Journal of Applied Sciences

ISSN 1812-5654

Journal of Applied Sciences 7 (9): 1260-1270, 2007
ISSN 1812-5654

Quantifying Landscape Pattern Change and Human Impacts on Southern Lowlands of the Mt. Ida (NW Turkey)

Recep EFE and Şermin Tağil
Department of Geography, Faculty of Arts and Sciences, Balıkesir University,
10100-Balıkesir, Turkey

Abstract: The aim of the study is to identify the interrelationship between landuse and landcover (LULC) change and land degradation, using remotely sensed data in the vicinity of the Gulf of Edremit and southern lowlands of the Mt. Ida, NW Turkey. We used a Landsat ETM+ image taken in June 2000, a Landsat TM image taken in May 1987 and a Landsat MSS image taken in June 1975. Construction of new buildings is rampant and often appears to be without concern for the physical environment or any future impact. The focus seems to be on developing now, meeting current demands only. This economically focused development contributes greatly to land degradation and a future inability of the region to function ecologically. Main conclusion of the study is that development of secondary residential areas aimed at tourists is irrevocably altering the agricultural landscape. Because of human impact on landscape, vegetation zones are changing. Landscape metrics represent that LULC change from brush and shrub rangeland to orchard land dominated by olive groves through secondary residential area or deforestation and that exposed rock and soil to cropland and pasture land through secondary residential area or deforestation.

Key words: Fragstats, land degradation, landscape pattern metrics, landuse/landcover change, remote sensing, sustainable development

INTRODUCTION

The landscape of the Mediterranean Basin has been profoundly influenced by human impact for thousands of years (Tzatzanis *et al*., 2003). Recently, increasing population pressure, over and early grazing by domesticated animals, fuel gathering and the cutting of trees to clear agricultural land have lead to extensive deforestation of the natural environment (Thornes, 1996; Irshad *et al*., 2007). 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).

The effects of land degradation on economy in developing countries are being tried to be betrayed with confirming the degradation in basins and especially in agricultural areas (Barbier, 1998; Maiangwa *et al*., 2007). Because of the developing population growth, the agricultural areas are overused and also they are used in diversion for settlement activities and degraded. The land degradation economically decreases the fertilities of agricultural areas. It is difficult to identify policy effects on land degradation stem not only from lack of suitable historical data, but also from the com-plexity of the interaction between policy measures and agro-ecological process (Benhin and Barbier, 2001). It is known that the government policies'support the olive agriculture in many basins in Turkey (Sesli and Tokmakoğlu, 2006). However, the coast of the Gulf of Edremit area and southern slopes, covered by orchard land dominated by olive groves, of Mt. Ida have been affected by increasing standards of living and the accompanying demand for second homes and tourist activities, since the beginning of the 1970s. Growing settlements arising from population pressure have caused the loss of fertile land and natural vegetation and are also threatening the natural environment of the area. Shortly, in Edremit Basin, being one of the most important olive cultivating areas in Turkey, the government policies are supporting the tourism and cause the degradation of olive areas.

Remote Sensing (RS) techniques and Geographical Information Systems (GIS) have big importance on specifying degraded areas. Satellite remote sensing provides synoptic, objective and homogeneous data which can be geographically and temporally registered and therefore, could be an efficient tool for providing standard, high quality information on agriculture

Corresponding Author: Recep EFE, Department of Geography, Faculty of Arts and Sciences, Balıkesir University, 10100-Balıkesir, Turkey Tel: +90-532-247-48-07

(Tsiligirides, 1998). Over the past 30 years there has been increased emphasis on the potential of remote sensing to assess agricultural landscapes (Hatfield and Pinter-Jr, 1993). In particular to distinguish between vegetation types based on satellite images has seen increased emphasis (Oetter *et al*., 2000).

Most important problems in the southern lowlands of Mt. Ida are deterioration of shoreline of due to tourism activities and illegal constructions, damage to the coastal ecosystem due to domestic/industrial wastewater discharges and some agricultural activities and disordered urbanization (Irtem *et al*., 2005). The aim of this study was primarily to assess changes in landscape structure in the southern lowlands of Mt. Ida, a Mediterranean site, resulting from human landuse (i.e., urban development). The main research goal was to identify the inter-relationship between landuse and landcover change (LULCC) and agricultural land degradation in the study area using remotely sensed data, and to analyze patterns of changes in the landscape of the study area during the period, with special focus on orchard fragmentation being dominant by olive trees. To achieve these goals, the LULCC in 1975, 1987 and 2000 was determined, landscape pattern change was quantified, and degraded areas attributed to LULCC during the period between 1975 and 2000 were defined. In order to ensure continuing economic development, the region needs to ensure that it is practicing ecologically sustainable development. This study emphasizes a preliminary assessment of the current development, its impacts and highlights important issues of concern.

MATERIALS AND METHODS

Study site: This study focuses on the Gulf of Edremit and southern lowlands of Mt. Ida, extending from Kucukkuyu to Burhaniye (Fig. 1), a region where development is currently accelerating in the Northwest of Turkey. It is located in the western part of Marmara Region in Turkey between 39°27'42"N-39°38'51"N latitudes and 26°30'05"E-27°13'00" E longitudes and in the northeastern of Mediterranean Basin. The total study area is ~1270 km^2. The vicinity of the Gulf of Edremit is composed of marginal olive agriculture-based areas with documented deforestation and agricultural extensification. The local population grew from 111801 to about 185253 between 1975 and 2000 (The important towns of the area are; Edremit, Altinoluk, Burhaniye, Havran and Zeytinli).

The climate of the region is predominantly Mediterranean which is distinguished by warm, dry summers and mild, wet winters. Average annual precipitation ranges from 500 to 1200 mm on the higher elevations. It is on the dry sub-humid zone with 600 mm.

The olive tree (*Olea europaea*), red pine (*Pinus brutia*), Turkish oak (*Quercus cerris*), Dyer's oak (*Quercus infectoria*) and maquis strawberry tree (*Arbutus unedo)*, eastern strawberry tree (Arbutus andrachne), large leaved jasmine *(Phillyrea latifolia)* and kermes oak (*Quercus coccifera*) are the leading plant species of the study area. The olive cultivation occurs abundantly in the foothills of the Mt. Ida. In Turkey, the Gulf of Edremit is the most prominent region of olive cultivation, reflecting both the agricultural and economic importance

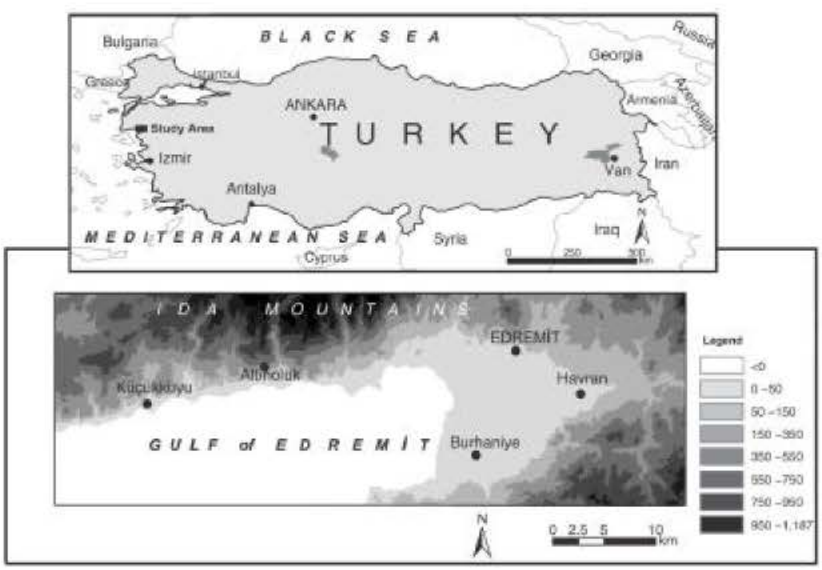

Fig. 1: Location and topographic map of the research site

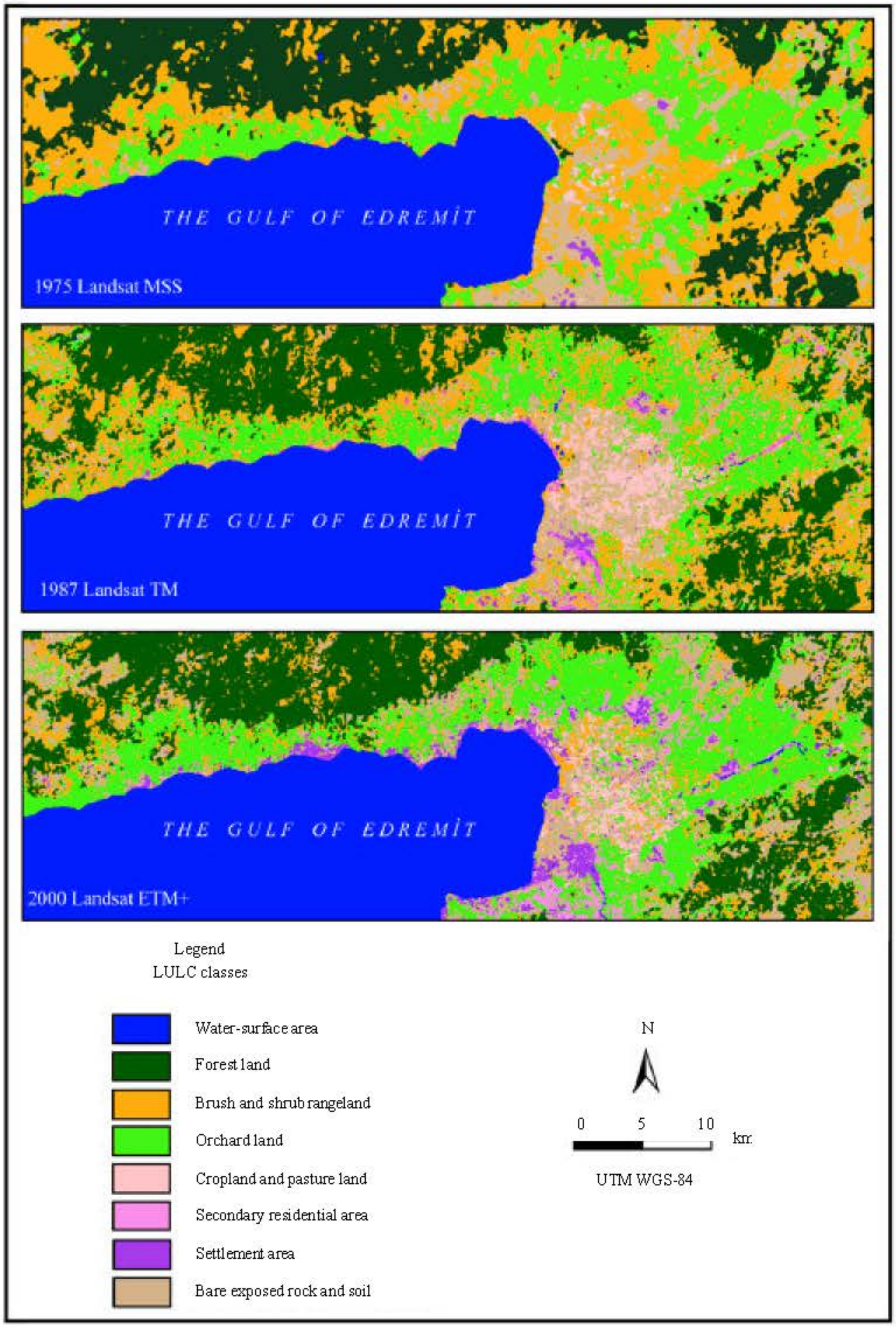

Fig. 2: LULC in years 1975, 1987 and 2000

of the area. In the region, olive cultivation is one of the most environmentally friendly agricultural activities. It has numerous important beneficial impacts on the social and natural environment such as limiting soil erosion.

Material studied: The datasets available for the Gulf area were: a Landsat Enhanced Thematic Mapper Plus (ETM+) image taken in 7 June 2000, a Landsat Thematic Mapper (TM) image taken in 11 May 1987, a Landsat Multispectral Scanner (MSS) image taken in 19 June 1975, a Digital Elevation Model (The Shuttle Radar Topography Mission, SRTM, 90×90 m), 1:25000 topographic maps and (f) field surveys. Remotely sensed data were downloaded from the USGS Earth Resources Observation Systems data center. To minimize vegetation differences from seasonal changes, all of the images used in the study were anniversary images from the summer months. All scenes were of good quality with no clouds, cirrus or scan line defects. Different field researches were conducted between the years of 2000-2006. This field studies and observations were taken into consideration, while making classifications and assessing the results.

Methods: The digital analysis was performed at the GIS laboratory at Balikesir University, using the ERDAS Image Processing and PC-based System. ERDAS Imagine, Version 8.6, was the principal software used throughout the mapping process. The following steps were taken during this study:

In order to prepare two or more satellite images for an accurate change-detection comparison, it is imperative to geometrically rectify the imagery (Macleod and Congalton, 1998; Kwarteng and Chavez, 1998). To minimize impact of misregistrationon the change-detection results, geometric rectification algorithms were used to register the images to a standard map projection (Universal Transverse Mercator-UTM, WGS 84) by selecting 100 Ground Control Points (GCPs). The root mean square errors (RMSerror) for the images were ~0.78 pixel error, less then 1 pixel.

The images were co-registered using a masterBslave process, with the aid of 1:25,000 scale topographic maps (Lu *et al*., 2004). TM and ETM+data were resampled to the MSS pixel size (79 m resolution) to have the same spatial resolution for the post-classification change detection. And the images from each date were subset using a single mask from a GIS layer. Because of the fact that the satellite images used to generate the post-classification comparison change were not affected by differences in atmospheric conditions, atmospheric corrections were not performed (Song *et al*., 2001; Crews-Meyer, 2004).

Hybrid supervised-unsupervised classification, mainly created and specified by Messina *et al*. (2000), was applied in this study (Crews-Meyer, 2001). Crews-Meyer at the University of Texas upgraded it most recently on August 5th, 2001. Data Analysis ISODATA clustering algorithm was run with maximum 25 iterations and a 0.98 convergence threshold to generate 255 spectral classes. Divergence and transformed divergence statistics were used in order to assess the separability of the information classes and to weed out redundant information classes. Remaining spectral classes (usually 30-45) were used as training data for the rest of the image in the supervised phase using a maximum likelihood estimator, followed by attribution. The last step was to perform post-classification smoothing. A 3 pixel by 3 pixel mode or majority filter was used. This operation removed any speckling on the images. These speckles usually result from random sensor error or extreme spectral mixing. The final image appeared much more homogeneous or smooth.

The attribution process followed a two-pronged method. One of the methods focused on the use of the spectral signatures of the final classes and assignment of class colors based upon visually interpretable band combinations. The second method used simple comparisons between the raw imagery in feature specific band combinations and vegetation index. Also, during the attribution process, field observations were taken into account. At the end of attribution process, the 255 classes that had appeared after the ISODATA classification were reduced to 8 classes (Fig. 2). LULC classification scheme was water-surface area (fresh water, saline water, seawater), forest land (dominated by *Pinus brutia*), brush and shrub rangeland, orchard land (dominated by olive groves, citrus fruits, etc), cropland and pasture land (dryland pasture, irrigated pasture, etc), settlement area (towns, cities, etc), secondary residential area (touristy recreational sites) and bare exposed rock and soil (roads, exposed sand and rock, quarries). Accuracy assessment has been carried out 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. The overall accuracy was 86% for the 1975 data, 88% for the year 1987 and 89% for the year 2000. Khat (Kappa Coefficient) for 1975, 1987 and 2000 was 0.85, 0.86 and 0.88, respectively.

After the classification of the images, to compare data between the years post-classification comparison change detection (Jensen, 1996; Crews-Meyer *et al*., 2004; Liu and Zhou, 2004) method was used. The purpose for this method was to present inter-annual change incited of seasonal change. To emphasize effects of the residential areas on the agriculture lands on the Edremit plain and the northern coasts of the Gulf of Edremit, these areas on all images were subsetted and analyses were done separately. Change detection analyses were performed between 1975 and 1987, 1987 and 2000 and 1975 and 2000. Results of the change detection analysis were shown on Table 1 and 2.

It is preferred to give information on the natural environment and LULC relationship, because the physical environment is often regarded as one of the important factors controlling LULC. It is believed that the potential use of land is directly related to physical attributes. For this reason, relation between altitude and LULC was examined. To do this, DEM was used and simple zone models such as cross tabulations on GIS were developed to estimate this interaction. Spatial stratification is based on the premise that some LULC types are associated with certain elevations. At the same time, spatial stratification employed to enhance the classification accuracy of the image. For example, olive trees grow at an elevation of 200-400 m.

To quantify landscape structure, after attribution, landscape pattern metrics (LPMs) were performed to put forward landscape patterns using the raster version of FRAGSTATS 3.3 (McGarigal and Marks, 1995) software, developed at Oregon State University. FRAGSTATS calculates up to 46 metrics at the landscape level, but 12 pattern indices of these were selected to describe the area, number, shape and spatial distribution characters at class and landscape levels. Percentage of landscape (PLAND), Edge Density (ED), Total Edge (TE), Patch Numbers (NP), Patch Density (PD), Largest Patch Index (LPI), Landscape Shape Index (LSI), Mean Shape Index (MSI), Area Weighted Mean Shape Index (AWMSI), Mean Patch Size (MPS), Shannon's Diversity Index (SHDI), contagion index (CONTAG) and interspersion and juxtaposition index (IJI) were used to indicate shape complexity and fragmentation (Table 3). Results of these indices were shown on Table 4-7. The value to specify the background as boundary proportion was 0 when the LSI was calculated. More detailed information on metrics is available from McGarigal and Marks (1995).

Table 1: Landuse and landcover change area of the southern lowland of the Mt. Ida (ha)

Location	1975-1987	1987-2000	1975-2000
Orchard land to settlement area	13	292	379
Orchard land to secondary residential area	13	70	132
Brush and shrub rangeland to settlement area	23	198	243
Brush and shrub rangeland to secondary residential area	19	55	45
Orchard land to exposed rock and soil	413	585	761
Brush and shrub rangeland to exposed rock and soil	348	1006	908
Brush and shrub rangeland to orchard land	1578	1814	2249
Forest land to orchard land	167	181	239

Table 2: Landuse and landcover change area of Edremit Plain (ha)

Location	1975-1987	1987-2000	1975-2000
Orchard land to settlement area	4	27	89
Orchard land to secondary residential areas	17	8	32
Exposed rock and soil to settlement area	86	243	181
Exposed rock and soil to secondary residential area	53	176	126
Brush and shrub rangeland to orchard land	427	104	830
Exposed rock and soil to orchard land	53	519	227
Brush and shrub rangeland to cropland and pasture land	1439	145	999
Exposed rock and soil to cropland and pasture land	519	815	351
Brush and shrub rangeland to exposed rock and soil	1891	226	1374
Cropland and pasture land to settlement area	3	100	50
Cropland and pasture land to secondary residential area	18	70	29

Table 3: Units, range of values and purposes of use for the landscape pattern indices

Indices		Range	Purpose
Area metrics	PLAND: Percentage of landscape	$0 < \text{PLAND} \leq 100$	To quantify landscape composition
Edge metrics	ED: Edge density (m ha^{-1})	ED$\geq$0	To measure energy flow and connection between landscapes
	TE: Total edge (m)	TE$\geq$0	
Patch density, Size and Variability Metrics	NP: Patch numbers	NP$\geq$1	To measure fragmentation and variability in the landscape
	PD: Patch density (N/%100 ha)	PD > 0	
	LPI: Largest patch index (%)	$0 < \text{LPI} \leq 100$	
	MPS: Mean patch size (ha)	MPS>0	
Shape metrics	LSI: Landscape shape index	LSI$\geq$1	To determine patch shapes in the landscape
	MSI: Mean shape index	MSI$\geq$1	
Diversity metrics	SHDI: Shannon's diversity index	SHDI$\geq$0	To quantify landscape composition by measuring richness and evenness of patch types
Contagion and interspersion metrics	IJI: Interspersion and juxtaposition index (%)	$0 < \text{IJI} \leq 100$	To quantify landscape configuration
	CONTAG: Contagion index (%)	$0 < \text{CONTAG} \leq 100$	

Table 4: Landscape pattern metrics for landscape characterization variables at 1975

Variables	PLAND (%)	NP No.	PD. (No./%100 ha)	LPI (%)	TE (m)	ED (m ha^{-1})	LSI	IJI (%)
Water-surface area	31.4	319	0.2	0.2	8,504.460	66.4	107	77
Forest land	20.2	2398	1.9	5.1	6,422.820	50.1	102	75
Brush and shrub rangeland	23.4	5629	4.4	1.2	8,856.000	69.1	130	75
Orchard land	16.7	3863	3.0	1.3	6,264.420	48.9	108	74
Croplands and pasture land	0.5	417	0.3	0.0	247.380	1.9	25	86
Settlement area	0.2	144	0.1	0.0	112.920	0.9	17	73
Exposed rock and soil	7.6	3582	2.8	0.0	3,510.480	27.4	90	77

PLAND: Percentage of Landscape; NP: Patch No. PD: Patch Density; LPI: Largest Patch Index; TE: Total Edge; ED: Edge Density; LSI: Landscape Shape Index; IJI: Interspersion and Juxtaposition Index

Table 5: Landscape pattern metrics for landscape characterization variables at 1987

Variables	PLAND (%)	NP No.	PD (No./%100 ha)	LPI (%)	TE (m)	ED (m ha^{-1})	LSI	IJI (%)
Water-surface area	31.5	364	0.3	0.9	8,538.420	66.7	107	84
Forest land	20.5	4119	3.2	4.5	7,086.060	55.3	111	75
Brush and shrub rangeland	18.5	10683	8.3	0.2	8,514.540	66.5	140	78
Orchard land	15.9	7443	5.8	0.8	6,798.480	53.1	120	76
Cropland and pasture land	2.9	2660	2.1	0.0	1,526.220	11.9	63	75
Settlement areas	0.6	784	0.6	0.0	350.760	2.7	32	86
Secondary residential area	0.5	701	0.5	0.0	293.340	2.3	29	88
Exposed rock and soil	9.6	8147	6.4	0.0	4,944.900	38.6	113	81

PLAND: Percentage of Landscape; NP: Patch No. PD: Patch Density; LPI: Largest Patch Index; TE: Total Edge; ED: Edge Density; LSI: Landscape Shape Index; IJI: Interspersion and Juxtaposition Index

Table 6: Landscape pattern metrics for landscape characterization variables at 2000

Variables	PLAND (%)	NP No.	PD (No./%100 ha)	LPI (%)	TE (m)	ED (m ha^{-1})	LSI	IJI (%)
Water-surface area	31.6	310	0.2	0.9	8,541.540	66.7	107	88
Forest land	20.4	3996	3.1	5.0	6,951.720	54.3	109	83
Brush and shrub rangeland	8.9	8431	6.6	0.0	4,681.740	36.6	111	83
Orchard land	20.0	6517	5.1	1.4	7,874.940	61.5	124	82
Cropland and pasture land	2.0	2073	1.6	0.0	1,095.540	8.6	54	79
Settlement areas	2.4	2200	1.7	0.0	1,263.060	9.9	58	91
Secondary residential area	2.0	2541	2.0	0.0	1,146.600	9.0	57	87
Exposed rock and soil	12.7	8367	6.5	0.1	6,038.820	47.2	120	84

PLAND: Percentage of Landscape; NP: Patch Numbers; PD: Patch Density; LPI: Largest Patch Index; TE: Total Edge; ED: Edge Density; LSI: Landscape Shape Index; IJI: Interspersion and Juxtaposition Index

Table 7: Landscape level indices for years 1975, 1987 and 2000

Date	NP No.	PD (No./%100ha)	LPI (%)	MPS ha	TE (m)	ED (m ha^{-1})	LSI	MSI	SHDI	IJI (%)	CONTAG (%)
2000	34435.0	26.9	5.0	3.7	18796980.0	146.8	132.5	1.3	1.7	84.0	24.8
1987	34901.0	27.3	4.5	3.6	19026360.0	148.6	134.1	1.3	1.7	78.4	26.9
1975	16352.0	12.8	5.1	7.8	16959240.0	132.3	119.5	1.6	1.6	74.7	28.8

NP: Patch Numbers; PD: Patch Density; LPI: Largest Patch Index; MPS: Mean Patch Size TE: Total Edge; ED: Edge Density; LSI: Landscape Shape Index; MSI: Mean Shape Index; SHDI: Shannon's Diversity Index IJI: Interspersion and Juxtaposition Index; CONTAG: Contagion Index

RESULTS

Changes in landuse and landcover: Changes in landuse are constantly evolving. Originally, forest land dominated by *Pinus brutia* on the northern part of the Gulf was cleared to make way for the olive groves in order to generate greater agricultural returns (Table 1). Olive cultivation and production in 1975 was restricted to the low-lying alluvial lands along the coastal zones, while the native vegetation continued to dominate the hill slopes. Latter, in response to Turkey's emerging prosperity, the real estate market was evolving as the demand for secondary houses and tourist development escalated. Real estate development may eventually replace agriculture as the economic engine driving the Gulf of Edremit region. This observation puts prime agricultural lands at risk, as well as heritage and other local endowments. The development of touristy facilities focuses on the alluvial plains on the coastal zone, clearing the land, replacing more traditional housing and pushing orchard land dominated by olive further uphill up to 650 m. There were few secondary houses in the coastal zone in 1975. From 1975 to 1987, secondary residential areas increased to 638 ha. By year 2000, the total area in question grew to 2550 ha. A site of antiquity, *Antandros*, was affected by this development. Some summer houses were built on this site. This is a striking example for the negative result of the LULCC in the study area. Summer houses in the region started with the governor's camping grounds built by Turkish Agricultural Supply Organization, Turkish State Railways, National Social Insurance Organization and Metropolitan Ankara, etc., However, in the year 2000, there were 54 buildings aimed at tourists (hotel, motel, etc.) with 3795 beds.

The shorelines of the region are increasingly characterized by low-intensity agricultural landuse (e.g., olive groves) and secondary residential areas are increasing (e.g., hotels, recreational facilities). In particular, these latter two factors are introducing instability into the region's natural environment. *Pinus brutia* forests have been replaced with olive groves at higher elevation, while second home construction has exploded at lower elevations over the last thirty years. The impact of human activities on the natural and cultural landscape is evident during field research, since relics of the red pine and oak forests are increasingly restricted to sites among the secondary houses and olive trees (Fig. 3).

The orchard land dominated by olive groves increased between 1975 and 2000. However this increase in olive area is the result of migration from original optimal areas to higher elevations. As houses were built upon old groves and highly productive land is lost, newer groves were established at higher elevations on the slopes. It is accepted fact that newly planted olive trees do not produce fruit for five years (Sesli and Tokmakoğlu, 2006). Shortly, cutting old olive trees is not beneficial economically.

As an example, nearly 26 ha in the southern slopes of the mountain of orchard land was changed to secondary residential areas during the period 1975-1987 and again between 1987 and 2000, nearly 362 ha more. In the area fast-paced construction has been continuous. During the same two periods, over 900 ha was changed from orchard land to bare exposed rock and soil.

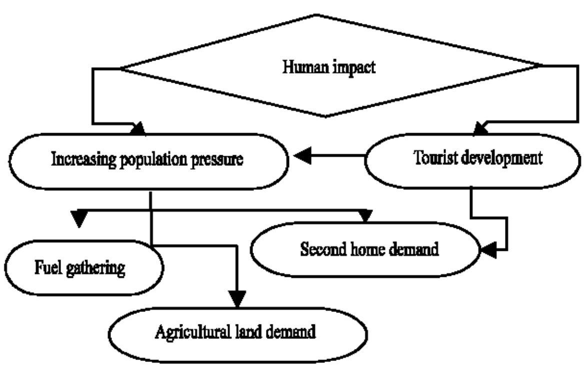

Fig. 3: Human impact and its major consequences in the vicinity of the Gulf of Edremit

If land degradation occurs as the result of human activities, maquis will be replaced by garrigue on lower lands. Brush and shrub land (maquis formations) are an important border between forest vegetation and human development. It can be hypothesized that the depletion of maquis formations will result in higher interaction between forest and human activities, leading to forest destruction. The Ida mountain national park was created to prevent such a disaster in 1994, protecting wild life and natural vegetation (Erdağ and Yayintaş, 1999). Field studies show that forest density increased after the establishment of the park. However, the same protection did not apply to brush and shrub rangeland.

Analyze show that the Edremit plain was covered by brush and shrub rangeland and orchard land in 1975 (Table 2). Changes in this area occurred in two distinct phases. First, Turkish national programs of 1980's gave incentive to replace brush and shrub rangeland with agriculture. Because of this, the area became more economically productive. Second, by the 1990's the land, unfortunately, was being taken over by real estate development. This resulted in a negative impact on traditional agricultural patterns, as well as on bordering wetlands near the coast, affecting vegetation and native and migratory wildlife.

The shifting of olive groves from the relatively alluvial plain to higher elevations has serious consequences for future land management. It is confirmed that the olive trees, being implanted the higher places over optimum grooving altitudes, are not growing and developing properly.

Development of second homes and buildings aimed at tourists are also irrevocably altering the landscape. Already, construction of the main highway (E 87, D 550) along the coast has altered drainage patterns within the study region, by impeding drainage from the alluvial plains toward the Aegean Sea. Bridges exist over creeks, but direct runoff and drainage from ephemerally flooded areas into the sea, is prevented by the raised levee on which the highway has been built. Insufficient and inadequate culverts exist for drainage past the road, increasing pounding and the presence of stagnant water to the north of the highway. Some of the rivers are also being canalized, entombed in concrete walls, in an engineering solution completely at odds with maintaining the natural processes of a river.

As developments continue to be built up the hill slopes, the issue of slope stability also needs to be raised. As construction of houses precedes further uphill, the region is increasingly subjecting itself to risks of overburdening the slopes.

Changes in landscape: To quantifying landscape pattern change, pattern metrics were calculated. From them, it can be concluded that: Landuse and landcover in each of the all landscapes was shown in Fig. 2. Water surface area dominated land use in all years. However, this dominance did not change, because of the fact that most water classes were seawater. The second most important land-use type in 1975 was brush and shrub rangeland. This dominance was progressively reduced by an increase in settlements (1975-2000). Both the year 1987 and 2000, the second most important land-use type was forest land. Its importance did not change so much from 1975 to 2000. Forestry was relatively unimportant in all four map-years, occupying between 20.2 and 20.4% of the total area. This indicates that there was a general decrease in brush and shrub rangeland. In 2000, brush and shrub rangeland decreased to 9% when orchard land increased to 20%. Also unfortunately, the bare exposed rock and soil, settlement areas and secondary residential areas had increased from 1975 to 2000.

Looking at the individual metrics in more detail, patch density, patch size, and variability metrics also serve as indicators of fragmentation processes within landscapes (Cumming and Vervier, 2002; Brown *et al*., 2006). NP and the PD show that brush and shrub rangeland fragmentation increased in the years 1975 to 2000. It had been observed that fragmentation in orchard land from 1975 to 1987 increased however from 1987 to 2000 it decreased. The reason for the increase in the number of patches in orchard land would have to be the ongoing activity in the secondary residential area. Settlement areas and secondary residential areas increased after the year 1975. In general, NP and PD at landscape level also show an increase of heterogeneity or the diversity gradient among landscapes. The landscape level, the number of patches (NP) showed a strong decline, as a consequence, MPS more than doubled.

LPI has been widely used as an indicator of landscape fragmentation. LPI decreases in both settlements (secondary residential area and settlement area) as deforested areas expand through time. The lignite pit determined the largest patch index (LPI) at the landscape level in 1975 and 1987, making up 5.1, 4.5 and 5.0%, respectively, of the entire landscape. Forestland made up the largest patch.

Another group of indicators of landscape fragmentation is represented by edge metrics (Bowersox and Brown, 2001). Significant changes were observed in either the TE or the ED in almost all the landscape classes except water surface areas and forest areas from 1975 to 2000. This shows that there was structural change in the area during that period. Conversely, the TE and ED have increased on the brush and shrub rangeland between 1975 and 1987. This shows that this landscape was under environmental pressure. When it comes to built-up lands, patch shapes of the secondary residential areas indicate the underdevelopment of urbanization in the area. This showed that study area was under constriction. ED has been increasing for secondary residential area, settlement area and bare exposed rock and soil as the process of occupation and LULCC advances. The landscape level metrics also show that the ED generally increased within the area of study from 1975 to 1987 most degradation time in the area. This, in turn, implies an increase in heterogeneity and that the landscape features were not organized. However, from 1987 to 2000, it increased slightly.

Shape metrics are as important as patch size metrics for the understanding of landscape configuration (McAlpine and Teresa, 2002). The shape metrics Landscape Shape Index (LSI) increased throughout the observed period. The Mean Shape Index (MSI) decreased from 1975 to 2000. For individual classes, LSI increased orchard land, cropland and pasture land, settlement area, secondary residential area and bare exposed rock and soil. Forest land and brush and shrub rangeland increased from 1975 to 1987 but decreased 1987 to 1975.

The Interspersion and Juxtaposition Index (IJI) results indicate that LULC classes were distributed among the available patch types at about ~70-90% of the maximum possible equitable distribution in landscape in all three periods. This shows that the classes were distributed randomly and that the spatial pattern is not homogeneous. The IJI increased from 1975 to 2000, indicating more uniform landscape configuration. Simpson's Diversity Index (SHDI) increased from 1975 to 1987, but stayed same between 1987 and 2000. Contagion index (CONTAG) decreased 14% from 1975 to 2000. These indices mean that, the landscape in the year 2000 was more diverse than the landscape in the year 1975.

DISCUSSION

LULCC, land and natural ecosystem degradation, erosion, loss of vegetation cover and the potential loss of agricultural resources are the main concerns facing the foothills of Mt. Ida and the vicinity of Gulf of Edremit. Some of the changes that appear to have taken place between 1975 and 2000 are directly related to degradation processes, namely:

The results of the landscape metrics analysis demonstrate the accelerated form which deforestation had taken place from 1975 to 2000. LPMs represent that LULC change from brush and shrub rangeland to orchard land being dominant with olive agriculture through secondary residential area or deforestation and that exposed rock and soil to cropland and pasture land through secondary residential area or deforestation. The IJI scores suggest that there was not only fragmentation but increasing interdigitation of classes. It can be conclude that human impacts on the landscape of the year 2000 and 1987 were higher than on the landscape of the year 1975, when the land was in a more natural state.

On the other hand, some of the changes observed in Edremit plain had a positive effect with respect to land degradation: A conversion or rehabilitation of 6% of the exposed rock and soil during 1975 to 1987 to cropland and pasture land (519 ha) and orchard land (53 ha). A conversion or rehabilitation of 11% of the exposed rock and soil during 1987 to 2000 to cropland and pasture land (815 ha) and orchard land (519 ha).

LULCC affect the environment since rapid development along Turkey's western and southern coasts has been ongoing since the start of the tourist boom in 1970s (Fig. 2). Same as study area, over the last few decades, farmers in Lesbos have partly turned to tourism and tourism related activities while complementing their income from olive cultivations (Loumou *et al*., 2000). Because of this, only a relatively small percentage of olive groves were lost in this Greece Island. This means that study area is under the same danger loss of olive groves and their conversion to pasture due to their location in inaccessible mountainous areas as other Mediterranean areas.

Olive cultivation and production is the main economic activity in the region. But the olive trees with other natural vegetation have been cleared and replaced with secondary homes along the coastal zone and lowlands of the Mt. Ida. Over the last few decades, farmers in Edremit have partly turned to tourism and tourism related activities while complementing their income from olive cultivations. The increase in urban land is partly because of tourism, but mainly takes places in areas near the gulf where the population is increasing. This is most importing change related to degradation. The most dramatic change is that the area of built-up land increased more rapidly than the population. Population increased 0.7 times in the all study area; however the extent of built-up land was increased 18 times.

Two factors are introducing instability into the region's natural environment. Red pine trees, which are dominant vegetation in the region and brush and shrub rangelands, which are natural border for Kazdağ National Park, had been replaced with olive groves at 200-400 m, while secondary houses and tourist developments have exploded at coastal zone over the last 30 years.

Irtem and Karaman (2004) explains the tourism's causing the degradation on olive agriculture areas like this: The coast sides, which were covered with olive trees, are filled with secondary residences now. With a simple calculation, a tree's giving 6 kg of olive oils in average per year; 18000 tons of olive oils will be gained from average 3 million trees, which were cut. One kilogram of olive oil in European countries is between € 1, 5 and 1, 7 € in average. The region has 1, 5 x 18000000 = 27.300.000 Euro loss per year. This value is nearly 9 times bigger than the tourism income of the region. The landcover change analyses, made in the region in periods between 1975-2000, show that the land degradation is in a continuing progress. It is certain that if the necessary cautions are not taken, these big economical problems will go on exponentially that land degradation causes.

There is not enough effort for planned development in the vicinity of the Gulf of Edremit region and that sustainable development is currently not sought at all. The region can lead irreversible environmental degradation, as has already been noticed along the southern coasts of Turkey. An ecologically sustainable development plan should be prepared and implemented for the region.

A proper inventorying of the natural and cultural resources in the Edremit region needs to be performed in order to implement sustainable development. This inventorying needs to include not only the potential for economic development through tourism and the growth of secondary residential areas, but also of the agricultural potential of the region, its natural environment and its cultural heritage-traditional agricultural activities such as olive growing.

Also, in the study area, soil is being irreversibly lost and degraded as a result of increasing and often conflicting demands from nearly all tourism sectors. Pressures result from the concentration of population and activities in localized areas, economic activities and changes in landuse. It can be hypothesized that when land degradation happened in the area, soil sealing, which is the covering of the soil surface with an impervious material or the changing of its nature so that the soil becomes impermeable, became another problem. As with the study area, over the past 20 years, much of Europe has seen the same problems of soil loss, degradation and sealing. Socio-economic factors in many countries have outstripped calls for sustainable development.

Implications and suggestions for future development: Natural environmental changes, land and natural ecosystem degradation, vegetation cover change and the potential loss of agricultural resources are the main concerns facing the Gulf of Edremit. Socio-economic forces are a significant contributor to changes being experienced in the natural environment of the Gulf of Edremit. A common pattern of change in the natural vegetation and ecological degradation is the altitudinal stratification of vegetation by the increasingly intensive landuse.

The impacts of human activity are clearly seen on the natural environment in both the Lower- and Oro-Mediterranean zones. Poor landuse practices have transformed the regional landscapes of the Lower-Mediterranean zone, putting intense pressure on land by removing and eliminating most pre-existing vegetation. Consequently, changes in landuse (e.g., forestry to agriculture, agriculture to residential, residential to tourism) and its associated impacts represent the primary mechanism resulting in the degradation of the natural ecosystems in the region. Altering the natural vegetation and moving olive groves to higher, steeper regions, thusly decreasing pine tree coverage, cannot be considered sustainable development in any form. The long-term effects of this trend include increasing soil erosion rates, declining biodiversity and the impoverishment of local farmers.

Simultaneously, secondary houses and building constructions for tourism on agricultural lands may eventually sprawl across much of the coastal zone of the area. Also, the decreasing occurrence of pine and olive tree areas may also induce adverse socio-economic impacts as the local economy adapts to changing markets. Overall, an inventory of potential problems facing the Gulf of Edremit includes the following: loss of forest resources, loss of prime agricultural lands, short term socio-economic restructuring and accelerating land degradation.

Nevertheless, developing and implementing sustainably oriented landuse policies and planning can mitigate all of these problems. Three primary strategies need to be investigated in terms of their efficiency and effectiveness in terms of their concerns facing the Gulf of Edremit. First, conservation of existing vegetative cover can be facilitated by controlling the logging of existing *Pinus brutia, Quercus infectoria* stands. Sustainable yields should not be exceeded. Second, sustainable farming techniques need to be incorporated into the olive industry. Third, the location and construction of second homes and tourist facilities should be concentrated in convenient locations, but face environmental impact assessment in order to minimize the impacts of each development on the natural environment. In implementing these strategies, a regional approach is advocated, with the individual communities needing to coordinate their efforts, pooling their resources and interfacing their landuse policies and plans. Models for evaluating of ecosystem health for sustainable development using GIS and RS technologies currently exist (Rapport et al., 1995) and should be implemented as a framework for managing a regional approach.

CONCLUSION

In this research, identifying the interrelationship between landuse and landcover (LULC) change and land degradation, using remotely sensed data in the vicinity of the Gulf of Edremit and the southern lowlands of the Mt. Ida, NW Turkey was aimed. This study demonstrates the effectiveness of the remote sensing and GIS technologies in detecting, mapping and monitoring the LULC change. The results of the study suggest that the use of landscape ecology metrics calculated from remotely sensed imagery as indicators of LULC change helped determine the intensity of the quality of landscape. Based on land cover classification and calculation of LPMs, it is clear that there have been changes in LULC in southern lowlands of the Mt. Ida, NW Turkey from 1975 to 2000. Analysis represent that LULC change from brush and shrub rangeland to orchard land dominated by olive groves through secondary residential area or deforestation and that exposed rock and soil to cropland and pasture land through secondary residential area or deforestation. In general, there was an increase in the residential areas between 0-200 m, where the optimum growing area of olive and an increase in the land degradation in the region during the study period. However, we could not link remotely sensed data on landcover and landuse with appropriate socio-economic data being measured in the study area due to lack of socio-economic data. The outcome of this type of studies represents a valuable resource for decision makers to guard against changing the agricultural land to the residential and touristic establishments and for future development projects in the study area in the Southern part of Mt. Ida.

REFERENCES

Barbier, B., 1998. Induced innovation and land degradation: Results from a bioeconomic model of a village in West Africa. Agric. Econ., 19: 15-25.

Benhin, J.K.A. and E.B. Barbier, 2001. The effects of the structural adjustment program on deforestation in Ghana. Agric. Resour. Econ. Rev., 30: 66-80.

Bowersox, M.A. and D.G. Brown, 2001. Measuring the abruptness of patchy ecotones: A simulation-based comparison of patch and edge metrics. Plant Ecol., 156: 89-103.

Brown, D.G., R. Aspinall and D.A. Bennett, 2006. Landscape models and explanation in landscape ecology-A space for generative landscape science, The Professional Geographer, 58: 369-38.

Crews-Meyer, K.A., 2001. Assessing landscape change and population-environment interactions via panel analysis. Geocarto Int., 16: 69-80.

Crews-Meyer, K.A., 2004. Agricultural landscape change and stability in northeast Thailand: Historical patch-level analysis. Agric. Ecosyst. Environ., 101: 155-169.

Crews-Meyer, K.A., P.F. Hudson and R. Colditz, 2004. Principle component analysis for aid in change detection: Assessing geomorphological change of the Rio Panuco, Mexico, Geocarto Int., 19: 1-12.

Cumming S. and P.Vervier, 2002. Statistical models of landscape pattern metrics, with applications to regional scale dynamic forest simulations. Landscape Ecol., 17: 433-444.

Erdağ, A. and A. Yayıntaş, 1999. A Contribution to the Moss Flora of Western Turkey: Moss Flora of the Kaz Mountain (Balikesir, Turkey), Turkish J. Bot., 23:117-125.

Hatfield, J.L. and P.J. Pinter-Jr, 1993. Remote sensing for crop protection. Crop Prot., 12: 403-413.

Irshad, M., M. Inoue, M.A. Faridullah, H.K.M. Delower and A. Tsunekawa, 2007. Land desertification-an emerging threat to environment and food security of Pakistan. J. Applied Sci., 1: 7.

Irtem, E. and E. Karaman, 2004. The effect of tourism activities along Edremit-Kucukkuyu region on the coastal area and proposed management program. ITUdergisi/d mühendislik, 3: 3-14.

Irtem, E., S. Kabdasli and N. Azbar, 2005. Coastal zone problems and environmental strategies to be ýmplemented at Edremit Bay, Turkey. Environ. Manage., 36: 37-47.

Jensen, J.R., 1996. Introductory Digital Image Processing: A Remote Sensing Perspective. 2nd Edn., Prentice-Hall, Upper Saddle River, NJ, pp: 316.

Kwarteng, A.Y. and P.S. Chavez-Jr., 1998. Change detection study of Kuwait City and environs using multitemporal Landsat Thematic Mapper data. Int. J. Remote Sens., 19: 1651-1662.

Liu, H. and Q. Zhou, 2004. Accuracy analysis of remote sensing change detection by rule-based rationality evaluation with post-classification comparison. Int. J. Remote Sens., 25: 1037-1050.

Loumou, A., C.H. Giourga, P. Dimitrakopoulos and S. Koukoulas, 2000. Tourism contribution to agro-ecosystems conservation; the case of Lesbos Island, Greece. Environ. Manage., 26: 363-370.

Lu, D., P. Mausel, E. Brondio and E. Moran, 2004. Change detection techniques. Int. J. Remote Sens., 20: 2365-2407.

Macleod, R.D. and R.G. Congalton, 1998. A quantitative comparison of change-detection algorithms for monitoring eelgrass from remotely sensed data. Photogrammetric Eng. Remote Sens., 64: 207-216.

Maiangwa, M.G., A.O. Ogungbile, J.O. Olukosi and T.K. Atala, 2007. Land degradation: Theory and evidence from the North West Zone of Nigeria. J. Applied Sci., 7: 785-795.

McAlpine, C.A. and J.E. Teresa, 2002. Testing landscape metrics as indicators of habitat loss and fragmentation in continuous eucalypt forests (Queensland, Australia), Landscape Ecol., 17: 711-728.

McGarigal, K. and B.J. Marks, 1995. Fragstants: Spatial Analysis Program for Quantifying Landscape Structure. Usda Forest Service General Technical Report PNW-GTR-351, Oregon, USA.

Messina, J.P., K.A. Crews-Meyer and S.J. Walsh, 2000. Scale Dependent Pattern Metrics and Panel Data Analysis as Applied in a Multiphase Hybrid Landcover Classification Scheme. Proceedings of the American Society of Photogrammetry and Remote Sens., ASPRS conference in 2000, Miami, FL, USA.

Oetter, D.R., W.B. Cohen, M. Berterretche, T.K. Maiersperger and R.E. Kennedy, 2000. Land cover mapping in an agricultural setting using multiseasonal Thematic Mapper data. Remote Sens. Environ., 76: 139-155.

Rapport, D.J., W.G. Whitford and K. Korporal, 1995. Evaluating ecosystem health: Opportunities for GIS. Proceedings of Ninth Annual Symposium on Geographic Information Systems, March 27-30, 1995. Vancouver, BC, Canada.

Sesli, M. and A. Tokmakoğlu, 2006. Olive Existence in Akhisar District in Manisa Province in Turkey. J. Applied Sci., 6: 2849-2852.

Song, C., C.E. Woodcock, K.C. Seto, M.P. Lenney and S.A. Macomber, 2001. Classification and change detection using Landsat TM data when and how to correct atmospheric effects. Photogrammetric Eng. Remote Sens., 75: 230-244.

Thornes, J., 1996. Desertification in the Mediterranean. In: Mediterranean Desertification and Land Use. Brandt, J. and J. Thornes (Eds.), Chichester: Wiley, pp: 1-12.

Tsiligirides, T.A., 1998. Remote sensing as a tool for agricultural statistics: A case study of area frame sampling methodology in Hellas. Comput. Electron. Agric., 20: 45-77.

Tzatzanis, M., T. Wrbka and N. Sauberer, 2003. Landscape and vegetation responses to human impact in sandy coasts of Western Crete, Greece. J. Natssss Conserv., 11: 187-195.