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Quantifying the Change Detection of the Uluabat Wetland, Turkey, by Use of Landsat Images

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Abstract

The objectives of this study were to determine land use and land cover (1), measure changes in the shoreline since 1975 (2), define hazard areas attributed to land cover change (3), and describe local landscape pattern characteristics (4) in the Uluabat Wetlands. Analyses were carried out using remotely sensed data from the Landsat MSS 1975, Landsat TM 1987 and Landsat ETM+ 2000 multi-spectral sensor systems. In brief, it has been determined that surface water had decreased by almost seventeen percent from 1975 to 2000. Analyses show an increase in fragmentation of the landscape. The overall change, that the lake experiences, is toward drying up.

Keywords: *Change detection, fragmentation, landscape change, pattern metrics, remote sensing.*

Landsat Görüntüleri Kullanarak Uluabat Sulak Alanında Değişimin Yönünü Ölçme

Özet

Bu çalışmada, Uluabat sulak alanında arazi kullanımı ve arazi değişimini belirlemek; 1975 ten beri meydana gelen kıyı değişimini ortaya koymak; arazi örtüsü değişimine bağlı olarak ortaya çıkan risk alanlarını tespit etmek ve yerel peyzaj patern karakteristiklerini tanımlamak amaçlanmıştır. Analizler Landsat MSS 1975, Landsat TM 1987 ve Landsat ETM+ 2000 çok bantlı sensor sitemleri kullanılarak yapılmıştır. Özet olarak, 1975 ten 2000 yılına kadar su yüzeylerinin yaklaşık yüzde onyedi oranında azaldığı belirlenmiştir. Analizler peyzaj parçalılığında artışın olduğunu göstermektedir. Genel anlamıyla göldeki değişim kuruma yönündedir.

Anahtar Kelimeler: *Değişimin yönü, parçalılık, patern metrikler, peyzaj değişimi, uzaktan algılama.*

INTRODUCTION

Due to rapid increase of the population, the landscape of the Mediterranean Basin has been profoundly influenced by human impact for thousands of years. During this period, issues of environmental concern, such as resource misuse and disregard for working with nature, have become more important. The subject of landuse and land-cover changes and the direct or indirect relationship these changes might have with the observed land degradation in the Mediterranean region has attracted attention (Thornes 1996). Land degradation is generally present by Wasson (1987) as "a change to land that makes it less useful for human being." Sediment transport is a function of many parameters related to water, and sediment's characteristic is probably one of the least understood of the important areas in land degradation research.

Because of land degradation, good quality water, an essential element for life, agriculture and industry, is scarce world-wide. When it comes to lakes, they are both sensitive ecosystems vulnerable to environmental pollution and very attractive for human activities. Lakes and wetlands are not only man-made landscape, recreational areas for tourists, drinking and irrigating water reservoirs, but are also gathering places for migratory birds and habitats for millions of animals and numerous types of plants. Shallow semi-arid waters and wetlands are even more important, because they play a vital role in our lives and contain remarkable communities of plants and animals.

Wetlands are described as areas where the water table is at, near, or above the land surface for a significant part of most years (Anderson et al. 1976). Another definition states that wetlands are a mix of the characteristics of terrestrial or upland areas and the characteristics of aquatic environments (Lyon 1993). Although the exact percentage of wetlands on the surface of the Earth is not unknown, the World Conservation Monitoring Center states it as approximately six percent of the Earth's land surface area, approximately 5.7 million km^2 (Acreman and Hollis 1996).

Throughout human history, the term wetlands for many people conjured up images of a swamp full of slimy creatures, harboring diseases such as malaria. Indeed it is this view of wetlands as wastelands that has led to extensive drainage and conversion of wetlands for intensive agriculture, fish ponds, industrial or residential land or to improve public health. However, in recent years there has been increasing awareness of the fact that natural wetlands provide free of charge many valuable functions (e.g., flood alleviation, groundwater), products (e.g., fish, timber, tourist attractions), and attributes (biodiversity, archaeology).

Wetlands are valued because they provide a unique environment for wildlife, and contain several plant and animal species economically important to humankind. However, wetlands are endangered due to soil erosion, increases in farming on inclined surfaces, industrialization, and excessive water consumption by both farming and urbanization. It has been difficult to quantify these threats with fieldwork, as identifying the dangers to wetlands is an intricate and time-consuming process (Lyon 1993). By illuminating the changes that have taken place over time, remote sensing has shown to be one of the most successful methods for identifying threats. Since the last century, landscape analyses have been performed using remote sensing techniques (Lee 1992). Land use and land cover (LULC) information gathered from different sensors prove to be especially important for understanding and presenting landscape changes (Liverman et al. 1998). More recent trends in the technology tend to concentrate on providing the pixel-history using Landscape Pattern Metrics (LPMs), rather than determining land use and land cover change (Crews-Meyer 2002).

Traditionally, the Landsat MSS, Landsat TM, and SPOT satellite systems have been used to study wetlands (Lunetta and Balogh 1999, Shaikh et al. 2001, Roshier and Rumbachs 2004). As for classification of these images, unsupervised classification or clustering is the most commonly used digital classification used to map wetlands, whereas the maximum likelihood algorithm is used with a supervised method (Özesmi 2000).

Turkey has many semi-arid wetlands. Most of them are affected by land degradation. The study was carried out in Lake Uluabat, the largest and most critical semi-arid wetland not only in the Southern Marmara Region in Turkey, but also in the Middle East. The main research goal of this study was to identify the effects of the surrounding land use and land cover on Lake Uluabat over the last 25 years. To achieve this goal, the following four objectives were pursued:

1. Determine land use and land cover (LULC),
2. Measure changes in the shoreline since 1975,
3. Identify hazard areas due to land use and land cover change (LULCC), and
4. Describe landscape pattern characteristics.

STUDY AREA

The Uluabat Wetland was chosen for this study due to its endangered status (Fig. 1). In terms of wintering waterfowl, it is one of the most important wetlands not only in Turkey, but also in the Middle East and Europe. The Wetland Area is located within the Marmara Region where climate, topography, soils, vegetation, and wildlife are characteristic of a semi-humit environment (40°05'50" N - 40°13'33" N and 28°26'46" E - 28°43'30" E). The total study area is ~180 km² and the average height of the area is ~5 m above the sea level. The lake's depth is nearly 2-5 m on average. It experiences a strongly seasonal Mediterranean climate. Summers are quite hot and dry, and winters are warm and wet.

Lake Uluabat is an A-class wetland assigned international priority and importance by the Turkish

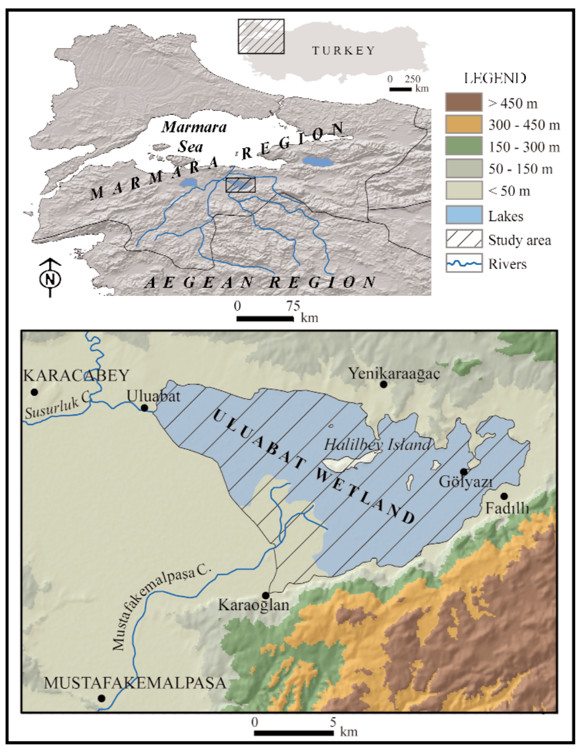

Fig. 1. The location and topographic map of the research site.

Ministry of the Environment. It is one of nine RAMSAR Convention (also known as The Convention on Wetlands of International Importance) sites in the Turkey due to its rich biodiversity and valuable freshwater sources (Anonymous 1996). The lake was added to the RAMSAR Contract on April 15, 1998, and included in the Living Lakes Network, an international partnership, in 2000.

Lake Uluabat is a large but shallow, eutrophic, freshwater lake. The most important source of water for the lake is Mustafakemalpaşa Creek which drains a large part of southern Marmara and the north Aegean region. Its outlet is in the northwest, where it drains into the Susurluk River which eventually empties into the Sea of Marmara. Today there are two large residential areas around Lake Uluabat, namely Mustafakemalpaşa and Karacabey districts. The lake is one of the more important fisheries for the region, and crayfish (*Astacus leptodactylus* Eschscholtz, 1823), carp (*Cyprinus carpio* Linnaeus, 1758) and pike (*Esox lucius* Linnaeus, 1758) are the primary harvest species.

As it is located on the seasonal migration route of birds entering Anatolia from the northwest, the Uluabat wetland is an important feeding and wintering site for the Dalmation pelican (*Pelecanus crispus* Bruch, 1832) and the pygmy cormorant (*Phalacrocorax pygmeus* Pallas 1773), both of which are endangered species. In terms of aquatic plant life, Lake Uluabat is one of Turkey's richest lakes. The shoreline is covered with the largest white water lily (*Nymphaea alba* Linnaeus, 1753) beds in Turkey.

METHODS

Landsat images were favored in this study for distinguishing between land and water and determining LULC. Because there is substantial contrast between land and water in the infrared section of the electromagnetic spectrum, Landsat images are very useful in determining the land, water, and interface regions.

For this study, Landsat Multispectral Scanner (MSS) image taken on June 18th 1975, Landsat Thematic Mapper (TM) taken on June 5th 1987 and Landsat Enhanced Thematic Mapper Plus (ETM+) taken on July 2th 2000 satellite images were employed. Landsat TM and Landsat ETM+ have a 30 m spatial resolution and 16 days temporal resolution. However, the Landsat MSS (Multispectral Scanner) has a 79 m spatial resolution with 16 to 18 days temporal resolution. Partial scenes of the area were downloaded from the USGS Earth Resources Observation Systems data center. To reduce scene-to-scene variation due to sun angle, soil moisture, atmospheric condition, and vegetation phonology differences, all data were collected near anniversary dates between the months of May and June, corresponding to the Uluabat's dry season. Remote sensing data which did not have clouds, haze, or extreme humidity were collected.

Other materials used included a topographic map (1:25,000), and field survey information. The topographic maps were scanned with a high-resolution scanner. The resulting scanned maps were converted into vector format using appropriate software for creating input into GIS (ArcGIS). Geometric correction of the Landsat images was achieved by using elevation data from the topographic map to generate a Digital Elevation Model (DEM). GPS (Global Positioning System) data were collected in the field by using a handheld GPS receiver for attribution process. For this purpose data from 21 points, detected using GPS, were taken into account during classification.

Nearest neighbor resembling was used to register the images to a standard map projection (Universal Transverse Mercator - UTM, WGS84). In this context, a geometric correction of the image was carried out, registering the image to the 1:25.000 scale topographic maps by selecting 250 Ground Control Points (GCP's). The total check point error was calculated at less than 1 pixel. For Landsat TM imagery, the acceptable Root Mean Square (RMS) error is approximately 0.5 pixels (Townshend et al. 1992). To reduce impact of misregistration on the change-detection results, geometric registration was performed on a pixel-by-pixel basis. The 1975 image was registered to the 1987 image, and the 1987 image was registered to the 2000 image, using 90 ground control points. To allow pixel-by-pixel comparison for all years, and to have the same spatial resolution in all images we re-sampled pixels in the 1987 and 2000 images to a 79 m resolution to match the earlier image using the resembling function (after classification) in ERDAS 8,6 for future pixel-by-pixel comparison. In other words, TM and ETM+ data were re-sampled to the MSS pixel size. Because the images were intended for post-classification change detection, no atmospheric corrections or normalizations were performed (Song et al. 2001, Crews- Meyer 2004).

Hybrid supervised-unsupervised classification, mainly created and specified by Messina et al. was applied in this study (Messina et al. 2000). This method is a modification of the Frizelle Version 1,2 and Messina Version 1,1 by Crews-Meyer (Messina et al. 2000). It was upgraded most recently by Crews-Meyer at the University of Texas on August 5th, 2001. 7 bands for Landsat TM and ETM+ and 4 bands for Landsat MSS were used. For this method, an unsupervised ISODATA classification (20 iterations, 255 classes, 0.98 convergence) was run. Then, signature editing was used to determine the classes. Next, signature evaluation was used to separate all pair-wise combinations, for which the transformed divergence (TD) values were less than 1950. In other words, a signature reparability mark of >1950 was used due to its response to very limited overlap between classes. A maximum-likelihood supervised classification was then run on the edited signatures. In order to remove the random pixels observed in each main class after the classification process, a clump algorithm was performed. The elimination algorithm removed speckled pixels, random pixels in the middle of a main class (essentially a 4x4 pixel MMU or 120 m^2) by comparing each pixel with neighboring pixels.

During the attribution process, the raw imagery in feature specific band combinations, field observations, GPS points, topographic maps, vegetation index, principal component, and spectral characteristics of each class were taken into account. Initially based on examination of the imagery and spectral signatures, the classification strategy was to isolate the land area from wetland area, and then to classify the wetlands. As a final step in data preparation, the land surrounding the wetland was masked from all images to increase the efficiency of data manipulation so that statistics produced from the data would be more meaningful. Since the change in the shoreline has been quite significant in the southern part of the area between 1975 and 2000, the images from 1975 were used for determining the masked land. After the masking process, classification of the water and wetlands was detailed. At the end of attribution process, the 255 classes that had appeared after the ISODATA classification were reduced to six.

Anderson scheme (Anderson et al. 1976) was adopted in classification of images and the distribution of cover types is illustrated in Fig. 2 for the study area. This scheme was selected, due to its reliance on remote sensing data to determine land cover. These final classes were deep water-surface areas (Class 1), shallow water-surface areas (Class 2), herbaceous wetlands (Class 3), sandy areas (Class 4), bare exposed soils (Class 5), and wooded lands (Class 6). Classes belonging to different years and produced via different image enhancement methods are shown in Fig. 2.

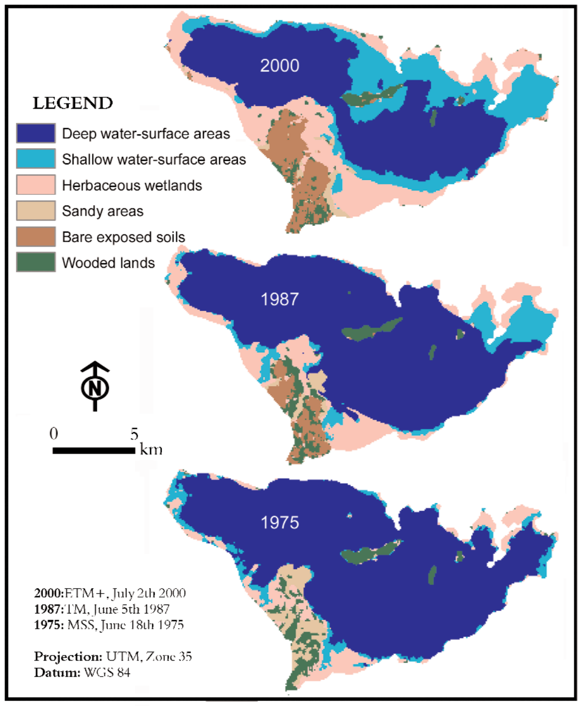

Fig. 2. LULC in years 1975, 1987 and 2000.

Accuracy assessment (Hudson and Ramm 1987) had been carried out through visual inspection, comparison with existing database like 1: 25.000 scale topographic maps, land cover maps provided by the General Directorate of Rural Services and field knowledge. Accuracy assessment points were derived from a stratified random sample (Story and Congalton 1986). We selected the 378 references pixels for each year to be on the safe side. The overall accuracy was 90% for the 1975 data, 88% for the year 1987, and 91% for the year 2000. Kappa coefficient (Khat) for 1975, 1987 and 2000 was 0.87, 0.84 and 0.88 respectively.

The use of Landscape Pattern Metrics (LPMs) is essential for providing quantitative descriptions of landscape mosaics and the quality of the habitat (Tağıl 2006). To quantify landscape structure, after attribution, a pattern matrix was performed to reveal landscape patterns using the raster version of the FRAGSTATS 3,3 (McGarigal and Marks 1995) software, developed at Oregon State University. The output statistics consisted of various class metrics and landscape metrics. Ten pattern indices were used in this study: Class area (CA), Percentage of landscape (PLAND), Edge density (ED), Total edge (TE), Patch numbers (NP), Patch density (PD), Largest patch index (LPI), Mean Shape index (MSI), Area-weighted Mean Index (AWMSI), Shannon's Diversity Index (SHDI), Shannon's Evenness Index (SHEI), Simpson's Diversity Index (SIDI), Modified Simpson's Diversity Index (MSIDI), Patch Richness (PR) and Interspersion & Juxtaposition Index (IJI). More detailed information on LPMs is available from McGarigal and Marks (1995) or Crews-Meyer (2002). The results of the class level pattern metric analyses are shown in Table 1 and those of the landscape level pattern metric analyses are shown in Table 2.

Table 1. The class level indices for years 1975, 1987 and 2000.

Classes	PLAND	NP	PD	LPI	TE	ED	MSI	AWMSI	IJI
2000									
Deep water-Surface areas	45,5	4	0,0	13,6	93852	1,6	1,5	2,5	41,9
Shallow water-Surface areas	22,2	20	0,0	4,9	149310	2,6	1,5	4,1	68,9
Herbaceous wetland	19,9	33	0,1	4,4	124425	2,2	1,5	4,2	88,6
Sandy areas	1,4	30	0,1	0,2	32706	0,6	1,2	1,9	84,0
Barren exposed soils	7,6	34	0,1	1,1	77973	1,4	1,2	3,2	63,0
Wooded lands	3,5	84	0,1	0,3	86110	1,5	1,2	2,3	77,3
1987									
Deep water-Surface areas	68,2	3	0,0	20,8	92193	1,6	1,5	2,5	75,5
Shallow water-Surface areas	8,6	50	0,1	1,5	97881	1,7	1,4	2,2	51,1
Herbaceous wetland	13,6	55	0,1	1,2	109178	1,9	1,4	2,3	79,2
Sandy areas	1,3	14	0,0	0,2	24964	0,4	1,3	1,7	90,9
Barren exposed soils	3,9	14	0,0	0,4	50481	0,9	1,4	2,5	50,0
Wooded lands	4,4	37	0,1	0,3	79711	1,4	1,3	2,4	80,4
1975									
Deep water-Surface areas	76,8	9	0,0	23,4	105860	1,9	1,2	2,8	72,6
Shallow water-Surface areas	5,7	83	0,1	0,3	122608	2,2	1,3	2,3	66,3
Herbaceous wetland	8,9	73	0,1	0,8	113286	2,0	1,3	2,3	89,5
Sandy areas	3,7	19,	0,0	0,4	50718	0,9	1,3	2,1	71,2
Wooded lands	4,8	53	0,1	0,5	86426	1,5	1,3	2,6	84,2

Table 2. Landscape level indices for years 1975, 1987 and 2000.

Date	NP	PD	LPI	TE	ED	MSI	AWMSI	IJI	SHDI	SHEI	SIDI	MSIDI	SIEI	PR
2000	205	0,36	13,81	282188	4,96	1,27	3,27	79,15	1,38	0,77	0,70	1,19	0,84	60
1987	173	0,30	20,81	27204	3,99	1,35	2,40	79,00	1,06	0,59	0,50	0,70	0,61	60
1975	237	0,42	23,42	239449	4,22	1,29	2,73	84,41	0,85	0,53	0,40	0,50	0,49	50

After the classification of the images, the post-classification comparison change detection (Singh 1989, Jensen 1996) based on the Hybrid supervised-unsupervised classification was used to compare data between the years to detect landscape change. The post-classification comparison change detection's assumption is that the satellite images used to generate the classifications were not affected by differences in geometric rectification, atmospheric conditions, illumination and viewing angle, changes in precipitation, and soil moisture levels (Dappen and Merchant 2003). The results identified the areas of risk. The purpose for this method was to present inter-annual change as opposed to seasonal change. During this comparison, great importance was given to water surfaces, herbaceous wetlands, and sandy areas, since the latter are important for new delta formation. Change detection analyses were performed between 1975 and 1987, 1987 and 2000, and 1975 and 2000. The results from the change detection analyses done to calculate the direction of the change on the coast of the lake are shown in Table 3 and Fig. 3.

Table 3. Percentage of changes in periods 1975-1987, 1987-2000 and 1975-2000 (%).

Changing		1975 1987	1987 2000	1975 2000
Deep water-Surface area	Always deep water-surface areas	88	66	59
	Deep water-surface area to shallow water-surface areas	8	25	27
	Deep water-surface area to herbaceous wetlands	3	8	12
	Deep water-surface area to sandy areas	1	1	2
Shallow water-Surface area	Always shallow water-surface areas	45	58	16
	Shallow water-surface area to herbaceous wetlands	51	32	60
	Shallow water-surface area to herbaceous wetlands, sandy areas, barren exposed soil or wooded lands	4	10	24
Herbaceous wetland	Always herbaceous wetlands	74	82	57
	Herbaceous wetland to barren exposed soils, sandy areas or wooded lands	26	18	43
Sandy area	Always sandy areas	10	12	6
	Sandy area to herbaceous wetlands	32	50	15
	Sandy area to barren exposed soils	36	35	60
	Sandy area to wooded lands	22	3	20

By tracing the last 25 years of changes to the delta that was formed by the Mustafakemalpaşa River located within the masked region it is possible anticipate a trajectory for the delta's future development. To this end, the rivers in the images were detected without altering the original images, while using different analysis results such as the tasseled cap and vegetation index. Comparison and analysis of river channels from different years since 1975 provided a model of the direction of river growth (Fig. 4).

Increases in suspended materials cause an increase in reflection. Suspended sediments increase the radiance emergent from surface waters in the visible and near infrared proportion of the electromagnetic spectrum (Ritchie and Schiebe 2000). While a pixel profile of uncorrected radiance data at one point is not sufficient to assess water clarity, it gives certain insight as to the change. In this issue, correlation between in situ data and remote sensing data was required- which was beyond the scope of this work. Nevertheless, results are present on Fig. 5 which shows the spectral signatures (profiles) of the Landsat bands of the same area for different years.

RESULTS

Results of Pattern Metrics

The class area (CA) and the class percentage (PLAND) were calculated in order to quantify landscape composition. The results of these analyses

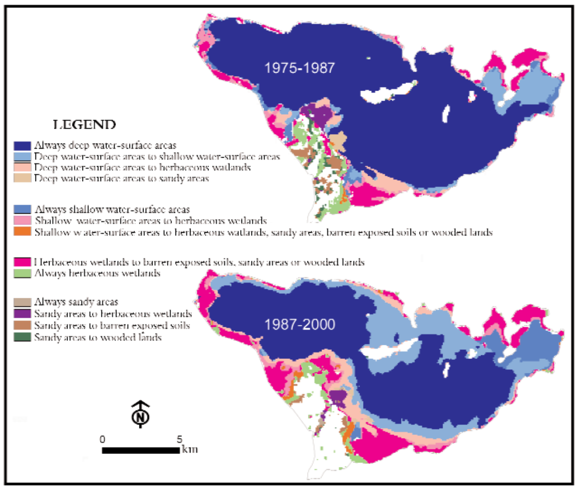

Fig. 3. The change in landuse and landcover in years 1975-1987 and 1987-2000.

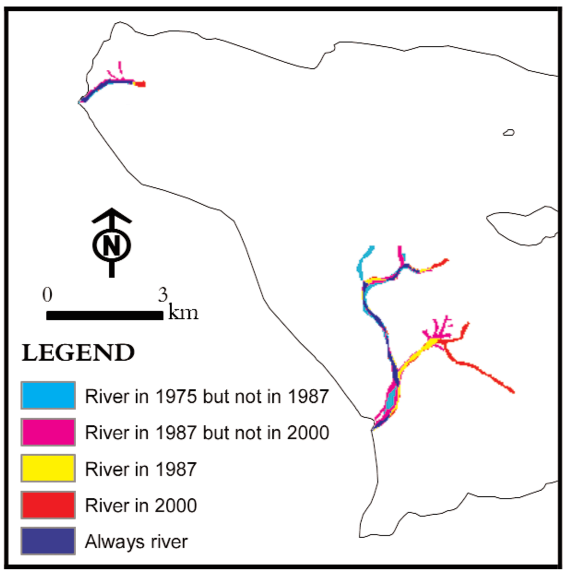

Fig. 4. The change in the riverbeds of the Mustafakemal-paşa Creek delta in years 1975-2000.

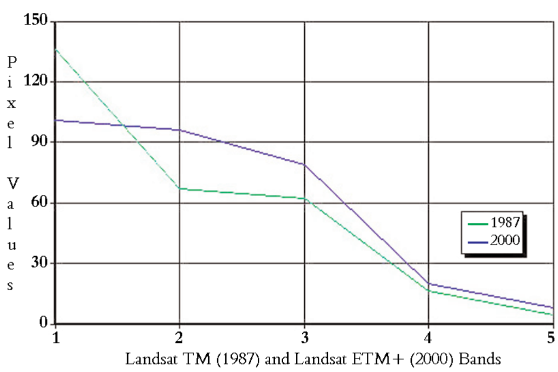

Fig. 5. Spectral profiles of the water surface at the same spot in years 1987 and 2000 (40°09'40" N - 28°35'47" E).

show that while the dominant landscape component did not change over the years, the secondary and tertiary components did change. In spite of percentage changes within the study period, the dominant landscape component was the deep water-surface area. The percentage of the dominant class decreased over the years, although it remained above roughly 45% of the landscape. More specifically, the percentage of the landscape decreased from 77% in 1975 to 69% in 1987, and then to 46% in 2000. In the years 1975 and 1987, the herbaceous wetlands comprised the second most dominant components, with shallow water-surface area in third place. In 2000, however, the latter increased to 22% of the landscape, with herbaceous wetlands at 20% of the landscape. This indicates that there was a general increase in the shallowness in this area. The barren exposed soils had increased from 1975 to 2000, and while the sandy areas made up 4% of the whole landscape in 1975, this percentage decreased over the following years. Additionally, it was found that the areas classified as barren exposed soils in 1975, on which agricultural activities were performed, were too small to be classified and were generally sandy areas that later became open fields. The percentage of wooded areas decreased from 1975 to 2000, due to rearrangements by local citizens to transform them into agriculturally productive areas or orchards.

Patch metrics were calculated in order to represent landscape configuration. Large patches consist of a greater number of species than the small ones. When taking into account the largest patch index (LPI), the deep water-surface areas hold the largest patch. However, the fact that the percentage of the largest patch index had been decreasing from 1975 to 2000 shows that fragmentation, or the subdivision of continuous habitat into smaller patches (Andren 1994), in this landscape had increased. The percentage of the largest patch that consists of deep water-surfaces dropped from 23% to 21% and then to 14%. Generally, the increase in the LPI of the other classes shows that their fragmentation had decreased. In all periods, the largest fragmentation was observed in the sandy areas. In fact, the LPI of this class never exceeded 1%. Additionally, landscape level analyses show that landscape heterogeneity had increased over the years.

The largest patch of deep water-surface areas decreased through each time period, when shallow water-surface areas and herbaceous wetland's largest patch increased. Overall, the area comprising the largest patch of the lake, which forms the deep-water area, was 13280 ha in 1975, falling to 11850 ha in 1987 and then to 7865 ha in 2000. Nevertheless, the largest patch areas of shallow water-surface areas and herbaceous wetland increased in the 1975-2000 period. The proportion of shallow water surface growth was ~5 times from 1975 to 1987, and ~3 times from 1987 to 2000. In herbaceous wetlands, the increase was ~2 times from 1975 to 1987 and ~4 times from 1987 to 2000.

When looking at the number of patches (NP) and the patch densities (PD), it can be seen that in herbaceous wetland and shallow water-surfaces, fragmentation had decreased in the years 1975 to 2000. This is due to the fact that the NP and PD had increased. The reason for the increase in the number of patches in sandy areas would have to be the ongoing activity in the multiple channels of the Mustafakemalpaşa Creek delta. Additionally, it is possible that the increase in the drying up of the bulrush areas in various sections of the lake has led to the formation of sand islands. As a result, the fragmentation of the sandy areas increased by a significant amount leading up to 2000. Similarly, in barren exposed soils, fragmentation had increased due to the terrestrial land process. The ongoing damage being done to the wooded areas, as well as the production of wooded areas on old deltas, contributes to the general growth of fragmentation in this landscape. In general, NP and PD at landscape level also show an increase of heterogeneity or the diversity gradient among landscapes.

The contrast between a patch and its neighborhood can influence a number of important ecological processes (Forman and Godron 1986). In any case, patch shape and orientation are critical in the dispersal of animals and plants across a landscape (Forman and Godron 1986). "It is now widely accepted that edge effects must be viewed from an organism-centered perspective because edge effects influence organisms differently; some species have an affinity for edges, some are unaffected, and others are adversely affected" (McGarigal and Marks 1995). Because they are essential for birds and marine life of the wetland, the herbaceous wetlands and water surfaces were monitored closely. No significant changes were observed in either the TE or the ED in the herbaceous wetlands between 1975 and 2000. This shows that there was no structural change in this landscape during that period. Conversely, the TE and ED had decreased on the water surfaces. The landscape level metrics also show that the ED generally increased within the area of study. This, in turn, implies an increase in heterogeneity and that the landscape features were not organized.

Shape metrics are other important indices with regard to ecological process. Because the Mean Shape index (MSI) and the area-weighted mean index (AWMSI) are larger than 1, the patch shapes in all landscapes were unshaped (not round or square). With the AWMSI being larger than the MSI values, the largest patches belonging to each landscape were more irregular than the remaining patches. At the landscape level, noncircular or irregular patch shapes can be seen distributed throughout the entire landscape.

In order to determine the contagion and interspersion of LULC within the area of research, the Interspersion & Juxtaposition Index (IJI) was computed. This metric defines how class patches are located in relation to other patches of the same class and to patches of other classes within the landscape. The IJI results indicate that herbaceous wetlands and sandy areas were distributed among the available patch types at about ~70-90% of the maximum possible equitable distribution in landscape in all three periods. This comes from the lake having almost its entire shoreline covered with herbaceous species. However, the deep water-surface area, which contained the largest patch in the landscape and the fewest number of patches, had a less uniform distribution (<50%) compared to the other classes. All other classes had an equal distribution in over 50% of the landscape. At the landscape level, the IJI indicates that the interspersion of available patch types was over 75% in the landscape in the study period.

To measure and monitor landscape diversity, landscape metrics can contribute to the understanding of how processes of (human) interferences affects the landscape's richness over time. According to Shannon's Diversity Index (SHDI), Shannon's Evenness Index (SHEI), Simpson's Diversity Index (SIDI), Modified Simpson's Diversity Index (MSIDI) and Simpson's Evenness Index (SIEI) the landscape in the year 2000 was more diverse than the landscape in the year 1975, because these indices increase approximately twofold from 1975 to 2000. Overall, diversity increased through each time period. Both Simpson's and Shannon's diversity showed the greatest increase, 80%, from 1975 to 1987. Otherwise, changes in diversity ranged from 70% to 80%. Both Shannon's and Simpson's evenness index increased from 80% to 89%. Patch richness increased from 1975-1987 and remained the same from 1987-2000.

Results of Change Detection

Table 3 and Fig. 3 show that water surfaces reduced in size by 8% in the period 1975-1987. During this period, 7% of the water surfaces changed into herbaceous wetlands and the remaining 1% became sandy areas, barren exposed soils or wooded areas. In the southern part of the wetland, a barrier or embankment that developed after 1975 cut off a shallow bay from the main body. By 1987, the bay had dried and was now categorized as terrestrial land. Owing to this constructed embankment by the Turkish State of Water Works (DSI) for protect low lying agricultural lands along the south -southwest coast; the coverage area of the lake can not be rich again mentioned past coverage. The coverage and volume of the lake were measured by DSI as 387 hm^3/year respectively in 1965. Contrary, water volume of the lake was 346 hm^3/year in 1995 because of embankment.

This progression shows that between 1987 and 2000, the water surfaces had decreased by 13% and that these areas were covered with either herbaceous or wooded areas, or by exposed soils. The loss of water surfaces between 1987 and 2000 was larger than the loss between 1975 and 1987. During this period, 10% of the water surfaces changed into herbaceous wetlands, 2% became sandy areas, barren exposed soils or wooded areas. Also, in the 13 years between 1987 and 2000, a 150% increase of herbaceous wetland was observed, and a 195% change was observed in barren exposed soil. It is also noticeable that villagers used some parts of barren exposed soil for seasonal agriculture on an ongoing basis.

Analyses show that in the 25-year period between 1975 and 2000, the average water surface decreased by 19%. Also, the percentage of herbaceous lands that became barren exposed soils or wooded areas was 43%. In the same period, a 200% increase of herbaceous wetland was observed. From 1975 to 2000, the direction of change was water surfaces to barren exposed soils.

The change in the shoreline is important because it demonstrates erosion and accumulation. It is clear that the Mustafakemalpaşa Creek, which carries the suspended material, was the cause of the changes in the wetland. Therefore, determining changes in the bed of the river on the delta and in the delta itself are especially important. The changes in the shoreline of Lake Uluabat occurred primarily in the southern part of the lake. Various formation directions were detected on the delta formed by Mustafakemalpaşa Creek (Fig. 4). When the 1975 image was carefully examined, it was seen that the delta was expanding towards the channel to the southwest of the Halilbey Island. However, the 1987 images revealed a new delta caused by a split in the original delta. The river ran through the newly formed delta with multiple branches. This new riverbed had a length of ~1.9 km. The 2000 image shows that the river has changed its direction with a sharp turn towards the southeast. This new riverbed, to the southeast, was ~2.5 km. The expansion of the delta in this direction also contributed to further loss of wetland. Fieldwork has shown that this river channel continues to be active. In summary, all of these changes in riverbeds show that the delta advanced west to east in the southern part of the lake.

Fig. 5, the spectral signatures (profiles) of the Landsat bands of the same area for different years, shows increasing reflection especially in the red (Band 3-Red) and near-infrared (Band 4-NIR) bands. This is an evidence of increasing suspended material in the lake and proves that there was a general shallowness along the lake. The most important suspended materials in the water are chloroform, zooplankton, phytoplankton and non-organic residues. An increase in the chloroform concentration results in fainter blue lights and brighter green lights. In this case, it can be stated that the suspended organic materials in the lake had also increased. Decreases in suspended matter levels could greatly change the aquatic ecology of Lake Uluabat. However, to verify this, more detailed station based analyses are needed. To characterize the fluctuation in lake level, DSI's coverage and volume measurement works shows that water level decreased from 8 m to approximately 3 m.

DISCUSSION

The purpose of this study was to demonstrate

LULCC that occurred between 1975 and 2000. Images taken in 1987, 1981 and 2000 were enhanced and analyzed. It was found that over a 25-year period, the area of water surface and the depth of water had decreased. These general changes can be attributed to several factors. First, a rapid sediment concentration occurred in the lake, followed by a rapid conversion from wetland to terrestrial land surrounding the body of water, particularly to the south. Second, there was an increase in suspended material throughout the entire lake. Finally, settlers were claiming increased areas of herbaceous wetland and barren exposed soils for agricultural uses. As long as these trends persist, it is tempting to predict the lake will eventually dry up. Same as Lake Uluabat, Ari (2002) have determined that Lake Manyas, which is in the same region with Lake Uluabat, is getting shallower due to rapid sedimentation.

As a result of the pattern metric analyses, it was found that for different classes, fragmentation was generally very common in all landscapes, and landscape heterogeneity had increased. This verifies that the quality of this wetland habitat, being an aquatic ecosystem, was starting to decline. This conclusion is similar to other studies of wetlands in the same region, which indicate that the most important threats are pollution and a decline of water quality (Altinsacli and Griffiths 2001, Ari 2002).

Research shows that the largest patch, which was classified as deep water-surface, and was also a vital habitat for the lake's fish, had shrunk in size over the years from 1975 to 2000. Namely, the *Astacus leptodactylus* E. population was an important element of the lake ecosystem until 1986, the year when the population was hit by fungi (Yarar and Magnin 1997). Obviously, due to decrease in the deep water surface and increase in sedimentation, the most striking negative effect was a sharp decline of the *Astacus leptodactylus* E. catch. Other literature (Ari 2002) suggests that the same decline has occurred at Lake Manyas since mid 1980.

The shrinkage of the largest patch of the lake not only can cause problems for the species living there but also can increase the natural pollution density caused by bird migration. The fact that the largest patch area of bulrushes increased, can be interpreted as an increase in the capacity for hosting more species. On the other hand, these values are important for determining the magnitude of shallowing and soiling. The decline in the largest patch percentage in the lake shows that landscape heterogeneity had increased.

The increases in shallow water-surfaces, herbaceous wetlands, and sandy areas revealed, without a doubt, that the overall change the lake was experiencing was toward drying up. The direction of this change was negative for the water surfaces but positive for herbaceous wetland and barren exposed soils. Additionally, since shapes of the patches were found to be non-uniform, this indicates that this change was a continuous process.

This indicates that the living environments of species that prefer deep water-surfaces had also decreased, thereby creating more living space for species that prefer shallow water. Examined another way, this might be considered an increase in the suitability of habitat for species that prefer heterogeneous structures.

Due to the fact that the landscape was irregular in shape, it was hypothesized that the anthropogenic fragmentation within the wetland had been considerable. In the area, the classes were distributed randomly, and that the spatial pattern was not homogeneous.

The most important risk zone is in the southern part of lake for the reasons stated previously and also because this part of the lake is under both human pressure and natural pressure caused by Mustafakemalpaşa River. It follows that this side of the lake should be given extra consideration when planning for development around the lake. Unfortunately, a proposed freeway project, which would cross near the south side of lake, is already on the table. If this project is completed, it will further accelerate changes in the lake. Also, it can be hypothesized that dwindling water-surfaces will create problems with pollution originating from pesticides carried to the lake by Mustafakemalpaşa river.

Finally, local farming of vegetables in fields created by the landcover process is a common feature in the study. The main reason for this condition is the lack of understanding about the fundamental importance of wetlands to the environment in which we live. In the long run, we are not able to foresee side effects of drying on this habitat. If the lake dries out, this agricultural activity will be disrupted because the disappearance of the lake changes the ecological conditions of the landscape. Local stakeholders should be alerted to this aspect of the declining wetland. Also, precautions should be taken to protect the lake as a RAMSAR area. The focus on socio-economic aspect can be achieved through a participatory ecosystem management approach. This conclusion is similar to other studies of wetlands in Mediterranean countries, which indicate that wetlands are an important source of livelihood for local people and therefore conservation and sustainable use must go hand-in- hand (Benessaiah 1988, Papayannis and Salathe 1999). Green et al. (1996) also noted that this is the same for Lake Burdur ecosystem in southwest Turkey and suggested a socio-economic and cultural study for the area to clarify the extent of human dependence on the lake's resources.

To reiterate, fragmentation, loss and degradation of the natural habitat is a common feature of the Uluabat Landscape. When habitats are fragmented into small areas, they support fewer species. Many birds and mammals need large areas in which to feed and breed. However some species mentioned before are protected by international agreements in the wetland, this is partly due to the fact that these species are part of the national ecosystems of several countries' wetland, and not only Uluabat, Turkey. Thus, any impact on the migratory birds nesting, breeding, resting or wintering in the Uluabat will have an adverse trans-boundary impact.

The degradation and loss of the Uluabat Wetland is not an isolated incident, and is but one example in Turkey of a far reaching global problem. For example, Greece and Spain which are countries sharing the same climatic conditions with the study area had lost 63% of its wetlands during the 1920-1991 and 60% of its wetlands during 1948-1990, respectively (Anonymous 1995). The United States has lost some 87 million hectares (54%) of its original wetlands (Tiner 1984), primarily to agricultural production. Not only in Uluabat Wetland but also in other wetlands in the Mediterranean Countries, degradation and loss are directly linked to drainage for agriculture, but also for industry, urban and tourism development (De Voogt et al. 2000, Kroll 2000).

The Uluabat wetlands are faced with increasing population demands and impact. Expansion of irrigated agriculture activities drains the lake, and agro-industrial plant waste contaminates it. Eutrophication of the lake is inevitable under these conditions. Improving agricultural techniques with an eye towards modern, environmentally sound practices would be part of the remedy needed. This also involves educating the farming community in the region as to the benefits of a healthier wetlands landscape. This, in turn, means that the government must take a hand in changing practices, with incentives if need be, and in improving and enforcing emissions standards for industries operating in the wetlands watershed. While the analysis done in this study describes the current degradation of the region, forecasting the actual lifetime of the wetlands is difficult. However, it is clear that a plan for reasonable change and protection is needed for the Uluabat Wetlands to survive through the next century. Many of these threats, such as agricultural activities are common to wetlands in other Mediterranean countries (Benessaiah 1988, Papayannis and Salathe 1999, Kroll 2000).

Shortly, to protect the wetland from habitat loss, fragmentation and alteration the fallowing recommendations are given:

-Monitor the changes in the wetland by using remote sensing and GIS techniques;

-Establish soil and water management plan for its catchments to decrease sedimentation caused water erosion due to upland farming and mining activities in the catchments;

-Bring in new irrigation methods and land use types around the wetland to reduce water withdraw in dry period (from June to September);

-Explore the effects or threats of highway being still under construction on water pollution and breeding birds.

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