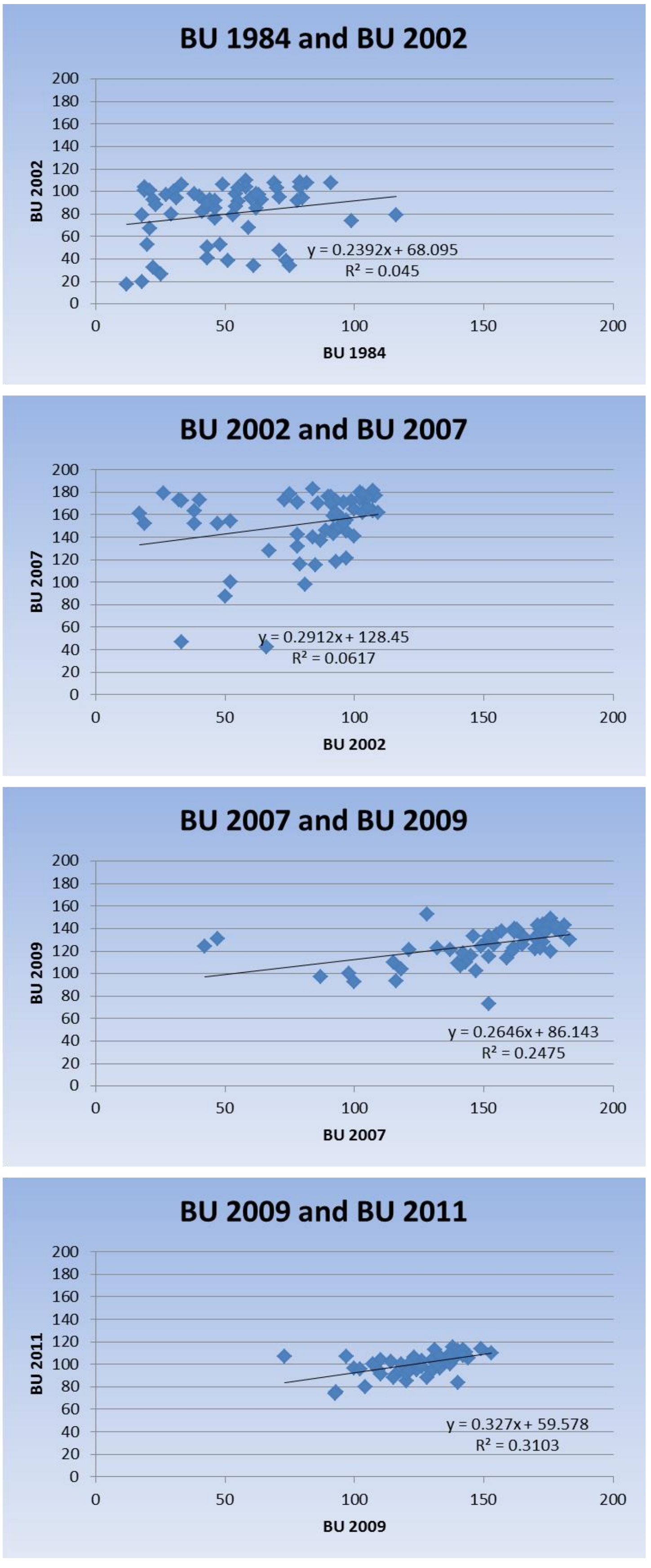

Figure 6.22 : Relation of BU index of four time interval, 1984-2002, 2002-2007, 2007-2009 and 2009-2011.

7. CONCLUSION

It has been explained that the potential of remote sensing and availability of remotely sensed data have provided us with the opportunity to understand the land cover change and identify the causes of this phenomena, particularly in big scaled regions such as cities and countries. To achieve the general objective of the research, the first focus of this study was the analysis of the land cover change and land use change in the study area for the period of 1984-2011, using the Landsat 5 TM data images of 1984, 2002, 2007, 2009 and 2011. Changes in vegetation cover of the study area were surveyed. The compatibility of remotely sensed data with other available spatial data such as maps, have enabled us to obtain the causes of land cover changes and compare the past and previous condition of the specific regions.

The second focus of this study was aimed at analyzing the effects of land cover change caused by natural variables and land use change caused by urbanization, mining activities and etc.; specifically on the vegetation cover of the study area. We probe the relation between the developing of the built-up areas and its consequences on environment specially the vegetation cover of the region.

Changes happened in vegetation cover and built-up area were displayed by applying the NDVI/SAVI index and BU index respectively. After overlaying the NDVI images, SAVI images and BU images of five years including 1984, 2002, 2007, 2009 and 2011, changes were detected by the resulted Layerstack images.

Water bodies affected the index images unfavorably. Increase in the size of water bodies were detected as vegetation changes when index images were overlaid. There are so many dams constructed between 1984 and 2011, which all detected as changes of vegetation cover in NDVI, SAVI and BU layerstack images. For solving this problem all existing water bodies until 2011 were masked out from all Landsat images before applying the indices and following analysis. The NDWI index was used for detecting the water bodies of Landsat image of 2011 for covering all the water bodies until 2011. After classifying the NDWI image of 2011 in two classes including water and non-water classes, classified image was applied on all images as water mask.

There were 150 points selected from changed areas that were detected by overlaying index images of five years in layerstack images and NDVI, SAVI and BU index values of each point for five years were listed, and the average of these values were calculated for detailed examinations.

Using different methodology changes caused in vegetation covers and built-up areas were clarified. Analyzing the NDVI, SAVI and BU values of the points that were selected from the changed area and comparing index values related to different years shows the significant decrease of vegetation cover in the built-up areas with high BU index values. Increase in built-up area (represented by increasing BU index values) caused significant decrease in vegetation cover (represented by low NDVI/SAVI index values). Portraying the trends of average values of the points selected from the changed areas gives the specific trends of decreasing vegetation and increasing built up areas in infrastructural completed residential regions.

The pixel data of index images such as SAVI, NDVI and BU images in the changed regions related to different years, were compared with each other and the significant effect of increased built-up area on vegetation cover of the region was displayed. Besides the intense decrease of the vegetation index values in the defined region, significant changes were apparent in the surroundings of new developed settlements. High values of BU index in changed areas shows the significant increase of built-up cover in the region.

Indices which showed the status of vegetation cover and built up areas have good information in relation with each other. Also results of each index in different years provides good results in relation with each other. SAVI and NDVI have high correlation, which expressed the compatibility of two indices. Although NDVI index offers greater values in comparison to SAVI index in most of the cases, but the trends of change in both indices are matching. Nevertheless, there is a key point about NDVI and SAVI index. The SAVI index provides better result in regions, which are sparsely vegetated such as built-up areas because of the specific feature of SAVI in adjusting the brightness of background soil. It should be stated that NDVI index provides reliable data about the vegetation status of densely vegetated surfaces. According to the relational value of BU index related to different years (**Figure 6.22**), it can be concluded that total amount of built-up area increased between 1984 and 2002. In addition to total change, it is possible to determine that in which time intervals (1984-2002, 2002-2007, 2007-2009 and 2009-2011) the most or least of change has happened. According to BU index values relations, the most of the changes happened between 1984 and 2002 where the most increase of BU index occurred. Low correlation between BU values of 1984 and BU values of 2011 explains the high difference between these two groups while there were not major changes in built-up areas in the two last time intervals of 2007-2009 and 2009-2011.

Vegetation cover of the areas, which have been gone under construction, decreases significantly between 1984 and 2002. Development of buildings and settlement continued until 2007 but after 2007 there is stability in the size of built-up area. Despite the construction of semi-vegetation around the newly constructed buildings and settlements and in other words the reorganization of the vegetation cover and residential cover in the region, the amount of vegetation cover never reverted to its earlier level in 1984. There are some dominant reasons which caused the land cover /use change. Developing new dwellings and settlements, road constructions as the consequences of the urbanization is the common cause of the land cover/use change. The other type of change is intense land cover changes due to the mining activities. Other than these two types of land cover/use change, there are changes occurring within the old urbanized regions which are related to agglomeration in the urbanized areas as a result of addition of several buildings and housings and rebuilding of old constructions within the limits.

Vegetation status in farmlands changes every year. Suppose the farm when it is planted. In this situation, according to the index images, the NDVI and SAVI index values are greater than the time, which the farmland is harvested. Another reason in conjunction with vegetation status in farmlands can be mentioned as variety of the crops that are planted in different periods. Non-photosynthesis vegetation, planted in the farmlands, may have similar spectral responses as impervious surface and though NDVI value of the farmland may be low while it is fully vegetated. These above-mentioned changes are assumed as land cover changes in overlaid index images; however, these alterations are related to farmland changes. It is important to consider the fact that farmlands do not confront functional changes such as built-up areas or other changes. The diversity between trend of changes in index values of 50 points +/*selected from farmlands and 150 points that were selected from actually changed areas can be observed and used for discriminating the changes of farmlands from other changes. In addition, farmlands can be masked by utilizing the classified image, which separates farmlands from non-farmlands.

Requisites for analysis of the vegetation cover and built-up areas are multi temporal remotely sensed images. If the reliable data such as Landsat images of consecutive years are available, land cover/use changes happening through years, are detectable by applying vegetation indices in a simple method.

Analyzing the land use change and vegetation cover change in parts of urban region is possible by utilizing the index values and index images of Landsat images. This can be used to improve our understanding of the phenomena of change at micro scale and contribute to the process of decision making for urban planners and enabling managers to forecast and reduce the possible damages on vegetation cover of the city. Applying the indices to Landsat images provides reliable data about the changes of built-up areas and vegetation covers, both increase and decrease is detectable from the layerstack index images.

Simplicity and rapidity of SAVI/NDVI and BU indices in detecting the changes of vegetation cover and the built-up areas respectively are among the main reasons of using these indices. Identifying the targeted feature from the land surface in least possible time and applying the following analysis are feasible by utilizing the relation between NDVI, SAVI and BU indices.

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