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ORIGINAL ARTICLE

Using landsat data to determine land use/land cover changes in Samsun, Turkey

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Abstract The rapid industrialization and urbanization of an area require quick preparation of actual land use/land cover (LU/LC) maps in order to detect and avoid overuse and damage of the landscape beyond sustainable development limits. Remote sensing technology fits well for long-term monitoring and assessment of such effects. The aim of this study was to analyze LU/LC changes between 1980 and 1999 in Samsun, Turkey, using satellite images. Three Landsat images from 1980, 1987 and 1999 were used to determine changes. A post classification technique was used based on a hybrid classification approach (unsupervised and supervised). Images were classified into six LU/LC types; urban, agriculture, dense forest, open forest-hazelnut, barren land and water area. It is found that significant changes in land cover occurred over the study period. The results showed an increase in urban, open forest/hazelnut, barren land and water area and a decrease in agriculture and dense forest in between 1980 and 1999. In this period, urban land increased from 0.77% to 2.47% of the total area, primarily due to conversions from agricultural land and forest to a lesser degree. While the area of dense forest decreased from 41.09% to 29.64% of the total area, the area of open forest and hazelnut increased from 6.73% to 11.88%.

Keywords Remote sensing · Land use/land cover · Image classification · Change · Landsat

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1 Introduction

For centuries, humans have been altering the earth's surface to produce food through agricultural activities. Nearly a third of the earth's land surface is composed of croplands and pastures and over half of the cultivated areas have been cleared in the last century (Houghton, 1994; Squires, 2002). In the last few decades, conversion of grassland, woodland and forest into cropland and pasture has risen dramatically (Houghton, 1994; Williams, 1994; Hathout, 2002). This acceleration has spurred renewed concerns about the role of land-use change in driving losses in biological diversity, soils and their fertility, water quality and air quality. These concerns have spawned a flurry of research on the causes and consequences of land use/land cover (LU/LC) change (Penner, 1994; Lunetta *et al.*, 2002).

Recently, remote sensing with multi-temporal high-resolution satellite data has become a strong tool for monitoring aspects such as vegetation cover, soil degradation, urban expansion and more generally for most types of LU/LC changes (Yıldırım *et al*., 1995; Mundia and Aniya, 2005; Yuan *et al*., 2005). In contrast to ground-based terrestrial data acquisition, valuable knowledge can be gained in a relatively short time and cost-effective way.

The importance of mapping land-use classes and monitoring their changes with time has been widely recognized in the scientific community. Remote Sensing (RS) and Geographical Information Systems (GIS) are important tools for studying land-use patterns and their dynamics. Land-use changes are invariably associated with the mining of natural resources. Studying changes in land-use pattern using remotely-sensed data is based on the comparison of time-sequential data. Change detection using satellite data can allow for timely and consistent estimates of changes in land-use trends over large areas and has the additional advantage of ease of data capture into a GIS (Prakash and Gupta, 1998).

Numerous methods have been developed for change detection: e.g. change detection using write function memory insertion (Jensen *et al.,* 1993; Lu *et al.,* 2005); multi-date composite image change detection (Eastman and Fulk, 1993); image algebra change detection (Green *et al.,* 1994) using univariate image differencing (Weismiller *et al.,* 1977), image regression (Singh, 1986), image rationing (Howarth and Wickware, 1981), vegetation index differencing (Nelson, 1983); manual on-screen digitization of change (Light, 1993); post-classification comparison change detection (Rutchey and Velcheck, 1994; Mas, 1999); knowledge-based vision systems for detecting change (Gong *et al.,* 1996).

Turkey is one of the most important countries for biodiversity and forest sources in the world. However, increasing population and urbanization have caused irregular land use in the last two or three decades. Changes in land use are generally in favor of urban and agricultural lands. Especially, increasing urbanization and agricultural areas have caused decreases in forest area. There are the most important forest areas in Blacksea region of Turkey including Samsun city where the study was conducted. Rich forest areas lie on all Blacksea region from the coast to 50–100 km inside. Even though changes are known in land use, effects on the environment and changing intensity have not been found exactly.

Up to now, uncontrolled and unregulated construction and urbanization/industrialization activities have presented an unsolvable problem in Samsun and other overcrowded regions of Turkey. The main aim of this study was to determine LU/LC changes and intense development pressure on environment using of multi-temporal satellite data for the period of 1980–1999. A comparison will be drawn among land-use patterns in different years (1980, 1987 and 1999) over the selected study area and will determine the affect of changes on land use types.

2 Study area

The study area covers part of Samsun province located in the middle of the Black Sea Region, northern Turkey. Samsun has an important role in the commercial structure of region. The population of study area was about 885 000 in 2000 (DİE 2000a). The study area extends between longitudes 35.56° and 37.08° E and latitudes 40.95° and 41.78° N (Fig. 1). The total area of Samsun is about 957 888 ha, including the water bodies of the lakes and dams. The study area lies on the northern side of Samsun, approximately 523 865 ha. The study was conducted in the sub-area including Bafra and Çarşamba plains where the population has increased rapidly. This area covers the Samsun city, Bafra, Ondokuzmayıs, Tekkeköy, Terme, Havza, Kavak, Salıpazarı, Asarcık, Ayvacık and Çarşamba districts. Çarşamba Plain placed at the east part of the study area where the Yeşilırmak river meets the sea is about 112 790 ha. Çarşamba, Terme and Tekkeköy districts are placed in this plain. Bafra plain, about 75 800 ha, is placed in the west of study area where the Kızılırmak river joins to the coast of the Black sea. There are five dams used to produce electricity to supply drinking and irrigation water. Except for the Çarşamba and Bafra plains (approximately 190 000 ha), most of the region have precipitous, sloping and complicated topography. Elevation of the area varies from sea level to 1900 m. Flat areas are mainly used for agricultural activities while the upper land with high slope is placed in forest and pasture areas. However, hazelnut and willow trees are cultivated in Çarşamba plain (Güler, 2001).

Samsun has two growing seasons in a year. The winter season starts in October or December and ends between April and June. Main crops are wheat, barley, potato, oats and cabbage and romaine lettuce. The summer of crops rice, maize, beans, tobacco, sugar beet,

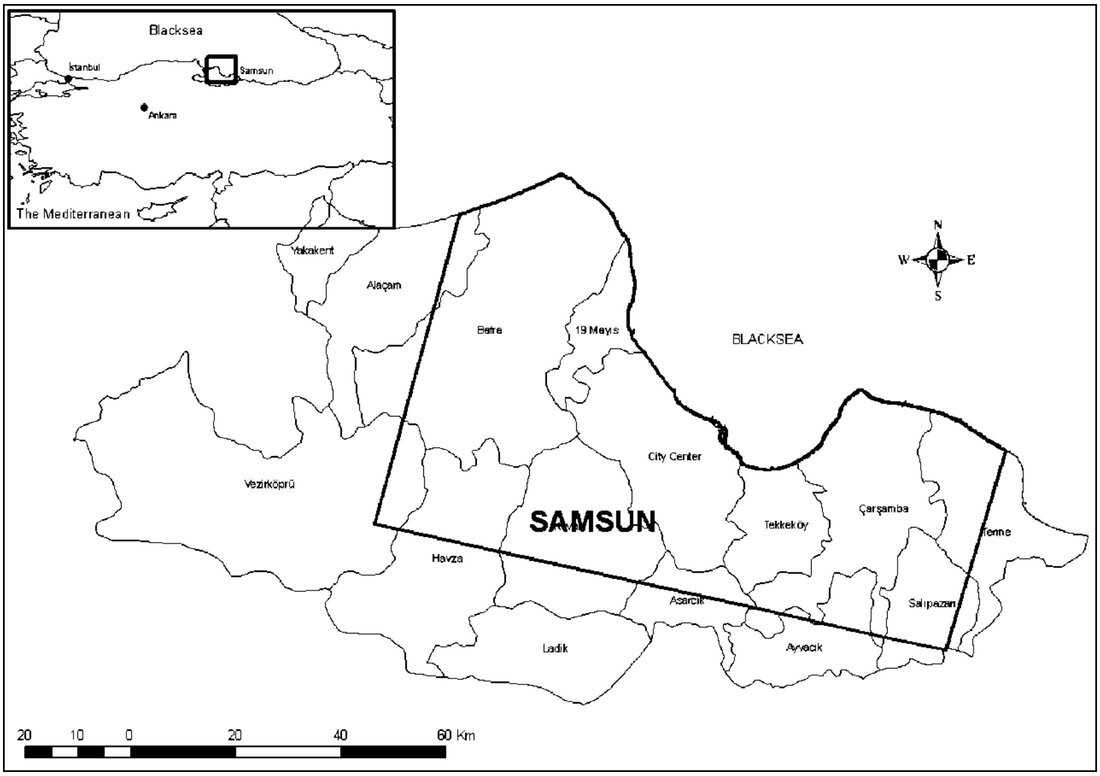

Fig. 1 Location of the study area (Samsun city, Turkey)

sunflower, soybean, melon, watermelon, tomato and pepper are sown from March to June and harvested from August to November (Özel *et al.,* 1999).

3 The satellite images and reference data

The choice of an appropriate source of satellite data was determined by the requirement that a long time-series of images should be available for the study area, the images being acquired in June, July or August, to minimize the likelihood of snow cover and preferably in mid-June, at the peak of the growing season. The images were also required to have less than 20% cloud cover. With these criteria, three predominantly cloud-free Landsat scenes of the Samsun region between 1980 and 1999 were employed. The first is Landsat MSS data obtained in 1981, the others are Landsat TM data obtained in 1987 and Landsat ETM data acquired in 1999. A sub-area of 520 413 ha covering the study area was extracted from the images. The characteristics of the image data are presented in Table 1.

The other data used in this study for reference and analyses mainly include: (1) color infrared aerial photographs at a nominal scale of 1/15 000 obtained in 1997; (2) detailed topographic maps, at scale of 1/5000 and (3) ground reference data obtained from land survey with hand held GPS.

Table 1 Characteristics of the satellite data used for land use/cover change mapping in the study area

Date	Type of imagery	Path/Row	Nominal spatial resolution (m)	Sun elevation (°)	Sun azimuth (°)
11.09.1980	MSS	189/31	79	41.27	142.25
08.10.1987	TM	175/31	30	38.36	149.34
14.08.1999	ETM+	175/31	30	56.45	137.79

Table 2 Land use/land cover classes used in this study and their brief definitions

No.	Classes	Definition
1	Urban	Areas covered by asphalt, concrete, typically commercial and industrial buildings with open roofs as well as open transportation facilities, airports, parking lots and multilane interstate/state highways, single/multiple family houses and public rental housing estate.
2	Agriculture	Characterized by high percentages of grasses, other herbaceous vegetation and crops; including lands that are regularly mowed for hay and/or grazed by livestock, city parks and regularly tilled and planted cropland.
3	Dense forest	Areas covered by dense forest with relatively darker green colours.
4	Open forest and hazelnut	Areas relatively sparsely covered by forest vegetation and the hazelnut.
5	Barren land	Areas of sparse vegetation cover that is likely to change or be converted to other uses in the near future; including clearcuts, cultivated land without crops and barren rock or sand along river/stream beaches.
6	Water	All areas of open water, generally with greater than 95% cover of water, including streams, rivers, lakes and reservoirs.

4 Methodology

Post-classification comparison change detection, the most commonly used quantitative method of change detection, was selected to perform LU/LC change detection in this study. It requires rectification and classification of each remotely sensed image. After the classification of image separately, resulting maps are then compared on a pixel-by-pixel basis using a change detection matrix. The image processing procedures employed in this study include; 1) pre-processing, 2) design of classification scheme, 3) preparation of Normalized Difference Vegetation Index (NDVI) – False Color (FC) band composition and unsupervised classification to collect training data, 4) image classification, 5) accuracy assessment and 6) change detection. These applications were carried out using ERDAS 8.4 software.

4.1 Image pre-processing

Radiometric correction of the images had already been carried out, so it was not applied. Geometric rectification is critical for producing spatially corrected maps of LU/LC changes through time. Geometric correction was done by satellite images belonging to 1999, aerial photographs and topographic maps at the scale of 1/5000 and control points obtained by GPS.

The nearest neighbor resampling method was used to avoid altering the original pixel values of the image data. Thus, the image of 1999 was geometrically corrected using 17 control points. The root mean square error (RMSE) was 0.57 pixels. Geometric correction of the other two images was done by image to image rectification strategy with reference to 1999 image. 1987 image of the study area was geometrically corrected using 16 control points and RMSE was 0.61 pixels. Image of 1980 was geometrically corrected with a RMSE of 0.84 pixels using 16 control points.

4.2 Design of classification scheme

Classification schemes that can readily incorporate LU/LC data obtained by the interpretation of remotely sensed data have been developed (e.g. U.S. Geological Survey LU/LC Classification System, US Fish & Wildlife Service Wetland Classification System, NOAA Coast Watch Land Cover Classification System, Asian Land Cover Classification System) (Jensen, 1996). The US Geological Survey Land Use/Land Cover Classification System (USGS) was chosen and referred for the classification system for this study. Anderson *et al*. (1976) determined that Landsat MSS data are only suitable for Level I LU/LC mapping according to the USGS Survey scheme. So, USGS Level I was chosen and referred to for the classification system in this study. Classification scheme and detailed descriptions were given in Table 2.

4.3 Training data collection

The training and testing data for the supervised classification and accuracy assessment were collected by using a false colour composite, an NDVI image, an unsupervised classified image, aerial photographs (1/15 000) and fieldwork approximating to a stratified random sampling. The data samples were then split into two subsets: the training data and the test data.

False colour composites can help to visualize LU/LC without any enhancement processes. The false colour images were generated with red = 4, green = 3, blue = 2 bands for Landsat ETM and TM, and red = 4, green = 2, blue = 1 for MSS images (Jensen, 1996).

The vegetation index indicates the amount of green vegetation present, which is useful and important for LU/LC identification because much of the Earth's land covers is vegetation. NDVI is calculated by the equation: NDVI = (NIR − RED)/(NIR + RED) where NIR is the near-infrared band response and RED is the red response.

An unsupervised classification approach allows natural spectral clusters to be defined with a high degree of objectivity. The ISODATA (Iterative Self-Organizing Data Analysis) algorithm was used to identify spectral clusters from the Landsat data. It uses minimum spectral distance to assign a cluster for each candidate pixel. The approach for finding clusters used by this algorithm is relatively straightforward and has considerable intuitive appeal (Vanderee and Ehrlich, 1995). As a result of ISODATA algorithm, fifteen land use classes were generated to collect training data.

There was excellent coverage of high-quality colour infrared aerial photographs of the Samsun region in 1997. Aerial photographs were used for geometric rectification of the Landsat image in 1999. Besides, training and test data were collected from these high resolution aerial images.

Field investigation was conducted to collect training data. The fieldwork supported the image interpretation of land-cover types defined in the classification scheme. The field observations provided essential independent reference data for identifying LU/LC types within the Landsat scenes as well as for accuracy assessment.

4.4 Image classification

The most obvious method of change detection is a comparative analysis of spectral classifications for times t1 and t2 produced independently (Singh, 1989). In this context it should be noticed that the change map of two images will only be generally as accurate as the product of the accuracies of each individual classification. Accuracy of relevant class changes depends on spectral separability of classes involved. In this study, Landsat data of three dates were independently classified using the supervised classification method of maximum likelihood algorithm. Spectral signature files for all classes were subsequently created and used by maximum likelihood classifier to categorize the continuum of spectral data in the entire image. The classified images were further smoothed with a majority filter with a 3 × 3 kernel to reduce the number of misclassified pixels (Erdas, 1999). Independently classified images were then compared with each other to determine the changes of LU/LC types.

4.5 Accuracy assessment

The number of reference pixels is an important factor in determining the accuracy of the classification. It has been shown that more than 250 reference pixels are needed to estimate the mean accuracy of a class to within plus or minus five percent (Congalton, 1991). An equalized stratified random sampling approach was used to assess the accuracy of each of the three land cover classifications. The overall accuracy and a KAPPA analysis were used to perform classification accuracy assessment based on error matrix analysis. Using the simple descriptive statistics technique, overall accuracy is computed by dividing the total correct (sum of the major diagonal) by the total number of pixels in the error matrix. KAPPA analysis is a discrete multivariate technique used in accuracy assessments (Jensen, 1996). KAPPA analysis yields a Khat statistic (an estimate of KAPPA) that is a measure of agreement or accuracy (Congalton 1991). The Khat statistic is computed as:

$$K_{hat} = \frac{N \sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r} (x_{i+} x_{+i})}{N^2 - \sum_{i=1}^{r} (x_{i+} x_{+i})} \quad (1)$$

where r is the number of rows in the matrix, x_{ii} is the number of observations in row i and column i, x_{i+} and x_{+i} are the marginal totals for row i and column i respectively and N is the total number of pixels.

Table 3 Results of accuracy assessment of the 1980 land use/cover map produced from Landsat MSS data

	Reference data								
Classified data	Urban	Agriculture	Dense forest	Open forest-hazelnut	Barren land	Water	Row total	User accuracy (%)	Kappa*
Urban	**74**	2	0	0	14	3	104	79.57	0.7645
Agriculture	1	**91**	8	19	4	2	125	72.80	0.6741
Dense forest	0	3	**111**	12	0	6	132	84.09	0.8044
Open forest-hazelnut	3	11	3	**96**	0	0	113	84.96	0.8137
Barren land	10	2	0	1	**102**	1	116	87.93	0.8527
Water	0	1	2	0	0	**83**	86	96.51	0.9593
Column total	88	110	124	128	120	95	**665**		
Producer's accuracy (%)	84.09	82.73	89.52	75.00	85.00	87.37			

Note: Number of pixels correctly classified: 665; overall classification accuracy: 83.76%.
*Overall kappa index of agreement: 0.8045.

Accuracy assessment was performed for 1980, 1987 and 1999 LU/LC maps. A stratified random sampling design was adopted in the accuracy assessment. For the 1980 LU/LC map, a total of 665 pixels were randomly selected. The result shows an overall accuracy of 83.76% and a kappa index of agreement of 0.81 (Table 3). In terms of producer's accuracy, all classes were over 80% except open forest-hazelnut, which was 75.00%. In terms of user's accuracy all classes were over 80% except urban and agriculture.

For the 1987 LU/LC map, a total of 794 pixels were selected. The result shows an overall accuracy

Table 4 Results of accuracy assessment of the 1987 land use/cover map produced from Landsat TM data

	Reference data								
Classified data	Urban	Agriculture	Dense forest	Open forest-hazelnut	Barren land	Water	Row total	User accuracy (%)	Kappa*
Urban	**94**	0	0	0	9	1	104	90.38	0.8895
Agriculture	0	**144**	3	21	5	2	175	82.29	0.7802
Dense forest	0	1	**154**	10	0	11	176	87.50	0.8439
Open forest-hazelnut	0	9	1	**77**	0	0	87	88.51	0.8670
Barren land	9	0	0	0	**143**	0	152	89.94	0.8779
Water	0	0	0	0	0	**100**	100	100	1
Column total	103	154	158	108	157	114	**794**		
Producer's accuracy (%)	91.26	93.51	97.47	71.30	91.08	87.72			

Note: Number of pixels correctly classified: 794; overall classification accuracy: 89.67%.
*Overall kappa index of agreement: 0.875.

Table 5 Results of accuracy assessment of the 1999 land use/cover map produced from Landsat ETM+ data

Classified data	Reference data: Urban	Agriculture	Dense forest	Open forest-hazelnut	Barren land	Water	Row total	User accuracy (%)	Kappa*
Urban	**141**	2	0	0	48	2	193	73,06	0,6799
Agriculture	8	**138**	0	3	2	0	151	91,39	0,8981
Dense forest	0	3	**157**	24	0	1	185	84,86	0,8173
Open forest-hazelnut	0	2	11	**131**	1	0	145	90,34	0,8849
Barren land	6	7	0	0	**129**	1	143	90,21	0,88
Water	0	0	0	0	0	**162**	162	100,00	1
Column total	155	152	168	158	180	166	**979**		
Producer's accuracy (%)	90,97	90,79	93,45	82,91	71,67	97,59			

Note: Number of pixels correctly classified: 858; overall classification accuracy: 87.64%.
*Overall kappa index of agreement: 0.852.

of 89.67% and a kappa index of agreement of 0.86 (Table 4). In terms of producer's accuracy, all classes were over 85% except open forest-hazelnut, which was 71.30% while in terms of user's accuracy; all classes were over 80%. For the conditional kappa statistics for each LU/LC class, they all exceeded 0.80 with the exception of agriculture, which could be confused with open forest-hazelnut land use.

For the 1999 LU/LC map, a total of 858 pixels were selected. The result indicated an overall classification accuracy of about 87.64% and a kappa index of agreement of 0.85 (Table 5). In examining the producer's accuracies, all land use classes were quite accurately classified except barren land. In terms of the user's accuracy, each class exhibited over 80% with the exception of urban. The urban and barren land classes showed significant confusion because the two land cover classes have a similar reflection value. In particular, the agriculture land, open forest-hazelnut, barren land and water area showed accuracies of over 90%. The conditional kappa statistics for each LU/LC, all exceeded 0.80 with the exception of urban use.

5 Results

Landsat images used in this study were taken from different months of the year. Although these images are belonging to consecutive months, when climate and land cover characteristic and agricultural production system of the region are taken into account, it is expected to get some considerable changes in the classification results depending on the image dates. This issue is particularly considered in the interpretation of the study results.

The entire project area of A = 520 413 ha has the size LU/LC classes for 1980, 1987 and 1999 as summarized in Table 6. The corresponding classifications can also be presented as maps and a chart, which are illustrated in Figs. 2 and 3. Based on Fig. 2, the spatial expansion of urban LU/LC is clearly visible. In 1980, the urban areas were small and mainly located in the seaside of Samsun. Urban expansion can be also seen in all rural villages, residential, industry areas had taken place by 1987 and 1999, with the emergence of three highly concentrated areas in Bafra and Çarşamba plains. In quantitative terms, urban areas have increased from 3992 ha in 1980 to 12 873 ha in 1999 for the study area, thus representing an increase of 322% in land area (Table 6). However, the population of the region increased less than urban expansion. Census data shows that population of the study area increased from 301 045 in 1980 to 536 225 in 2000, 78% (DİE, 1980a, 2000a). Barren land area has also shown an important increase from 133 070 ha (or 25.57%) in 1980 to 171 158 ha (or

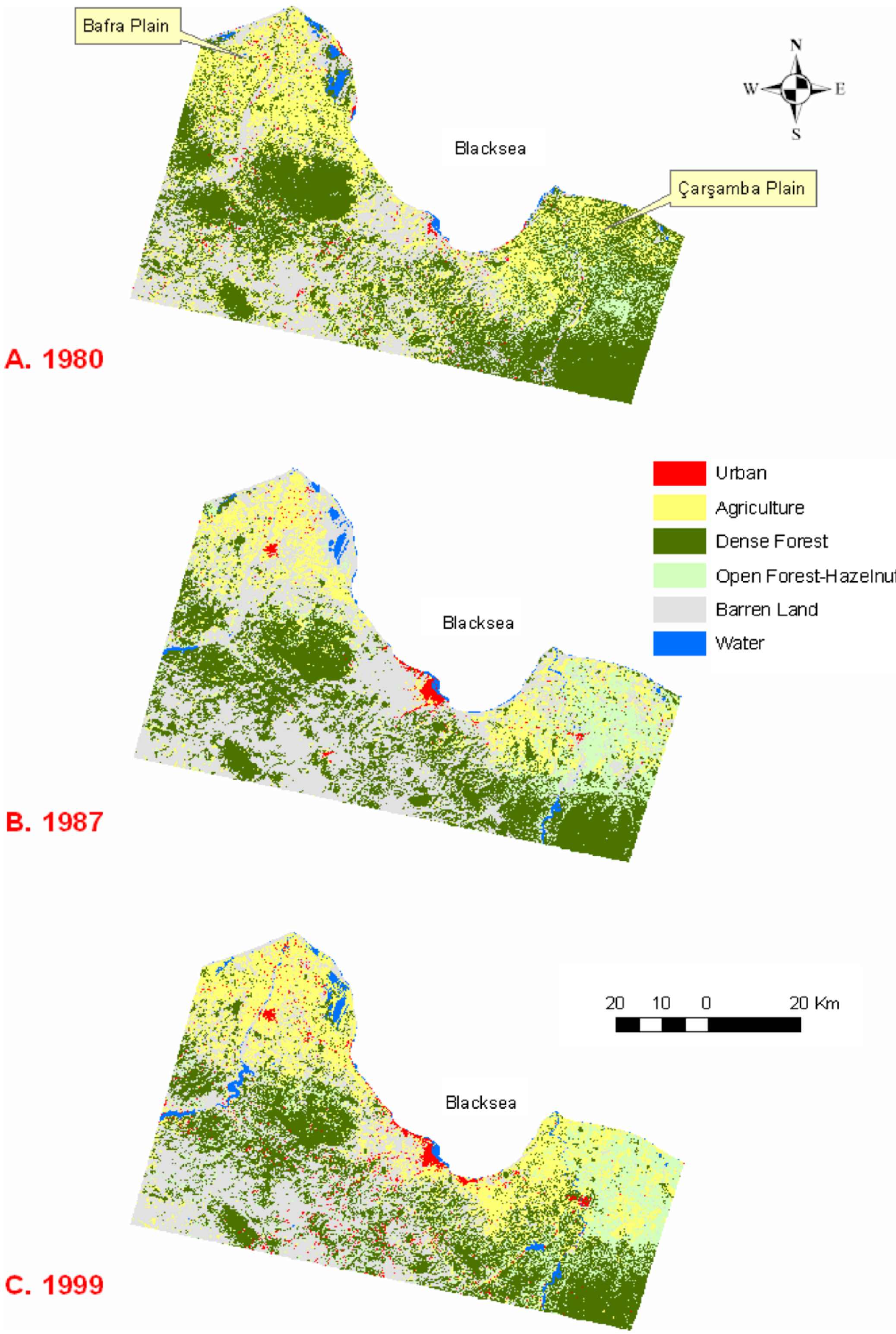

Fig. 2 LU/LC classification maps for each time step

Table 6 Results of land use/land cover classification for 1980, 1987 and 1999 images showing area of each class, class percentage and area changed

Class name	1980 Land use/cover (ha)	1980 Land use/cover (%)	1987 Land use/cover (ha)	1987 Land use/cover (%)	1980–1987 Area changed (ha)	1999 Land use/cover (ha)	1999 Land use/cover (%)	1987–1999 Area changed (ha)	1980–1999 Area changed (ha)
Urban	3992	0.77	4983	0.96	+990	12 873	2.47	+7891	+8881
Agriculture	130 461	25.07	102 646	19.72	−27 816	129 141	24.82	+26 494	−1322
Dense forest	213 862	41.09	180 797	34.74	−33 066	154 274	29.64	−26 523	−59 589
Open forest and hazelnut	35 020	6.73	54 856	10.54	+19 836	61 804	11.88	+6947	+26 783
Barren land	133 070	25.57	171 158	32.89	+38 088	152 907	29.38	−18 252	+19 836
Water	4008	0.77	5973	1.15	+1965	9415	1.81	+3442	+5407
Total	520 413	100	520 413	100		520 413	100		

32.89%) in 1987. When the period of 1980–1999 is taken into consideration, the increase of barren land has been 19 836 ha in total.

According to Table 6, 27 816 ha decrease was observed in agricultural areas, while there was an increase of 38 088 ha in open areas between 1980 and 1987. In the similar way, 26 494 ha increase was detected in agricultural areas, whereas 18 252 ha reduction was occurred in open areas between 1987 and 1999. Agricultural production is higher especially in July and August in the region. Following the summer crops are harvested, it takes 2 or 3 months to prepare the field for next plantation. The images used in this study are dated as September 1980, October 1987 and August 1999 (Table 1), respectively. Since the areas had already harvested in October, there were problems encountered in classification of true agricultural areas in 1987 image. As a result, it could be said that these areas were actually agricultural, but it has been classified as barren land because of harvest time in 1987 image.

Between 1980 and 1999, conversion from dense forest into open forest and hazelnut with scattered agriculture was one of the major changes in the study area. The area of dense forest declined 59 589 ha (or 28%), while the area of open forest and hazelnut increased by 26 783 ha (or 76%) (Table 6). This clearly indicates that human impacts are the reasons for the change. The difference between 1980 and 1999 was a result of deforestation. Well planned, long-term land conservation and rehabilitation are definitely needed.

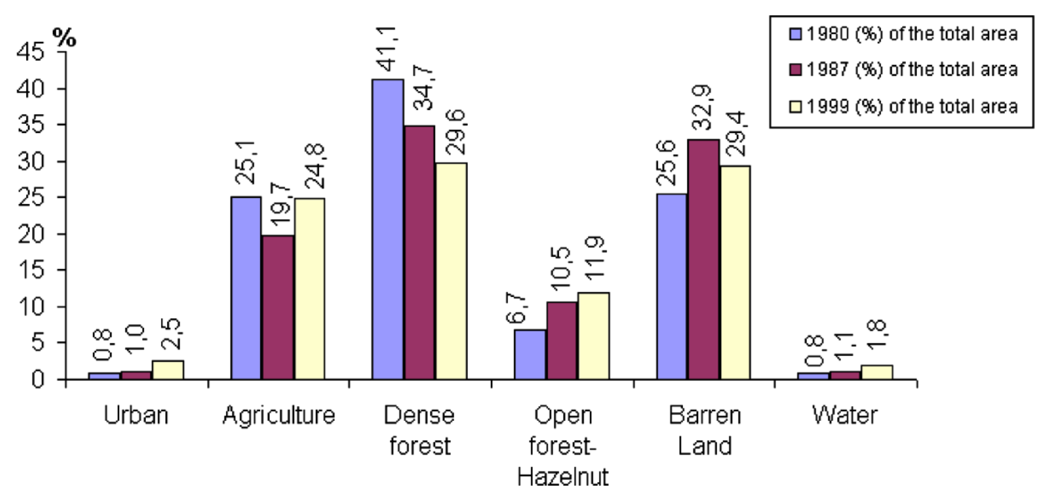

Fig. 3 LU/LC types within Samsun throughout the study period (1980–1999)

The open forest and hazelnut area had a fairly consistent increasing trend between 1980 and 1999. This class increased between 1980 and 1999 by 26 783 ha (76%) (Table 6). The statistical estimates showed that hazelnut production in the study area has increased from 10111600 in 1980 to 29670729 hazelnut trees in 2000 (DİE, 1980b, 2000b). As it can be seen from Fig. 2, hazelnut trees are mainly located in Çarşamba plain. Kılıç (1996) reported that the percentage of hazelnut trees in farming area was about 53.09% in Çarşamba plain. Ağdağ *et al*. (2000) also reported that willows and similar trees used to determine land boundary have covered about 17.8% of Çarşamba plain. It can be said that the current agricultural practices in Çarşamba plain are not at their optimum uses.

Water had an area of 4008 ha (0.77%) in 1980, 5973 ha in 1987 (1.15%) and 9415 ha in 1999 (1.18%). This represents a net increase of 5407 ha (135%). In the study area, Altınkaya and Derbent dams started to hold water in 1988 and 1991, respectively, which resulted in an increase in water areas between 1980 and 1999.

Some subset areas were chosen for pointing out the changes of LU/LC types in the study area. These subset areas including Bafra district, Tekkeköy district and Çarşamba district can be seen from Fig. 4. While Figs. 4a, 4c and 4e belong to 1980 Landsat MSS images, Figs. 4b, 4d and 4f belong to 1999 Landsat ETM+ images.

Figures 4a and 4b shows changes in the Bafra district. While there is no water area in the image of 1980 (Fig. 4a), Altınkaya and Derbent dams and dam reservoirs constructed in order to irrigate Bafra plain and to produce electrical energy can be noticed easily in the image of 1999 (Fig. 4b). In the same image, changes of settlement area in Bafra district can be also perceived. Comparing 1980 and 1999, we can clearly observe that settlement area has been expanded and the districts having sparse settlement area have changed to dense settlements.

Samsun industrial area is expanding through Tekkeköy district. Industrial foundations have moved to the district on account of investments in the region. This movement is clearly seen in Figs. 4c and 4d. The settlement areas close to industrial area have also developed parallel to industrialization.

Finally, changes in land use can be observed as a result of dam building in subset area selected from Çarşamba district. Water areas are increased by Çakmak and Hasanuğurlu dams built in the southeastern region (Figs. 4e and 4f).

When the subsets indicated in Fig. 4 are evaluated, it can be said that urban, industrialization areas and highways are on the flat and productive agricultural areas, sparse settlement areas have changed to dense settlement areas. Agricultural and forest areas in the region have been flooded as a consequence of dam structures.

6 Conclusions

Land use patterns change over time in response to economic, social and environmental factors. Understanding the nature of change in the use of land resources is essential knowledge to facilitate proper planning, management and regulation of the use of land resources. The change detection procedure most appropriate to given situation also has significant impact. However, this depends on the type of the application (type of environment, targets of interest) and the amount of detail required and also requires an extensive knowledge of both the study area and the logical and spectral interrelationships between land use classes.

There is an increasing need for the use of science-based decisions for policy making in Turkey. Information on LU/LC change is thus critically important. Natural resource managers in particular have recognized the value of this type of information for resource management and sustainable development.

This study has demonstrated the usefulness of satellite remote sensing and digital image processing in producing accurate LU/LC maps and change statistics of the Samsun area for the past 20 years. In summary, the following conclusions can be drawn from the above analysis:

1. The study shows that by 1999, 23% of the 1980 land cover changed over the study period. 27% (59 589 ha) of forest and 1% (1322 ha) of agriculture area were lost and turned into land characterized by urban, barren land, open forest-hazelnut and water.
2. The open forest and hazelnut area covered 36 420.8 ha (6.99%) in 1980, 47 504.3 ha in 1987 (9.12%) and 50 151.4 ha in 1999 (9.63%). This represents a net increase of 13 730.6 ha (37.7%).
3. Conversion of forest could be the result of increasing population in the area and exploitation of wood resources. Without appropriate land-use management

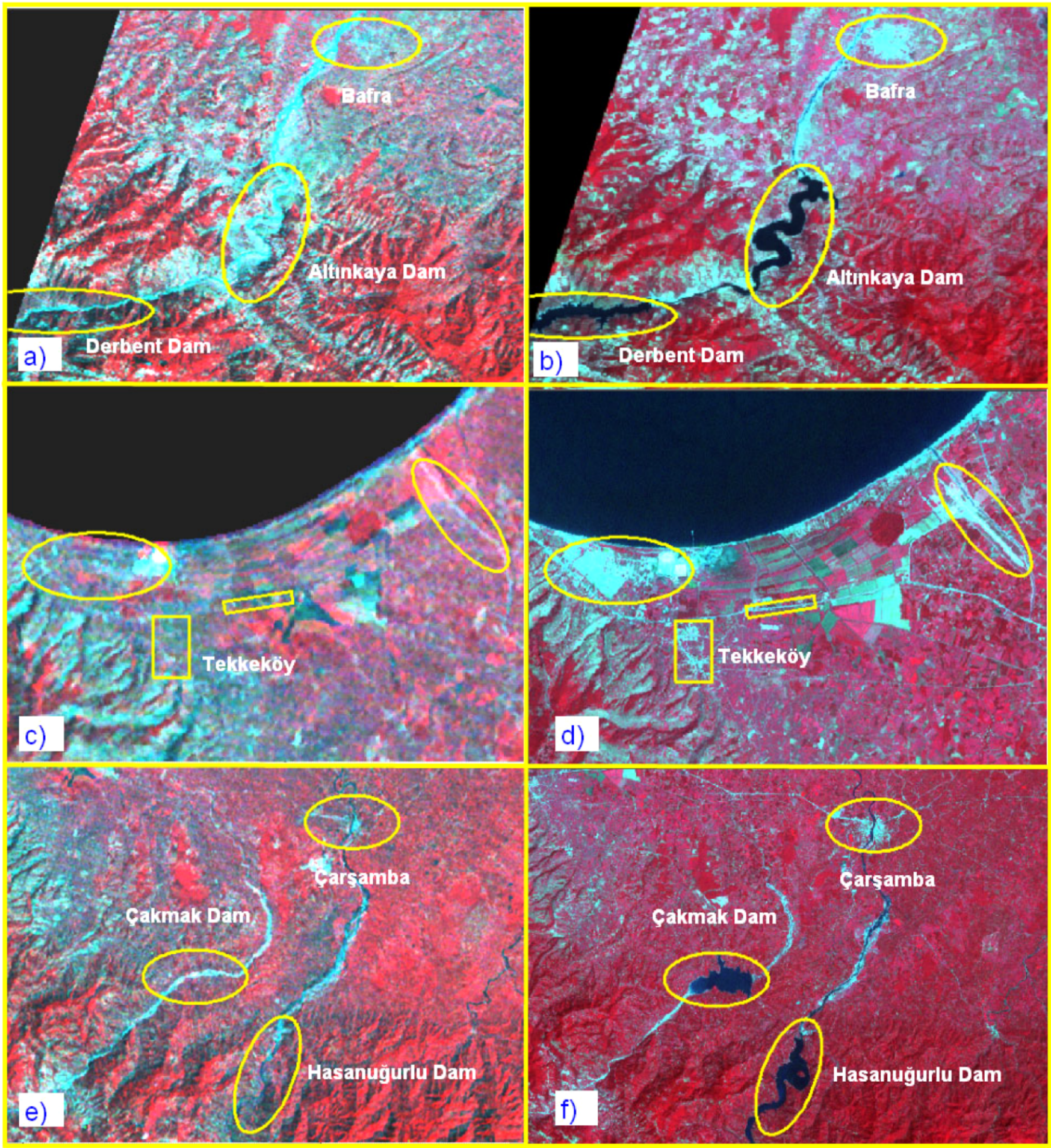

Fig. 4 Land-use change of the study area between 1980 (a, c, e) (RGB:421) and 1999 (b, d, f) (RGB:432) time period and comparisons of the changes in the subset area around the Bafra (a–b), Tekkeköy (c–d), and Çarşamba districts (e–f)

and sustainable agricultural practices, the loss of forest will continue with associated consequences such as desertification, soil erosion and sedimentation. The implication of this study is that terrestrial land use, especially agriculture and forestry, is critical to sustainable development and planning.

4. The present agricultural practices in this study area are mostly not at their optimum. Large areas in these optimal regions are mostly covered by hazelnut and boundary trees (e.g. poplar). Replacement and change of this practice in favor of agriculturally and economically more valuable crops need to be planned and planted by Ministery of Agriculture. Initiatives of local agricultural offices on this line should be supported and implemented by government authorities.

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