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

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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 landcover 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 complexity 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 Tokmakoglu, 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.

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MATERIALS AND METHODS

Study site: This study focuses on the Gulf of Edremit and southern lowlands of Mt. Ida, extending from Kucukkaya 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 km². 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, Altnoluk, Burhaniye, Havran and Zeytili). 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 faginea) and maquis strawberry tree (Arbutus unedo), eastern strawberry tree (Arbutus andrachne), large leaved jasmine (Philyrea latifolia) and kernsys oak (Quercus cocciifera) 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
(i) 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 misregistration on 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 (RMSE) for the images were ~0.78
pixel error, less than 1 pixel.

The images were co-registered using a master/slave
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
attributions. 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
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 occurred 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 (PLAN), Edge Density (ED), Total Edge (TE), Patch Numbers (NP), Patch Density (PD), Largest Patch Index (LP), Landscape Shape Index (LSI), Mean Shape Index (MSI), Area Weighted Mean Shape Index (AWMSI), Mean Patch Size (MPS), Shannon’s Diversity Index (SHD), 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: Landscape and landcover change area of the southern lowland of the Mt. Ida (ha) |
|-----------------------------|----------|----------|----------|
| 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: Landscape and landcover change area of Edremit Plain (ha) |
|-----------------------------|----------|----------|----------|
| 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      | 59       |
| Cropland and pasture land to secondary residential area | 18        | 70       | 29       |

| Table 3: Units, range and purposes of use for the landscape pattern indices |
|-----------------------------|----------|----------|
| Indices                     | Range    | Purpose |
| Area metrics                | 0 < PLAN < 100 | To quantify landscape composition |
| Edge metrics                | ED < 0   | To measure energy flow and connection between landscapes |
| TE < 0                      |           | |
| Patch density               | NP < 1   | To measure fragmentation and variability in the landscape |
| Size                        | PD < 0   | |
| Variability Metrics         | LPI < 100 | To determine patch shapes in the landscape |
| MPS < 0                     |           | |
| Shape metrics               | LSI < 1  | To quantify landscape composition by measuring richness and evenness of patch types |
| Diversity metrics           | MSI < 1  | |
| Contagion and interspersion metrics | IJI < 100 | To quantify landscape configuration |
| CONTAG < 100                |           | |

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

<table>
<thead>
<tr>
<th>Variables</th>
<th>PLAND (%)</th>
<th>NP No.</th>
<th>PD (%)</th>
<th>LPI (%)</th>
<th>TE (m)</th>
<th>ED (m ha⁻¹)</th>
<th>IJI (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water-surface area</td>
<td>31.4</td>
<td>319</td>
<td>0.2</td>
<td>0.2</td>
<td>8,564,460</td>
<td>66.4</td>
<td>107</td>
</tr>
<tr>
<td>Forest land</td>
<td>20.2</td>
<td>2398</td>
<td>1.9</td>
<td>5.1</td>
<td>6,422,800</td>
<td>50.1</td>
<td>102</td>
</tr>
<tr>
<td>Brush and shrub rangeland</td>
<td>23.4</td>
<td>5629</td>
<td>4.4</td>
<td>1.2</td>
<td>8,856,000</td>
<td>69.1</td>
<td>130</td>
</tr>
<tr>
<td>Orchard land</td>
<td>16.7</td>
<td>3863</td>
<td>3.0</td>
<td>1.3</td>
<td>6,264,420</td>
<td>48.9</td>
<td>108</td>
</tr>
<tr>
<td>Croplands and pasture land</td>
<td>0.5</td>
<td>417</td>
<td>0.3</td>
<td>0.0</td>
<td>247,380</td>
<td>1.9</td>
<td>25</td>
</tr>
<tr>
<td>Settlement area</td>
<td>0.2</td>
<td>144</td>
<td>0.1</td>
<td>0.0</td>
<td>112,920</td>
<td>0.9</td>
<td>17</td>
</tr>
<tr>
<td>Exposed rock and soil</td>
<td>7.6</td>
<td>3582</td>
<td>2.8</td>
<td>0.0</td>
<td>3,510,480</td>
<td>27.4</td>
<td>90</td>
</tr>
</tbody>
</table>

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

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

<table>
<thead>
<tr>
<th>Variables</th>
<th>PLAND (%)</th>
<th>NP No.</th>
<th>PD (%)</th>
<th>LPI (%)</th>
<th>TE (m)</th>
<th>ED (m ha⁻¹)</th>
<th>IJI (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water-surface area</td>
<td>31.5</td>
<td>364</td>
<td>0.5</td>
<td>0.9</td>
<td>8,538,420</td>
<td>66.7</td>
<td>107</td>
</tr>
<tr>
<td>Forest land</td>
<td>20.5</td>
<td>4119</td>
<td>3.2</td>
<td>4.5</td>
<td>7,086,060</td>
<td>55.3</td>
<td>111</td>
</tr>
<tr>
<td>Brush and shrub rangeland</td>
<td>18.5</td>
<td>10683</td>
<td>8.3</td>
<td>0.2</td>
<td>8,514,540</td>
<td>66.5</td>
<td>140</td>
</tr>
<tr>
<td>Orchard land</td>
<td>15.9</td>
<td>7443</td>
<td>5.8</td>
<td>0.6</td>
<td>6,798,400</td>
<td>53.1</td>
<td>120</td>
</tr>
<tr>
<td>Cropland and pasture land</td>
<td>2.9</td>
<td>2660</td>
<td>2.1</td>
<td>0.0</td>
<td>1,526,220</td>
<td>11.9</td>
<td>63</td>
</tr>
<tr>
<td>Settlement area</td>
<td>0.6</td>
<td>784</td>
<td>0.6</td>
<td>0.0</td>
<td>3,507,600</td>
<td>2.7</td>
<td>32</td>
</tr>
<tr>
<td>Secondary residential area</td>
<td>0.5</td>
<td>701</td>
<td>0.5</td>
<td>0.0</td>
<td>293,340</td>
<td>2.3</td>
<td>29</td>
</tr>
<tr>
<td>Exposed rock and soil</td>
<td>9.6</td>
<td>8147</td>
<td>6.4</td>
<td>0.0</td>
<td>4,944,900</td>
<td>38.6</td>
<td>113</td>
</tr>
</tbody>
</table>

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

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

<table>
<thead>
<tr>
<th>Variables</th>
<th>PLAND (%)</th>
<th>NP No.</th>
<th>PD (%)</th>
<th>LPI (%)</th>
<th>TE (m)</th>
<th>ED (m ha⁻¹)</th>
<th>IJI (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water-surface area</td>
<td>31.6</td>
<td>310</td>
<td>0.2</td>
<td>0.9</td>
<td>8,541,540</td>
<td>66.7</td>
<td>107</td>
</tr>
<tr>
<td>Forest land</td>
<td>20.4</td>
<td>3996</td>
<td>3.1</td>
<td>5.0</td>
<td>6,951,720</td>
<td>54.3</td>
<td>109</td>
</tr>
<tr>
<td>Brush and shrub rangeland</td>
<td>8.9</td>
<td>8431</td>
<td>6.6</td>
<td>0.0</td>
<td>4,681,740</td>
<td>36.6</td>
<td>111</td>
</tr>
<tr>
<td>Orchard land</td>
<td>20.0</td>
<td>6517</td>
<td>5.1</td>
<td>1.4</td>
<td>7,874,940</td>
<td>61.5</td>
<td>124</td>
</tr>
<tr>
<td>Cropland and pasture land</td>
<td>2.0</td>
<td>2073</td>
<td>1.6</td>
<td>0.0</td>
<td>1,095,450</td>
<td>8.6</td>
<td>54</td>
</tr>
<tr>
<td>Settlement area</td>
<td>2.4</td>
<td>2200</td>
<td>1.7</td>
<td>0.0</td>
<td>1,263,000</td>
<td>9.9</td>
<td>28</td>
</tr>
<tr>
<td>Secondary residential area</td>
<td>2.0</td>
<td>2541</td>
<td>2.0</td>
<td>0.0</td>
<td>1,146,600</td>
<td>9.0</td>
<td>57</td>
</tr>
<tr>
<td>Exposed rock and soil</td>
<td>12.7</td>
<td>8367</td>
<td>6.5</td>
<td>0.1</td>
<td>6,038,820</td>
<td>47.2</td>
<td>120</td>
</tr>
</tbody>
</table>

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

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

<table>
<thead>
<tr>
<th>Date</th>
<th>NP No.</th>
<th>PD (% of 100 ha)</th>
<th>LPI</th>
<th>MPS (ha)</th>
<th>TE (m)</th>
<th>ED (m ha⁻¹)</th>
<th>IJI (%)</th>
<th>CONTAG (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>34435.0</td>
<td>26.9</td>
<td>3.0</td>
<td>3.7</td>
<td>18799680</td>
<td>148.6</td>
<td>112.5</td>
<td>1.3</td>
</tr>
<tr>
<td>1987</td>
<td>34901.0</td>
<td>27.3</td>
<td>4.5</td>
<td>3.6</td>
<td>19026360</td>
<td>148.6</td>
<td>134.1</td>
<td>1.3</td>
</tr>
<tr>
<td>1975</td>
<td>16352.0</td>
<td>12.8</td>
<td>5.1</td>
<td>7.8</td>
<td>16959240</td>
<td>123.2</td>
<td>119.5</td>
<td>1.6</td>
</tr>
</tbody>
</table>

NP: Patch Numbers; PD: Patch Density; LPI: Largest Patch Index; MPS: Mean Patch Size; TE: Total Edge; ED: Edge Density; IJI: Landscape Shape Index; JJI: 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 tourism 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.

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 Yaymam, 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 growing 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 ephemeral 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.

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

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**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 51.1, 45.5 and 5.0%, respectively, of the entire landscape. Forest land 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 IIJ scores suggest that there was not only fragmentation but increasing interdigitiation 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 important 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 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.

İtem 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 impermeable 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 Ori-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**

