# MONITORING URBAN EXPANSION IN THE BÜYÜKÇEKMECE DISTRICT OF İSTANBUL USING SATELLITE DATA

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## ABSTRACT

Unplanned city growth is an indicator of rapid industrialization which, usually, reduces the quality of the environmental health of a region – sometimes disastrously. Controlled urban growth through planning is, therefore, very important. The use of multitemporal and multispectral satellite data, in combination with ground observations, can be used for land use change detection analyses which, in turn, can be used as a basis in planning. In this study, LANDSAT-TM and SPOT-P multidate data were used to monitor the urban changes in the Büyükçekmece district of İstanbul in Turkey. An automatic image registration process has been developed, and difference image and ratio image methods were used. Change detection analyses results showed a great urban expansion at the eastern and southeastren parts of the study area between the period of 1984-1998.

## 1 INTRODUCTION

The urban fringe area is often characterized by a conflict between competing demands for land from many types of development. In oder to avoid chaos and to protect the quality of the environment, active, long-established, and publicly recognized planning is required to: develop the infrastructure; prevent urban coalescence; protect agricultural activity; and provide recreational access. Good planning and adequate administration are important but these are only possible if they are based on reliable, accurate, and up-to-date information. Historically, in Turkey, there has not been the available resources to map, plan, and monitor developments in an adequate and timely fashion. Nowadays, owing to the availability of different satellite data and ancillary information, Geographic Information Systems can be established and urbanisation and urban expansions/changes can be monitored much more effectively.

The availability of satellite image data in different forms has ensured that many successful applications in land cover and land use mapping have been carried out (Larry, R.G., Martin P. J., Howarth, 1989; Green, K., Kempka, D., Lackey, L., 1994; Steinnocher, K., Kressler, F., 1999; Archer, D.J., 1999; Barr, S., Barnsley, M.J., 1999; Bauer, T., Steinnocher, K., Barr, S., 1999). For the purpose of land use mapping, the wide and repetitive coverage, at reasonable cost, afforded by the satellite platforms are especially important enabling cost effective data collection and ease in updating land use maps. In order for this to be effective, however, suitable methods for extracting the information need to be developed, and compared, and the results presented in a suitable manner. For such techniques to be adopted by the administrations of the municipalities, it has to be shown that the information is reliable, accurate, timely, impartial, and, not the least, relatively cheap.

The urban expansion and land use change in the region around İstanbul has been, and still is, rapid and almost uncontrolled. More than half of the total population of İstanbul live on the European side. The areas between the Bosphorus and the Büyükçekmece Lake contain the highest concentration of İstanbul settlements. Most of the core functions of the city are also located here. The area has been rapidly, and constantly, changing since 1850. There are both old and new settlements, residential areas are juxtaposed with industry, and there have been severe losses of greenspace in the urban areas. Housing covers the private, public, and cooperative sectors and includes all social levels. The range of type and style of housing is large, and can be categorised by building typology and historical development:

yalis, detached and semi-detached houses; terrace-houses, apartment blocks, mass housing; and social housing, all of which can be observed at different places in the area.

The area of Büyükçekmece is one of the biggest regional municipalities in Istanbul. In this area, the development has been rapid and change is constant. Some of this change is planned, some of it is not. Planning, and monitoring, are essential in order to develop the area's infrastructure and keep the region functioning properly. It is, therefore, essential for planning and government, that the current situation and the extent of change are assessed. For that purpose, a pilot study was carried out to provide an initial assessment of urban expansion in the area. To do this, multidate LANDSAT-TM (Thematic Mapper) (10 February 1983, 12 June 1984 and 16 April 1998) and SPOT-P (Panchromatic) (16 April 1989 and 22 July 1998) covering the study area were obtained. Potentially, the higher spatial resolution of the SPOT-P imagery is of particular use in the urban environment where the increased spatial acuity outweighs the poorer spectral characteristics. This inadequacy in spectral resolution was companseted by merging SPOT-P with LANDSAT-TM imagery. The impacts of the urban growth and land use changes in the region were evaluated using conventional image processing techniques, i.e. multidate classification and change detection. The area is under particularly severe development pressure where settlements are being established to the detriment of the largely, semi-natural, environment.

## 2 STUDY AREA

The area of Büyükçekmece is one of the biggest regional municipalities (213 km$^2$) in Istanbul with approximate central geographic coordinates 41º 02' N and 28º 32 E' (Figure 1). To the east of Lake Büyükçekmece satellite towns have been established, a secondary housing belt now exists on the shores of the Sea of Marmara, and there are new, uncontrolled, squatter settlements. Some interesting, large development projetcs such as mass housing projects and private house projects have also been undertaken along the new Trans European Motorway (TEM) system. In this area, Büyükçekmece Lake is a lagoon formed at the point where the Karasu river descends from the north. Other rivers feeding the lake include the Sar□su and the Çak□l. The lake is 30 km from □stanbul on the □stanbul - Edirne E5 highway. The lake is separated from the Marmara Sea by a coastal strip, over which the E-5 highway connecting Europe and Asia passes. The □stanbul Directorate of Water and Sewage has had the lake deepened and widened by building a high dike at one end. The lake waters, whose link with the sea has been cut and which have therefore become fresh, are used to supply the city of □stanbul with water for drinking and other purposes. The lake's shores are shallow and covered on the north and west by reedbeds and cattails. Settlements and industrial plants are located on the east side. The lake's maximum depth does not exceed 4 meters. A larger lake called Küçükçekmece Lake is located 15 kilometers to the east of Büyükçekmece Lake which is completely surrounded by settlements and individal installations (TCV, 1993).


Figure 1. Study Area

## 3 MATERIALS AND METHODS USED

### 3.1 Materials

Requirements for urban change detection and mapping applications using remote sensing methods are *(i)* high resolution data to obtain detailed information, *(ii)* multispectral optical data to make fine distinction among various land use classes. Sensors operating in the visible and infrared portions of the electromagnetic spectrum are the most useful data sources for land use analysis. Radar sensors also have some use for different land use applications (Remondiere, S., Lichtenegger, J., 1995; Lemoine, G., De Groof, H., Van Leeuwen, H. J. C., 1995; Nezry, E., Genovese, G., Solaas, G., Remondiere, S., 1995; Aschbacher, J., Pongsrihadulchai, A., Karnchanasutham, S., Rodprom, C., Oaudyal, D.R., Le Toan, T., 1995; Nieuwenhuis, G., Kramer, H., 1995; Sunar, F., Maktav, M., Lichtenegger, J., 1999) In this study, high resolution SPOT-P data dated 22 July 1998, and LANDSAT-TM multispectral optical satellite data dated 12 June 1984 and 16 April 1998 were used (Table 1). The satellite data was supported with 1/25000 topographic maps and 1/5000 orthophoto maps. Municipality and village boundary coordinates in DXF format were obtained from the Büyükçekmece Municipality.

| Satellites | Sensors | Bands | Wavelengths (μm) | Dates |
|---|---|---|---|---|
| LANDSAT | TM | 1-Visible | 0.45-0.52 | 12.6.84 |
| | | 2-Visible | 0.52-0.60 | 16.4.98 |
| | | 3-Visible | 0.63-0.69 | |
| | | 4- Near-IR | 0.76-0.90 | |
| | | 5-Near-IR | 1.55-1.75 | |
| | | 6-Thermal-IR | 10.4-12.5 | |
| | | 7-Middle-IR | 2.08-2.35 | |
| SPOT | HRV | Panchromatic | 0.51-0.73 | 22.7.98 |

Table 1. LANDSAT and SPOT data used.

### 3.2 Methods

#### 3.2.1 Development of an Automatic Image Registration Process

Image registration is the matching of two or more different images to a common spatial framework. It is the process of geometrically aligning two or more sets of image data such that resolution cells for a single ground area can be digitally or visually superposed. Data being registered may be of the same type from very different kinds of sensors, or collected at different times. The problem with using imagery from different dates, or from different sensors such as LANDSAT-TM and SPOT-P which is the case here in this study, is that, in order to be useful, they have to be registered to a common coordinate system (Harrison, B.A., Jupp, D.L.B., 1990). This coordinate system can be one of the images, taken as a reference, or can be a map projection. Any conversion to another coordinate system not only implies a loss in radiometric accuracy through resampling, but is extremely time consuming and error prone. Usually it is done through the manual identification of ground control points of the same object in both coordinate systems. Control point identification is difficult, the difficulty increasing with decreasing spatial resolution, and time consuming as it requires a matrix of sufficient number of suitably spaced control points.

In order to reduce the time taken, remove subjective human intervention, whilst achiving the highest accuracies, an automatic procedure has been developed. The objective of this procedure is to automatically register the image to a subpixel level of accuracy. It is assumed that gross distortions, rotations and scale changes will not be encountered. The registration is carried out on the shapes of significant objects in the imagery. Both the reference image, which supplies the reference coordinate system, and the image to be warped, are first subjected to an edge detection (differential) technique in order to define the significant boundaries in the scene (Harrison, B.A., Jupp, D.L.B., 1990; Ton, J., Jain, A.K., Enslin, W. R., Hudson,W.D., 1989).

Matching between scenes is carried out using local correlations, in the frequency domain. The matching algorithm has to be area-based because the confidence and precision increase with the number of samples. When matching, there is essentially an array of reference and image pixels which are correlated to each other. If this is done in the frequency domain, the result is an array, equal in size to the input arrays, where the contents of each element correspond to the correlation of the two images. An array results because it is as if the image to be warped is passed over the reference image, shifted a pixel at a time and the correlation computed at each location. The result is a correlation map, and the location of the elements with maximum correlation gives the necessary x, y shift to give the best fit.

With manual control points selection, 20-30 carefully distributed points would be considered the norm for the images under consideration. The automated procedure just described produced over 1600 points in an almost complete matrix distribution described by a polynomial with a fit to within ± 0.5 pixel RMS. An even finer matrix of points would be possible, but was considered unnecessary.

The 1984 LANDSAT-TM image was registered to the 1998 LANDSAT-TM image with this approach and a set of control points were also defined to describe the polynomial to transform all image data set to UTM coordinates.

The 1998 SPOT Panchromatic data was also registered to the (1989) reference scene, to sub-pixel accuracy, based on the same procedure as before.

### 3.2.2 Data Merging

The merging of multisensor image data is becoming a widely used procedure because of the proliferation of satellite sensors, and the complementary nature of various data sets. Among many techniques for combining digital data, color display transformations, such as Intensity-Hue-Saturation (IHS) can be used to produce more effective and controlled visual presentations of the data for both qualitative and quantitative image analysis (Sunar, F., Musao□lu, N., 1998). In this study, three bands of the LANDSAT-TM imagery (7, 4 and 1) were chosen and transformed into IHS space. The higher spatial resolution image, SPOT-P, after being linear stretched, replaced the intensity component image before the images were retransformed back into the original RGB color space. The merged image is given in Figure 2. As can be seen from Figure 2, the resulting false color composite SPOT-P (22.7.98) + LANDSAT-TM (16.4.98) image has spatial resolution properties similar to those of the reference image, yet provide excellent spectral discrimination between natural and cultural features in the urban environment.

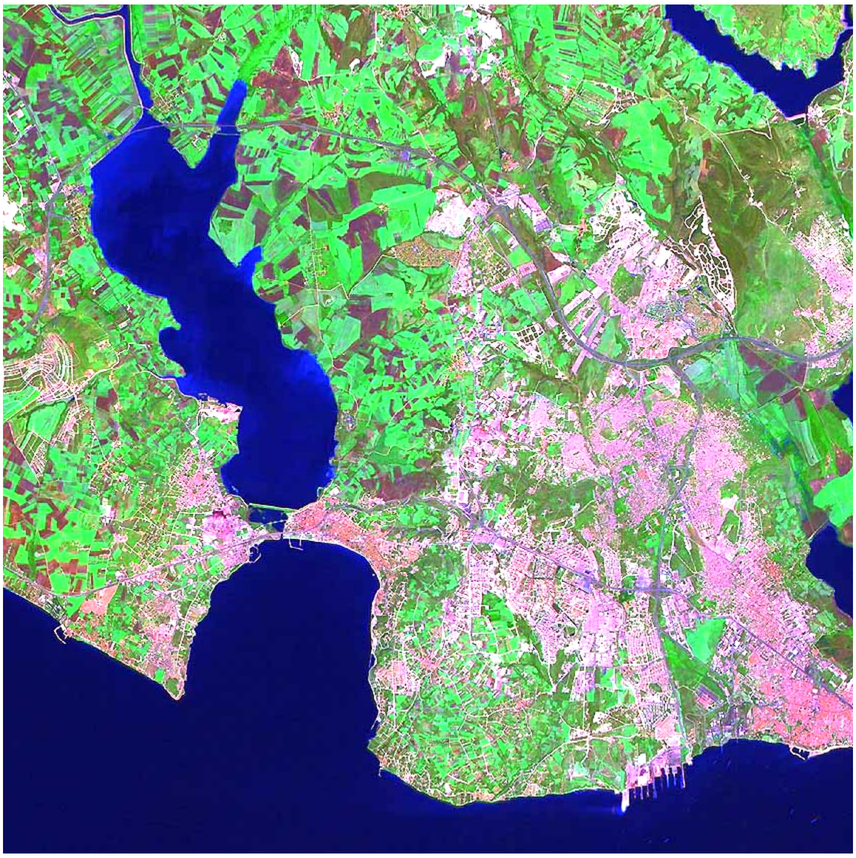

Figure 2. Merged LANDSAT-TM and SPOT-P image.

### 3.2.3 Change Detection

Change detection is the sensing of environmental changes between two or more scenes covering the same geographic area acquired at different times or over a period of time. This method has many potential uses: for monitoring urbanization,; agricultural development; forest land management; and coastal zone management. The most widely used methods are:

1. Image differencing where an image is created by subtracting the mean value of parcels of pixels in two different images of the same area.
2. Image rationing where an image is created by dividing the mean value of parcels in two different images of the same area.
3. Change vector analysis where spectral or spatial differences are used to determine a change or disturbance where the two images are plotted against each other on a graph and the two spectral variables show the magnitude and direction of change over time.
4. Classification comparisons (Sunar, F., 1998; Carsten, J., 2000).

In this study, the image differencing and ratioing methods were used. Table 2 shows the change detection results from LANDSAT data obtained at the two different dates (12.6.1984 and 16.4.1998).

Since 1984 one can see a great, and rapid, expansion of urbanization in the Büyükçekmece area. The expansions is predominantly in the eastern, south eastern and western borders of the Büyükçekmece Lake (Figure 3). Yellow areas show the mass housing, industrial areas, private settlements, exhibition centers, airport and harbours. Table 2 confirms the urban expansion, in associataion with the population increase, in the area over the same period. This number reaches 1.5 million people in the summer. A detailed table showing the areal information for the changes, their planning dates, number of houses, and number of people as the result of the change detection is given in Table 3.

| 1935 | 1940 | 1945 | 1950 | 1955 | 1960 | 1965 | 1970 | 1975 | 1980 | 1985 | 1990 | 1997 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7.127 | 12.815 | 16.244 | 8.337 | 12.021 | 13.061 | 11.952 | 13.936 | 20.063 | 33.792 | 56.999 | 120.516 | 287.569 |

Table 2. Official population records in study area.

## 4 CONCLUSION

As the population increases and economies continue to move away from systems based on agriculture, cities will grow and spread. With multitemporal analyses, satellite remote sensing gives a unique perspective of how cities evolve. The results shown here illustrate that multitemporal and multispectral satellite data and digital image processing techniques, when integrated with ground observation information, can be very practical and attractive tools for detection of urban changes or urban growth mapping. In this study, change detection analyses results clearly show that the urban expansion at the Büyükçekmece district of İstanbul is mainly located at the eastern and southeastern parts of Büyükçekmece Lake. Investigation into the casue of this suggests that expansion is because that in this area *no unplanned housing is allowed* – unplanned housing is one of the main problems related to settlement and urbanization in Istanbul. In this newly developed area, land use planning for the period 1984-2000, covering a 15 year period, is complete and the area is very attractive to many people in İstanbul. Industry, also, gravitates here due to the easy and convenient motorway, sea, airway and railway access. This type of important information can be used for upgrading government and municipality services and planning for increased transportation routes.

In the near future, the settlement development will also increase at the western and northern parts of the lake mainly concentrating on private housing development. The land use planning will be done so that green areas per person will be 51% - which is much better than the international norm. Furthermore, coastal conservation zones 300 m (absolute conservation) and 700 m. (near conservation) from the lake coastline will be considered.

| Name | Definition | Type | Area | Planned by | Start | Finish | Nr of houses | Nr of houses (practices)/people | Details |
|---|---|---|---|---|---|---|---|---|---|
| | | | (ha) | Municipalities | | | (practices)/people | (planned) | |
| **Tepekent (1)** | PS | villas | 600 | Tepecik | 1997 | cont. | 230 / 1150 | 2000 / 10000 | |
| **Bat□kent (2)** | MH | villas+ms4 | 350 | BÇ + M.Sinan | 1988 | 1998 | 7200 / 36000 | 7200 / 36000 | Sinanoba, Mimaroba |
| **Alkent 2000 (3)** | PS | villas+ms | 1000 | BÇ | 1989 | cont. | 600 / 3000 | 2000 / 10000 | |
| **Beylikdüzü (4)** | MH | ms4 | 700 | BÇ | 1992 | cont. | 30000 / 150000 | 60000 / 300000 | Migros, Tatilya, TÜYAP, TV Tower |
| **Esenyurt (5)** | MH | villas+ms4 | 345 | Esenyurt | 1991 | cont. | 6600 / 33000 | 13200 / 66000 | Habitat II award |
| **Bahçe□ehir (6)** | PS | villas+ms4 | 470 | BÇ + Emlakbank | 1989 | cont. | 6000 / 30000 | 15000 / 75000 | |
| **Gürp□nar (7)** | MH | ms4 | 110 | Gürp□nar | 1993 | cont. | 6000 / 30000 | 12000 / 60000 | |
| **Yakuplu (8)** | MH+PS | villas+ms | 445 | BÇ + Yakuplu | 1994 | cont. | 4800 / 24000 | 1600 / 80000 | |
| **BÇ Munic. Industrial Area (9)** | I | oö+li | 900 | BÇ | 1985 | cont. | 330 / 33000 | 1700 / 170000 | |
| **Kavakl□ Industrial Area (10)** | I | kö+li | 40 | BÇ | 1987 | 1999 | 70 / 3500 | 70 / 3500 | |
| **Yakuplu Industrial Area (11)** | I | ss+ms+ls+ li+hi | 600 | BÇ | 1987 | cont. | 170 / 8500 | 220 / 11000 | |
| **Yakuplu Kumcular Dock (12)** | D | Dock | * | BÇ | 1989 | 1999 | * / 3500 | * / 3500 | 1.250.000 grosston for loading and unloading/year |
| **TUYAP/TV Tower (13)** | EC | Exhibition Center | 15 | BÇ | 1996/ 1997 | 1999/ cont. | * / * | * / * | In Turkey 1., in Europe 4., in the world 12. (H=236 m) |
| **Hezarfen Airport (14)** | A | Private Airport | 45 | Private | 1991 | 1992 | * / * | * / * | training purpose |
| **BÇ Passenger Terminal (15)** | T | Public Transport | * | BÇ | 1996 | 1998 | * / * | * / * | 300 yachts capacity marina, sea buses, city connection |
| **BÇ Treatment/Discharge Plant (16)** | P | * | 10 | BÇ + □SK□ | 1996 | 1998 | * / * | * / * | |

MH:Mass housing, PS:Private Settlement, I:Industrial Area, D:Dock, T:Terminal, EC:Exhibition Center, A: Airport, P:Treatment/Discharge Plant

BÇ: Büyükçekmece, □SK□: State Water Directory of □stanbul

ms: Multistorey (2-4 storey), ms4:Multistorey ( >4 storey)

ss/ms/ls: small scale/medium scale/large scale industryi

li:light industry, hi: heavy industry

Table 3. Change detection results in tabular form.

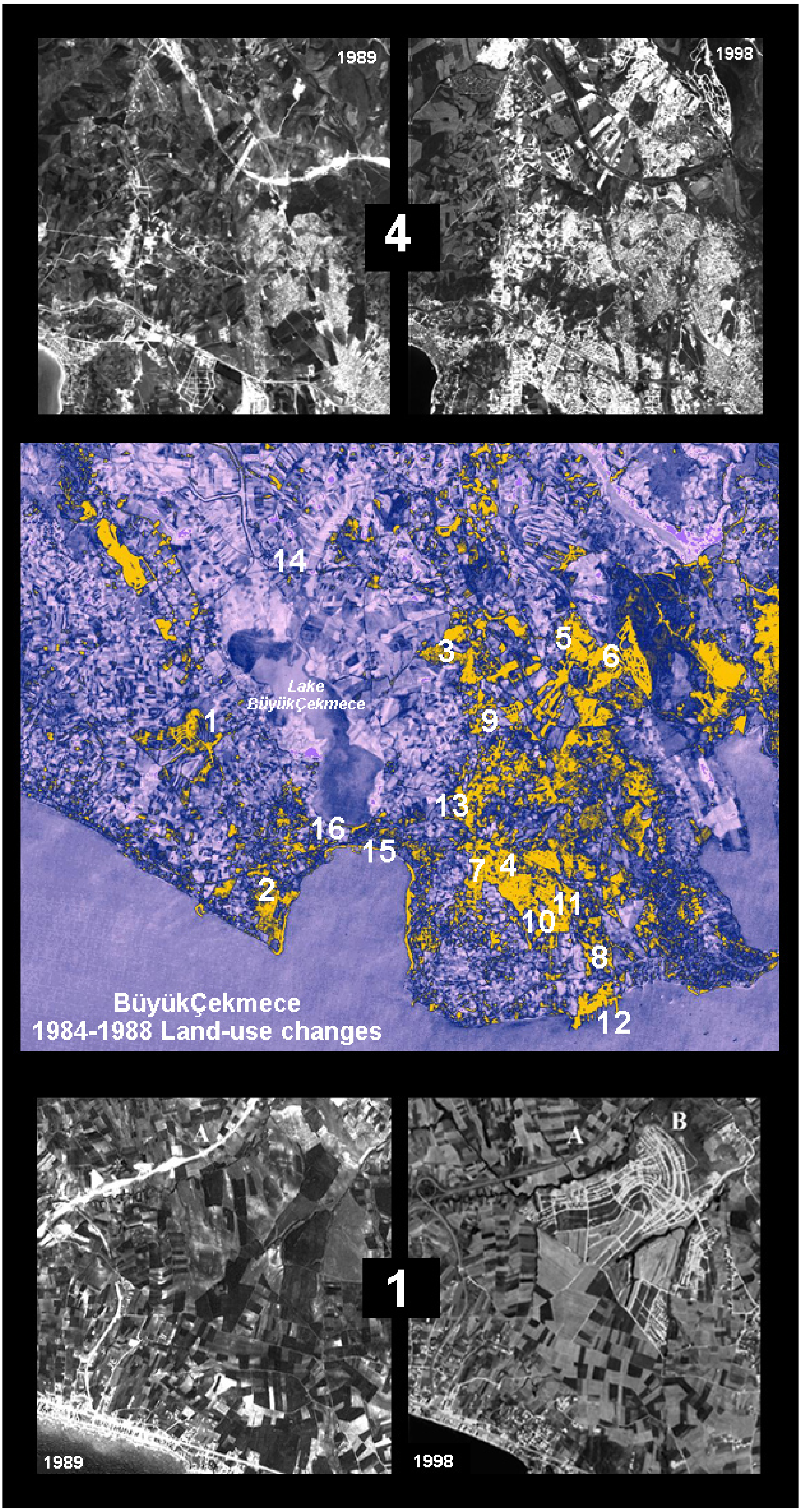


Figure 3. Change detection results.

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