Vikas Nagar, Lucknow, INDIA
editor@jeb.co.in
Full paper available on: www.jeb.co.in

J. Environ. Biol.
33, 439-447 (2012)
ISSN: 0254-8704
CODEN: JEBIDP

Land use and land cover change detection in Karinca river catchment (NW Turkey) using GIS and RS techniques

Author Details

Recep Efe (*Corresponding author*)	Department of Geography, Faculty of Arts and Sciences, University of Balikesir, 10145 Balikesir - Turkey e-mail: recepefe@hotmail.com
Abdullah Soykan	Department of Geography, Faculty of Arts and Sciences, University of Balikesir, 10145 Balikesir - Turkey
Isa Curebal	Department of Geography, Faculty of Arts and Sciences, University of Balikesir, 10145 Balikesir - Turkey
Suleyman Sonmez	Department of Geography, Faculty of Arts and Sciences, University of Balikesir, 10145 Balikesir - Turkey

Publication Data

Paper received:
17 October 2010

Revised received:
16 July 2011

Accepted:
30 July 2011

Abstract

The basin of Karinca river, in the north-west of Turkey, covers an area of 29,840 ha. Pronounced changes in land use emerged as a result of the development of activities in the tourism sector in Turkey in the 1970's. The basin has been significantly affected in the course of this process. This study was conducted in order to determine the land use changes (as well as the type of changes and their direction) occurring in the use of land in the Karinca river catchment for the period 1979-2007. The geographical data were gathered by using 1:25000 scale topographical maps as a basis. Thus, the existing soil and land use data from 1979 were processed on these bases and the the main materials rendering the land use were produced. Geometric verification was made by putting the previously prepared bases onto landsat ETM+ and satellite images of 2007. In the final stage, results pertaining to the changes in land use were obtained by overlapping the two sets of data. All processes were done using the ArcGIS Desktop v9.x program. According to the data of the year 1979, the catchment area consisted of 43.4% forest, 26.5% grassland, 18.3% olive groves, 10.6% agriculture and 1.2% built-up lands. Comparing these coverage with the data of 2007, show a clear shift among residential areas, olive groves and forest terrain. It was found that the agricultural areas, particularly along the shoreline, were converted into resort houses and that the olive groves (the dominant land use) shifted from lower regions to its upper sectors. All these changes caused loss of natural habitats leading to degradation.

Key words

Turkey, Land use change, Land degradation, Geographical information systems, Remote sensing

Introduction

Land degradation and soil erosion together represent important problems in the Mediterranean Region as a result of intense human pressure. Land degradation is a complex issue due to the co-existence of various causes at different levels. Mediterranean region is characterized by fragile natural ecosystems, with insufficient rainfall for suitable vegetation recovery. These areas suffer especially from serious processes of degradation frequently originated by anthropogenic factors (Ozturk *et al.*, 2002; Aranda and Oyonarte, 2006)

The main reasons of land degradation and soil erosion are landuse change (Gomez *et al.*, 2007), destruction of vegetation, forest fires (Cerda and Doerr 2005; Tedim, 2008), overgrazing and tourist development (Cerda, 1997, 2007; Symeonakis *et al.*, 2004). Climatic and geomorphologic conditions of the area have an accelerating impact on land degradation (Efe, 2005).

In the past two centuries the impact of human activities on the land in the Mediterranean region has grown enormously, altering entire landscapes and ultimately affecting the earth's nutrient and hydrological cycles as well as climate (Cerda, 1997; De Sherbinin, 2002; Crews-Meyer, 2001).

Over the last few decades, in Mediterranean region, agriculture has also added pressure on the ecosystems as forests and natural vegetation have been cleared for croplands and livestock populations increased (Loumou *et al.,* 2000, Olszewski, 1993;

Special Issue - **Environment and Geography in the Mediterranean**
Guest Editors - **Dr. Recep Efe, Dr. Munir Ozturk and Dr. Sumati Gaumat**

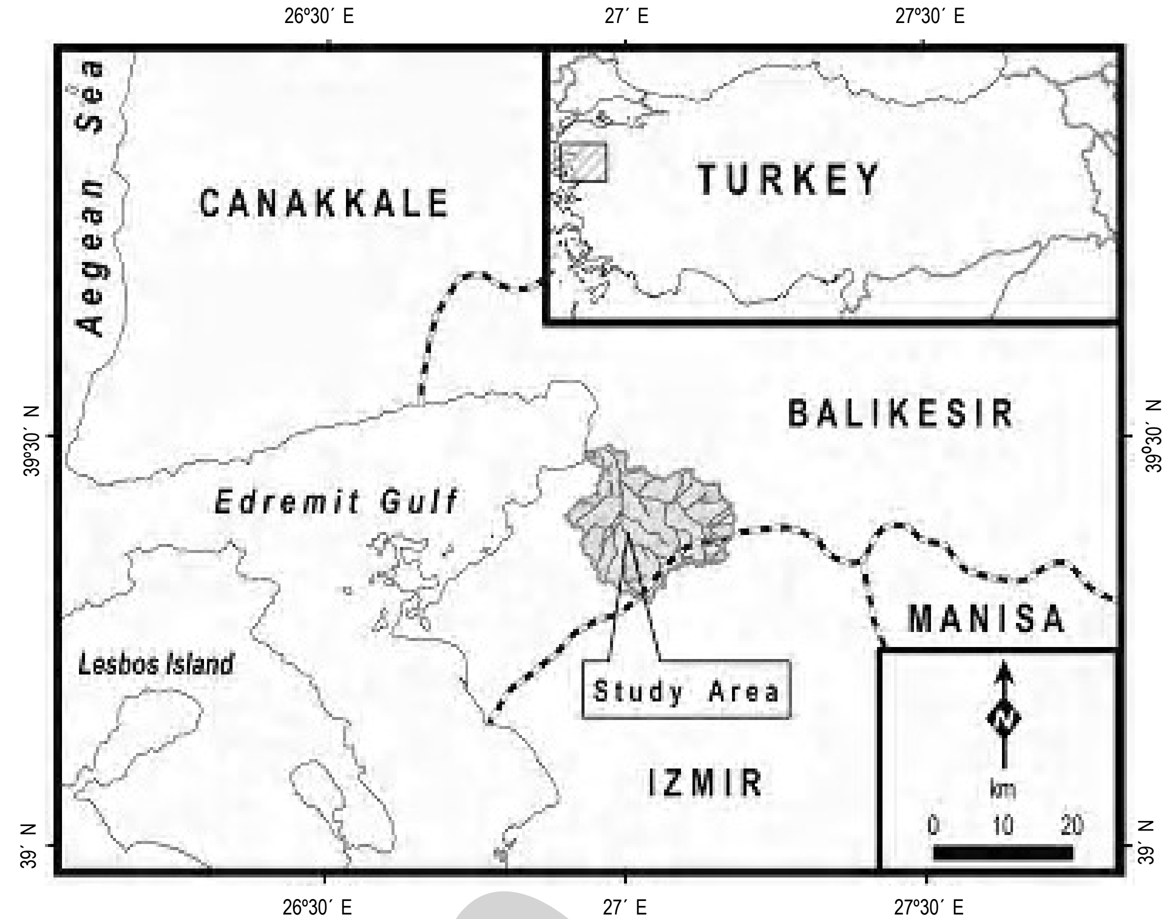

Fig. 1: Location of the study area

Cardille and Foley, 2003). These factors explain very clearly the rapid and intense degradation of soil and land, which can easily be observed nowdays as much as over history.

Rapid land-use change has taken place in the Mediterranean region of Turkey over the last three decades as a result of human activities. Most of these changes are due to the demand for agricultural land, tourism facilities and more income. Land-use change due to resort houses, tourism development on the coastal areas of Turkey, has also caused a loss of wetlands and agricultural lands (Efe, 2000; Atalay and Mortan, 2006; Cerda, 2007). Until the middle of 20th century, the population density on the coastal regions was very low but, it increased tremendously after 1970 (Efe *et al*., 2008a,b). For example, in Istanbul (1994-2000) the largest increase took place in settlement areas (1,720.2 ha - 4.76%) whereas the greatest decrease occurred in the other non-forest areas (1,684.9 ha - 4.67%) rather than in forest lands for 6 year period (Yener and Koc, 2006).

The Karinca river watershed covers about 29,840 ha in Western Turkey on the Aegean sea coast. Land uses within the watershed are rural, agricultural, urban, industrial and forest. The distribution of land cover has changed significantly over the past 30 years as there has been a decrease in crop land for olive agriculture and urban development.

The objectives of this study was to analyze land use change and to explore the interaction between these changes and the environment in the Karinca river basin in Balikesir province in the Western Turkey over a 28 year period from 1979 to 2007.

Materials and Methods

The study area: The study area is located between 26º55´ and 27º02´ E longitudes and 39º17´and 39º28´ N latitudes in the northwest of Turkey (Fig. 1). The area covers roughly 29,840 ha and is predominantly used in agriculture, mainly for olive growing. However, there are surfaces covered by native origin grasslands and forests. The Karinca river basin is surrounded by higher lands (Mt. Sabla 1,110 m, and Mt. Yaylacikdede 1,220 m) on the east and south. The altitude of the study area ranges between 0 and 1,223 m.

There are different rock types belonging to Paleozoic, Mesozoic, Tertiary and Quaternary in the study area. The site is found at south of one of the major exposures of igneous rocks such as granite and granodiorite. These are the oldest lithological units that are recognized in the area. These rocks are surrounded by metamorphic rocks (Ercan, 1984). Neogene igneous rocks such as dacite, basalt and tuffs lie to the north of the area. Neogene lake sediments are found on the low plateaus. Alluviums widely occur on the low land of coastal plain.

The Karinca river basin is surrounded by hill ranges of 900 to 1,223 m altitudes with their upper parts morphology, developed in igneous and metamorphic rocks. The Karatas, Sabla and Yaylacik hills at the south and southeast limit of the area are examples of the typical geomorphologic features of the area. In this sector, there are some remarking elevations such as Karatas hill (1,223 m), Yaylacik hill (1,220 m), Çalkaya hill (1,176 m) and Sabla Hill (1,110 m) which constitutes watershed of the basin. Average height of the basin is about 400 m. Areas where the height ranging between 100 and 200 m constitute 21.7% of the basin. Each elevation steps between 0 and 900 m takes 9% of the area.

On the mountainside of the basin where inclination is high there occur Entisols, and in the flat areas there appears Mollisols, and in hillsides there occurs Inceptisols. The Entisol is formed on the deposited alluvium, Mollisol is formed near Neogene lake deposits, and Inceptisol is formed on the volcanic and metamorphic rocks of the basin. The soil depths in Entisol and Mollisol is greater, but comparatively less in Inceptisols. The soil depth changes prominently depending on inclination, vegetation cover and use of land.

The Mediterranean climate in which the summers are hot and dry and the winters are rainy and warm prevail in the study area. There are 20 settlements in the Karinca Basin, and population as a whole is about 40000. Seventy perccent of the people living in the area make their living through agricultural production. Olive, cereal, pulses, vegetable and fruit are the staples produced in the area. In the region where olive agriculture is common, there are 18 olive-oil factories. In Ören, which is in the coastal region, there are many summerhouses, so the population increases substantially in the summer period.

Land use/land cover (LU/LC) data were derived from a time series of historic topographical and land use maps of the study area. The data produced in this study was obtained by manipulating the land data of different years on computer. The first data of the study area dates back to 1979, and consists of land asset dated-maps belonging to Balikesir and Izmir provinces. The other data being compared with the first field data is the 2007 dated satellite image. Besides, 1:25,000-scaled topographic maps were used as a base to compare and control different-scaled scales.

At the first stage of study, topographic maps were transferred to the digital format base maps. These toposheets, by considering corner points of each map chart sheet, were coordinated as UTM (Universal Transverse Mercator - European Datum, 1950). Thus, the maps were edge matched in one coverage using ArcGIS Desktop v.9x software and its extensions. Geographic characteristics of the basin such as rivers, basin boundary, elevation points and contour lines were transformed separately in point and polyline layers by on screen digitizing process.

A 1979-land assets map was also transferred to digital format georeferenced as UTM based on obvious points, derived from the topographic sheets, thus two different maps were overlapped. Later, land use map was elaborated by on screen digitizing process. After this process, land use types, distribution and the land values in hectare type were obtained (Fig. 2 and Table 1).

Multispectral Enhanced Thematic Mapper Plus (ETM+) satellite-image from multi-band sensors was preferred to determine the land use in the basin in 2007. ERDAS IMAGINE v.8x software was used to process satellite-image. The satellite image was rectified geometrically to be compared with the previous land assets data. Ground control points (GCPs) were used in the geometric correction using the standard map projection (*i.e.* Universal Tranvese Mercator – UTM). The value of the root mean square error (RMS) was less than 1.

Unsupervised classification technique was applied to process satellite image using Iterative Self-organizing analysis technique (ISODATA) of Landsat ETM+ image. It resulted in differentiating the classes of forest, olive, agriculture, grassland and bareland and settlements on bases of previous land asset data, topographic maps and land studies. The data comprising land coverage categories were united by cluster analysis order. By transforming the united data into polygon format, land use types, distribution and the land values they cover in hectare were obtained as shown in Fig. 3 and Table 2.

The difference and change amount between the two data shown in Table 3 was calculated by comparing multi-temporal land use values. Later, intersect points were determined by overlapping land use layers to determine the change and cycle in land use, and the data shown in Fig. 4 and Table 4, 5, 6 and 7.

In the last stage of study, data belonging to the changes occurred in land use and data obtained in field studies were brought together and explained.

Results and Discussion

According to the land use data in 1979, the basin consisted of 43.4% forest, 26.5% grassland, 18.3% olive, 10.6% cropland areas. The remaining small areas were settlements and wetland area (Table 1 and Fig. 2). According to the land use data of 2007, the basin consisted of these: 44.2% forest, 25.4% olive, 20.7% grassland, 7.9% agriculture areas. The remaining 1.8% represented by settlements (Table 2 and Fig. 3.) In the period between 1979 and 2007, explicit changes occurred in land use that is in the research area. In this period, while fields covered by some land use types had expanded, some others had decreased. The most explicit change occurred in the olive groves representing an area of 2,125 ha, replaced by construction. Changed area of

Table - 1: Land use changes between 1979 (land registration data) and 2007 (Landsat ETM+ satellite image)

Land use	Area (ha)		Change(ha)
	1979	2007	
Forest	12,949	13,182	233
Grassland	7,908	6,163	- 1,745
Olive	5,465	7,590	2,125
Cropland	3,165	2,351	- 814
Built-up land	349	552	203
Wetland	4	0	- 4
Total Area	29 840	29 838	-2

Table - 2: Sources of land use shifting into and out of Cropland, 1979 to 2007

Land use	Shifts	Area (ha)
Cropland to	Olive	648
	Built-up land	169
	Total	817
Olive to	Cropland	3
	Total	3
	Change	- 814

Table - 3: Sources of land use shifting into and out of Grassland, 1979 to 2007

Land use	Shifts	Area (ha)
Grassland to	Forest	1,339
	Olive	881
	Built-up land	29
	Total	2,249
Forest to	Grassland	488
	Olive	14
	Wetland	2
	Total	504
	Change	- 1,745

Table - 4: Sources of land use shifting into and out of Forest land, 1979 to 2007

Land use	Shifts	Area (ha)
Forest to	Olive	618
	Grassland	488
	Total	1,106
Grassland to	Forest	1,339
	Total	1,339
	Change	233

grassland represents 1,745 ha. In the stated period, the whole Karince river basin has decreased by 2 ha because of the lands converted into sea from wetland areas (Table 3 and Fig. 4).

Since 1979, the surface covered by olive, forest land and built-up land in the study area has increased by almost 2,561 ha, whereas the area of crop land, wetland and pasture land has declined by about 2,563 ha. Cropland has decreased by about 2.7% from 1979 to 2007 while olive groves, forests and built-up areas have increased by about 7.1, 0.8 and 0.7%, respectively.

The most significant change was found to have occurred from grassland to olive areas, which accounts for about 881 ha. In a descending order, the change from cropland to olive areas accounts for about 647 ha; change from forest to olive amounts 618 ha; change form cropland to settlement accounts for about 169 ha, and change from grassland to forest accounts for about 1,339 ha (Table 4, 5, 6). The olive and forest lands were mainly transferred from grassland, except for built-up area. The built land mostly came from crop land and grassland.

Sources of land converted to olive agriculture: Spatially, the most significant change occurred in olive lands. Land continued to be converted from less intensive uses, like grassland and rangeland, to agricultural uses, like olive growing. About 2,146 ha land was converted to olive agriculture in the period 1979-2007. Grassland contributed 881 ha of the land that shifted into olive agriculture from 1979 to 2007. Total land shifted out of olive agriculture was 22 ha; which was very small compared to the value shifted to olive agriculture. Meanwhile 648 ha of cropland and 618 ha of forest were converted to olive agriculture. This implies that shifts occured from less profitable agricultural production to more profitable ones. Such change often occurred in different parts of the Mediterranean basin (Allen *et al.*, 2006).

Sources of land converted into and out of forest: Between the years 1979 and 2007, forest land increased 233 ha. An area of 1,106 ha has been converted from forest land to other uses, while an area of 1,339 ha was converted from other uses to forest land. In this conversion, the most striking was the area converted from grass land to forest representing 1,339 ha (Table 7).

During the last three decades 1,339 ha of grassland were converted to forest land. Much of the shift from grassland to forest use was due to afforestation and natural reversion of grassland to trees. If the land was not used for grazing, is covered by woody plants due to natural generation. On the other hand, 618 ha of forest were converted to olive agriculture land and 448 ha into grassland.

Olives can grow in different soil types as long as they are well drained. Steep slopes, greater than 15° to 20° should be avoided since the yield decreases. Olives can be grown without irrigation, but water stress will significantly reduce yields.

Sources of land converted to built-up area: Settlement area was 542 ha in 2007, while it was 349 ha in 1979. Rationally, the most explicit expansion had occurred in settlement areas. In this conversion, the most effective one was settlement conversion with 169 ha from agriculture lands (Table 8). Increased resort housing construction after 1980 was concentrated on the coastal zone of the basin and especially on the area around Karinca river mouth. This area, which was previously used as grassland, was the part in which second housing construction and other kinds of housing

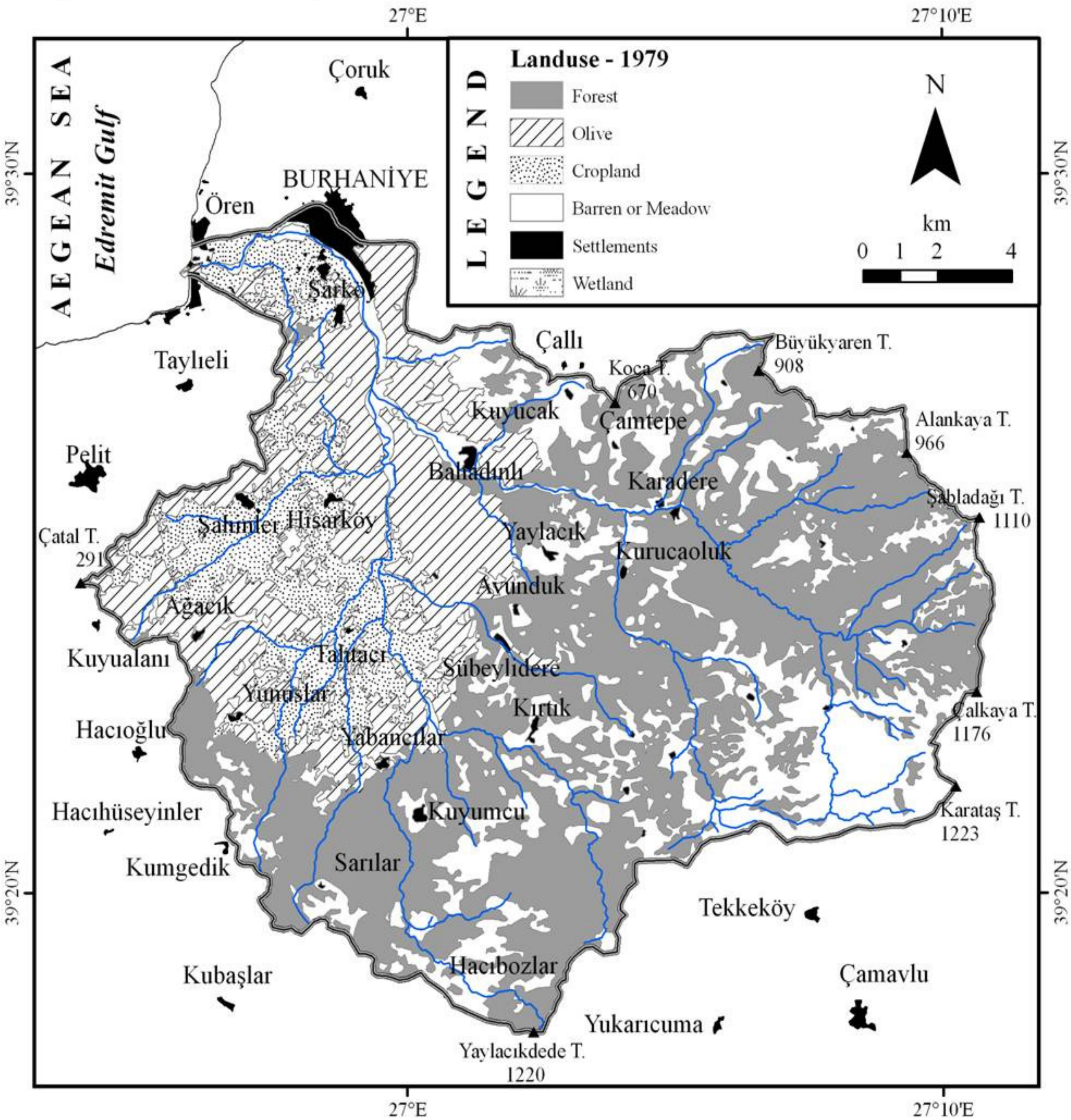

Fig. 2: Land use map (1979)

became common. The housing, which was built on the alluviums carried by the river, affected the natural structure of the river bed negatively.

Change in the other land use types: The most remarking change in the land use occurred in grassland representing 1,745 ha after the olive land. An area of 2,249 ha conversion had occurred from this kind of use to other use, and 504 ha conversion occurred from other uses to grassland. With the comparison of these two values, it is stated that 1,745 ha reduction occurred in the grassland. 1339 ha of grassland were converted into forests, 881 ha of them were converted into olive groves and 29 ha of them were converted into the residential areas.

During the research period, 814 ha reduction have occurred in agricultural lands. 817 ha conversion have occurred from this type of land use to other uses and 3 ha have occurred from other uses to agricultural lands. Consequently, agricultural lands registered a decrease of 814 ha. The area which have been converted into olive groves from agricultural lands represents 648 ha.

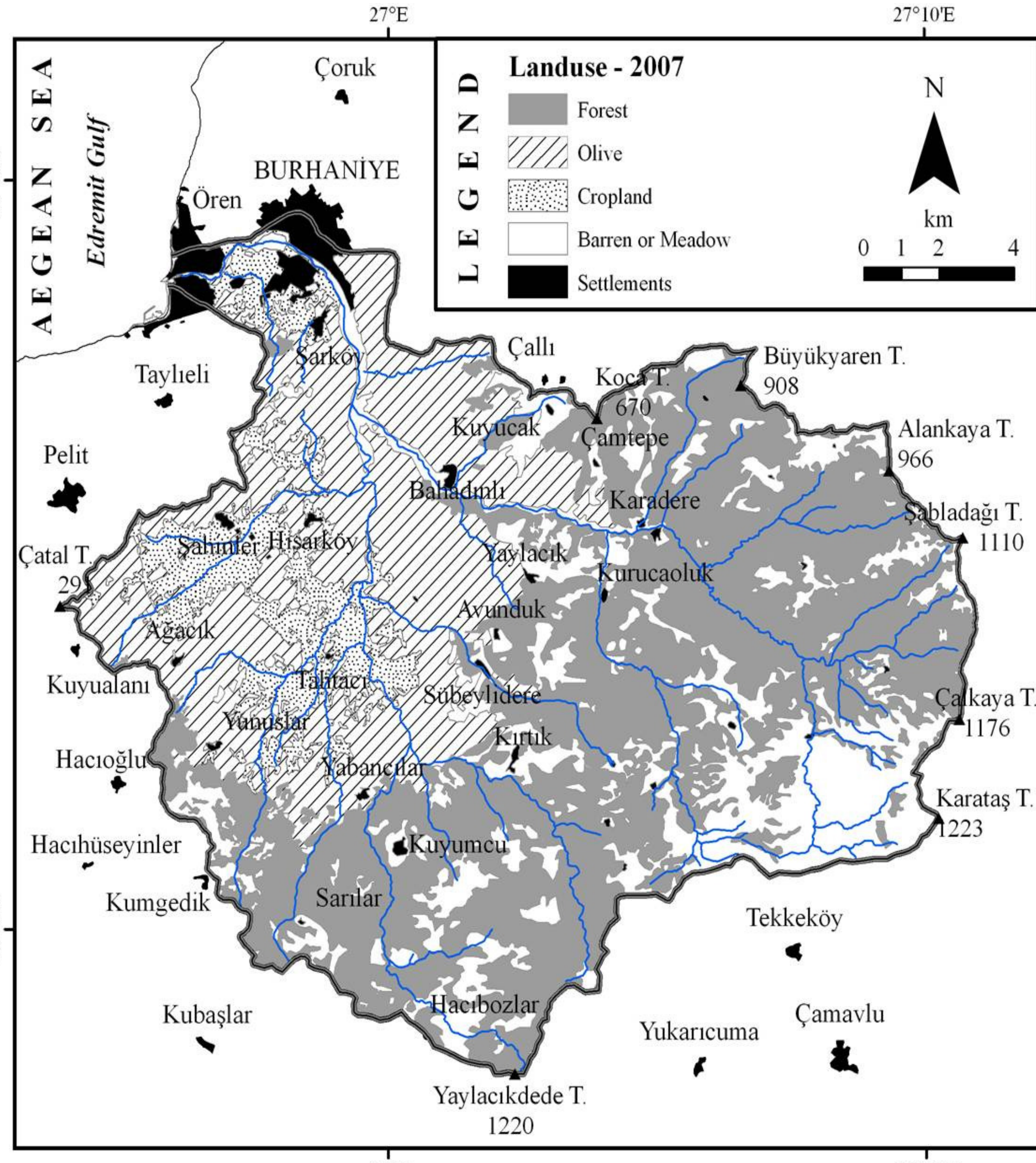

Fig. 3: Land use map (2007)

The kind of land use which takes less space in the basin is the wetlands. According to 1979 data, 4 ha of wetland existing in the area where the Karinca river flows into the sea completely disappeared in 2007. Two ha of wetland were eroded and converted into sea and two other ha were completely dried and converted into grassland. The reduction of the material eroded from the basin and taken to the outfall destroyed the balance of deposition. As the rate of erosion is faster than the rate of accretion, the wetland was destroyed by the waves and flows. Coastal currents and winds are the main factors that caused the significant changes on coastal area. Land use was found to be highly dynamic with significant internal shift among the land-use classes. The results of land use analysis revealed that the river basin was subjected to high erosion in the past and is still susceptible to surface erosion hence soil degradation.

Land use change according to the elevation levels: The land use change in the study area was mostly between 0 and 500 m. Between 0 and 250 m, 1,637 ha land, including 645 ha

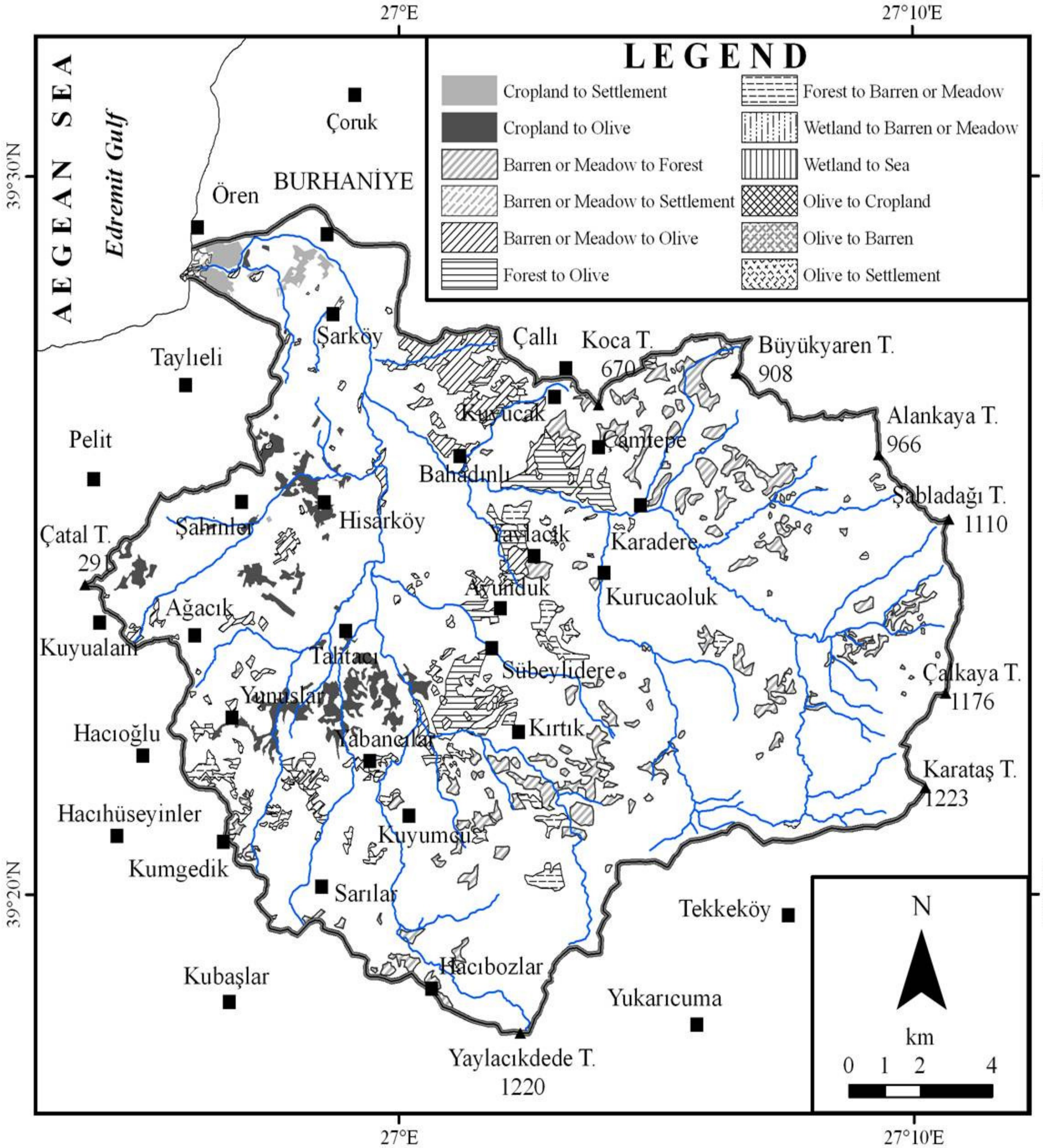

Fig. 4: Land use shifts, 1979 to 2007

agricultural land, 616 ha grassland, 376 ha forest, were converted into olive. In addition, 29 ha agricultural land were converted into residential areas. In the lands between 251 and 500 m, 265 ha grassland, 242 ha forest were converted into forests and 254 ha forest were converted into grassland. Land use change occurred less in higher parts and while 210 ha grassland were converted into the forest in the zone between 500 and 750 m, 86 ha forest were converted into the grassland by destruction. In the higher parts of area, the land use change was less. The change between other land uses was less in all elevations.

Land use changes depend largely on population increase and economic and social factors. Difficulties and low yields in cereal agriculture have led the people who live in the area to take up activities with higher income. However, higher land use benefits resulted in environmental degradation and loss of natural habitats in the study area.

Table - 5: Sources of land use shifting into and out of olive, 1979 to 2007

Land use	Shifts	Area (ha)
Olive to	Grassland	14
	Built-up land	5
	Cropland	3
	Total	22
Grassland to	Olive	881
	Cropland	648
	Forest	618
	Total	2,147
	Change	2,125

Table - 6: Sources of land use shifting into built-up land, 1979 to 2007

Land use	Shifts	Area (ha)
Cropland to	Built-up land	169
	Grassland	29
	Olive	5
	Total	203

Table - 7: Land use shifting out of wetland, 1979 to 2007

Land use	Shifts	Area (ha)
Wetland to	Grassland	2
	Sea	2
	Total	4

Unfeasible land use patterns and land reclamation by human beings resulted in loss of grassland and agricultural land. People in the study area allocated land to the use they expect will yield the highest benefit over time. The most important of these are investments in tourism, summer houses, and the centuries-old traditional cultivation of olives in the study area. Tourism activity and the construction of holiday homes have intensified in low-lying areas of river basins and in coastal areas and as a result, these fertile crop and olive cultivation areas have been lost. As olive production is a high-yield agriculture, the destruction of coastal areas has seen olive growing areas spring up in hilly regions of river basins and on the lower slopes of mountains. Some of the grassland in these regions has even been converted into olive growing land. These changes have caused not only the destruction of natural habitats in coastal regions, but also erosion and land degradation on hillsides. Especially, the reestablishment of the olive groves on steep slopes accelerated soil erosion. Reduced soil depth induced by erosion, causes reduction of soil productivity over time. Similar results have been found in studies in other countries in the Mediterranean basin (Miranowski and Hammes, 1984; Cerda, 1997 and 2003). A large amount of croplands was transformed into olive lands on the steep slopes. Hence, compared with 1979, there was an increase in olive-dominated landscape and a decreasing of in grassland and cropland-dominated landscape. Olive land area increased from 5,465 ha to 7,590 (39%) and grassland area decreased from 7,908 to 6,163 ha (22%) during the period 1979-2007.

Over the last few decades, farmers in the study area and its vicinity have partly turned to tourism activities; which occurred in other countries in the Mediterranean region (Loumou *et al.*, 2000). However, the olive cultivation is still the major agricultural activity in the Karinca river basin. Tourism and tourism related activities are complementing their income from olive cultivations. This is why olive groves and built-up areas increased 39 and 58% respectively. But still, 22 ha of olive fields where ecologically olive best grows have been transformed to other forms of uses. While the olive groves in the coastal zone, which had been lost because of the transformation to residential and touristic areas, were being reestablished to the steep hilly areas.

The results reveal that in the Karinca river catchment land use has changed significantly over the past three decades. More than 5,000 ha land- which is 1/6 of the study area was converted to different uses during the period of 1979-2007 in the basin. One of the most significant changes in land use over the past three decades was an increase in the area occupied by resort houses, often with an associated loss of agricultural land. Lands of low agricultural quality are more likely to move into olive agriculture. These important changes occurred in landuse in the study area between 1979 and 2007 (Fig. 4). The observations of land use change provided in the historical maps and satellite images reveal the complex human-environmental interactions, which have been at work in the Karinca river basin. The present land uses were modified by the some human activities that took place throughout the last three decades.

We hope that, this study may contribute to the land use and planning projects of the local and central authorities. It is possible for sustainable land use to be practiced with environmental, economic and social dimensions. The land and natural resources in the Karinca river catchment should be sustainably managed to meet the economic, ecological and social needs of the people. Social and economic indicators were not used in this study and therefore the data collected will serve as a useful source for the local and central authorities in the establishment of a land use project with social and economic dimensions.

References

Allen, H.D., R.E. Randall, G.S. Amable and B.J. Devereux: The impact of changing olive cultivation practices on the ground flora of olive groves in the Messara and Psiloritis regions, Crete, Greece. *Land Degradation and Development,* **17**, 249-273 (2006).

Aranda, V. and C. Oyonarte: Characteristics of organic matter in soil surface horizons derived from calcareous and metamorphic rocks and different vegetation types from the Mediterranean high-mountains in SE Spain. *Eur. J. Soil Biol.*, **42**, 247-258 (2006).

Atalay, I. and K. Mortan: Regional geography of Turkey. 3rd Edn. Inkilap publication. Istanbul (2006).

Cardille, J.A. and J.A. Foley: Agricultural land-use change in Brazilian Amazoˆnia between 1980 and 1995: Evidence from integrated satellite and census data. *Rem. Sen. Environ.,* **87**, 551-562 (2003).

Cerda, A.: Soil erosion after land abandonment in a semiarid environment of Southeastern Spain. *Arid Soil Res. Rehabil.*, **11**, 163-176 (1997).

Cerda, A.: Soil water erosion and agriculture in Spain. A State-off-the-art throughout the scientific literature NATO-CCMS and science committee workshop on desertification in the Mediterranean region. A Security Issue. Valencia (Spain), 2-5 December 2003. Book of Abstracts. p. 58 (2003).

Cerda, A.: Citrus production and soil loss in Eastern Spain. EGU. *Geophysical Ress Abst.*, **9**, 511 (2007).

Cerda, A. and S.H. Doerr: Influence of vegetation recovery on soil hydrology and erodibility following fire: An 11-year investigation. *Int. J. Wildland Fire*, **14**, 423-437 (2005).

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

De Sherbinin, A.: A guide to land-use and land-cover change (LUCC). A collaborative effort of SEDAC and the IGBP/IHDP LUCC Project, USA (2002).

Efe, R.: The impact of land use changes on natural vegetation along the coastal zone between Edremit and Küçükkuyu (Western Turkey). International Symposium on Desertification, Konya-Turkey. Proceedings. pp. 222-227 (2000).

Efe, R.: Land degradation in Taurus mountains (Southern Turkey). European Geosciences Union, 2nd General Assembly, 24-29 April 2005, Wien, Austria. EGU-*Geophy. Res. Abst.*, **7**, 922 (2005).

Efe, R., A. Soykan, S. Sönmez and I. Cürebal: Quantifying the effect of landuse change on olive tree cultivation in the vicinity of Edremit between 1979 and 2006 using GIS and RS techniques. *Fresenius Environ. Bull.*, **17**, 696-704 (2008).

Ercan, T.: Geology and petrography of igneous rocks in the vicinity of Dikili-Çandarli-Bergama (Izmir) and Ayvalik-Edremit-Korucu (Balikesir) (in Turkish). General Directorate of Mineral Research and Exploration Institute (MTA) Report, Ankara. (1984).

Gómez, J.A., J.V. Giráldez and E. Fereres: Cover crop effect on soil conservation in olive orchards. EGU, *Geophy. Res. Abst.*, **9**, 1015 (2007).

Loumou, A., C.H. Giourga, P. Dimitrakopoulos and S. Koukoulas: Tourism contribution to agro-ecosystems conservation: The case of Lesbos island, Greece. *Environ. Manage.,* **26**, 363-370 (2000).

Miranowski, J.A. and B.D. Hammes: Implicit prices of soil characteristics for farmland in Lowa. *Am. J. Agric. Eco.,* **66**, 745-749 (1984).

Olszewski, D.I.: Subsistence ecology in the Mediterranean forest: Implications for the origins of cultivation in the Epipaleolithic Southern Levant. *Ame. Anthropol.,* **95**, 420-435 (1993).

Ozturk, M., A. Celik, C. Yarci, A. Aksoy and E. Feoli: An overview of plant diversity, land use and degradation in the Mediterranean region of Turkey. *Environ. Manage. Hlth.*, **13**, 442-449 (2002).

Symeonakis, E., S. Koukoulas, A. Calvo-Cases, E. Arnau-Rosalen and I. Makris: A landuse change and land degradation study in Spain and Greece using remote sensing and GIS. XXth International Society for Photogrammetry and Remote Sensing. Congress, Istanbul. Commission VII, WG VII/4 (2004).

Tedim, F.: The management of forest fires in protected areas in Portugal. *In*: Natural environment and culture in the Mediterranean region (*Eds.*: R. Efe, G. Cravins, M. Öztürk, I. Atalay). Cambridge Scholars Press. pp. 473-488 (2008).

Yener, H. and A. Koc: Monitoring changes in forest and other land use forms in Istanbul. *J. Environ. Biol.*, **27**, 77-83 (2006).