

ENVIRONMENTAL MONITORING OF LAND-USE AND LAND-COVER CHANGES IN AMIK PLAIN, TURKEY

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ABSTRACT:

Unprecedented rates of changes in land use/cover (LULC) on the local and regional scales lead to alterations of global biogeochemical cycles, and loss of productive ecosystems and biodiversity. Driving forces behind LULC changes mainly include rapid growth rates of population and consumption, lack of valuation of ecological services, poverty, ignorance of biophysical limitations, and use of ecologically incompatible technologies. One of the major ecological tragedies of the commons in the province of Hatay is the case of the loss of the Amik Lake, which reveals the urgent need for adoption of sustainable and adaptive ecosystem management strategies if escalating land use conflicts are to be avoided and environmental degradation is to be reversed in the Amik plain of the southeastern Mediterranean region of Turkey. In the 1940s, the Amik lake was started to be discharged into the Orontes river by a large-scale campaign launched to increase the area of croplands. The study quantified LULC changes and explored constraints and opportunities for future LULCs in the study area. Land use/cover changes were detected from a time series of satellite images of Landsat-MSS in 1972, Landsat-5 TM in 1987, and Landsat-7 ETM+ in 2000 using remote sensing and geographic information systems (GIS). The study revealed that the increase in croplands between 1972 and 1987 took place at the expense of the irreversible losses of the Amik lake and its related wetlands of over 53 km² used to provide vital ecosystem goods and services for the region. In the period of 1972 to 2000, croplands, settlements, and evergreen forests increased by 174%, 106%, and 14%, respectively, in parallel to the decreases in shrublands-orchards, and bareground. The increase in settlements occurred mostly to the detriment of croplands. The prospects for halting environmental degradation and destruction, rehabilitating damaged ecosystems, and developing sustainable ecosystem management practices need to be dealt with in light of the institutional and economic constraints facing Turkey.

1. INTRODUCTION

Human-induced disturbances such as land use/cover (LULC) changes, pollution of air, water and soil, and losses of productive lands and biodiversity are increasingly threatening ecosystem productivity and health on the local, regional and global scales (Wali et al., 1999; Evrendilek and Ertekin, 2002; Evrendilek, 2004). Land use/cover changes are the most common cause of loss of biological productivity and biodiversity in aquatic and terrestrial ecosystems. Changes in LULC are defined broadly to include the conversion of lands into croplands and pastures, the abandonment of agricultural lands, deforestation, reforestation, afforestation, shifting cultivation, and urban sprawl (Evrendilek, 2004a; 2004b; Evrendilek and Wali, 2004). The worldwide trajectory of LULC changes over the last 300 years has been to decrease the area of forests and increase the area of agricultural lands (Houghton, 2003). For the period 1850 to 2000, atmospheric CO₂ concentrations have increased by *ca.* 175 Pg C (*ca.* 85 ppmv) in association with the CO₂ emissions from combustion of fossil fuels (275 Pg C) and LULC changes (155 Pg C) (Houghton, 2003). The annual terrestrial flux of carbon (C) from LULC changes to the atmosphere was estimated at 2.2 (± 0.6) Pg C yr⁻¹ in the 1990s (Houghton, 2003).

About 80% of all wetlands in some areas of Europe, and *ca.* 50% of all wetlands in the United States have been lost or destroyed. For example, more than 100 million ha of U.S.A. wetlands have been filled, tilled, or channeled (Gibbs, 2000). Globally, *ca.* 1000 bird species many of which are particularly dependent on aquatic habitats including wetlands are on the verge of extinction (Lemly et al., 2000; Amezcaga et al., 2002; Ellison, 2004). Introduction of agricultural activities into Mexico's Sonora desert, for example, has diminished 97% of the region's water resources, thus decreasing the migratory bird populations from 233,000 in 1970 to less than 100,000 recently (Davis et al., 2002). The nearly complete destruction of the Aral Sea of 64,000 km² in Central Asia, once the fourth largest inland sea in the world, is one of the most disastrous human-induced LULCs, which resulted from the diversion of the two feeder rivers (the Amu Darya and the Syr Darya) of the Aral Sea for irrigation of cotton fields and rice paddies. This diversion resulted in loss of the surrounding wetlands of over 530,000 ha, 135 mammal species, and 215 migrant bird species (Lemly et al., 2000).

Sustainable management of natural resources requires that ecological goods and services be used to meet both current and future generations' needs by recognizing and adapting to the inevitable biophysical limitations and interdependences

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(Evrendilek and Doygun, 2000; Wali et al., 2002). For example, increasing the amount of land, water and nitrogen fertilizers used to meet the ever-increasing food consumption which in turn increases environmental degradation leads to an unsustainable cycle, for environmental degradation makes it more difficult to meet our basic human needs of food and clean water in the long-term (Kilic et al., 2003; Kilic et al., 2004). On the other hand, multi-temporal high-resolution, remotely sensed data and geographic information systems (GIS) have facilitated the derivation of ecological inventories and the monitoring of LULC changes on the local, regional and global scales (Berberoglu, 2003; Berberoglu et al., 2004). In particular, the visible to shortwave infrared (VSWIR) bands of Landsat Multispectral Scanner (MSS) and Thematic Mapper (TM) data have been extensively used for surveys and analyses of forest and agricultural resources since the initiation of Landsat program in 1972 (Berberoglu et al., 2000; Townshend and Justice, 2002).

This study region was selected because it is located in one of the most biologically diverse regions as well as the most water-short regions of the Mediterranean Basin. There is a lack of quantification and identification of LULC changes in ecologically productive and hotspots of the study region. Sustainability of vital ecosystems in the region are threatened by increased rates of population growth, consumption and waste disposals, and the keen competition among LULCs for both rate-limited ecological services and stock-limited natural resources. For example, draining of the Amik lake and its surrounding wetlands has led to continued problems with water quality and quantity and escalated flood damages. Preventive and mitigative measures are urgently needed in the supply- and demand-side managements of natural resources in order to assure long-term productivity and health of ecosystems before the point of irreversible losses is reached. The main objective of this study was to reconstruct past LULC changes over the last 28 years at the scale of the province of Hatay, Turkey, based on a time series of Landsat imagery acquired from 1972, 1987, and 2000.

2. MATERIALS AND METHODS

2.1 Study Region

The study region is located in the province of Hatay (Turkey) (35° 47'-36° 24' E; 35° 48'-36° 37' N) and has a total area of *ca.* 3930 km² with an elevation range from sea level up to 2100 m (Figure 1). The study region is delimited by the Mediterranean



Figure 1. Location of the study region in Turkey.

Sea in the west, by Syria in the south and east, and by the province of Gaziantep in the east. The prevalent climate regime is Mediterranean climate characterized by a mild winter during which about 67% of the annual precipitation of 1124 mm falls, and a hot dry summer. Average annual temperature reaches a maximum of 44°C in the summer and a minimum of -15°C in the winter, with an average annual temperature of 18°C. Parent materials in the study region consist mostly of sedimentary rocks of highly calcareous clays, limestone, dolomites, and sandstones. The major soil orders include entisols, inceptisols, vertisols, mollisol, and alfisol (Kilic, 1999). The alluvial soils formed in the Amik plain by the Orontes river are the most productive soils covering the northeast of the study area. The dominant Mediterranean vegetation consists of evergreen forests of *Pinus brutia*, and shrublands composed of maquis, and garrigues. Regressive succession stages of evergreen forests have taken place under drastic human-induced disturbances such as overgrazing, overcutting, and clearance for cultivation.

2.2 Data Processing

The following remotely sensed cloud-free data were used in the classification of LULCs in the province of Hatay through ERDAS Imagine and TNTmips software: Landsat MSS of December 15, 1972, Landsat-5 TM of October 1, 1987, and Landsat-7 ETM+ of June 22, 2000. The images were geometrically corrected and geo-coded to the Universal Transverse Mercator (UTM) co-ordinate system, using 1:25 000 scale topographic maps and aerial photographs taken in 1992. Approximately 45 evenly distributed ground control points were selected from each image. These were used to spatially resample the images using a nearest neighbor algorithm, which takes the value of the pixel in the input image that is closest to the computed co-ordinate. This method is fast and does not alter the original pixel values. The transformation had a root mean square (RMS) error of between 0.4 and 0.7 pixel, indicating that the image rectification was accurate to within one pixel. The acquired Landsat images were classified using a maximum likelihood classifier method of ERDAS Imagine and TNTmips software. A supervised maximum likelihood classification was performed with 2682, 11689 and 8107 pixel training data sets, and the images were classified into 6 (1987 and 2000) and 7 (1972) LULC classes.

3. RESULTS AND DISCUSSION

On the basis of a time series of the Landsat images, LULCs of the study region was classified into seven categories: evergreen forest, shrublands-orchards, the Amik lake and its related wetlands, croplands, water bodies, settlements, and bareground (Table 1). The study area occupied 392,970 ha. The annual rates and cumulative amounts of LULC changes were estimated over the two periods: 1972 to 1987 (period 1), and 1987 to 2000 (period 2). Land use/cover changes were of highest amount in croplands, evergreen forests, shrublands-orchards, and the Amik lake-related wetlands in the first period and in settlements and bareground in the second period. In both periods, bareground decreased, while croplands and settlements increased. In the first period, the rate of change of the Amik lake-its related wetlands, and shrublands-orchards was negative, whereas the rate of change of evergreen forests was positive. In the second period, a decrease in evergreen forest took place, whereas an increase in shrublands-orchards occurred. Comparisons of LULCs in 1972, 1987 and 2000 derived from the Landsat images indicated that the Amik lake and its

Land use/land cover	Land area (ha)			Rate of LULC change (ha yr ⁻¹)			Amount of LULC change (%)
	1972	1987	2000	1972-1987	1987-2000	1972-2000	1972-2000
Amik lake & wetlands	5325	-	-	-	-	-	-100
Croplands	46,658	92,098	127,883	3029	2753	2901	174
Evergreen forests	110,417	141,904	125,964	2099	-1226	555	14
Shrublands & orchards	74,057	12,193	41,130	-4124	2226	-1176	-44
Settlements	2090	2276	4297	12	155	79	106
Bareground	154,424	144,500	93,696	-662	-3908	-2169	-39
Total area*	392,970	392,970	392,970	392,970	392,970	392,970	-

* Figures may not give the totals due to rounding.

Table 1. Detection of 28-year changes in land uses/covers (LULC) in the province of Hatay, based on time series satellite images of 1972, 1987, and 2000 (negative values indicate a decrease)

surrounding wetlands covered 5325 ha in 1972 and were annihilated completely by 1987 (Figure 2). With the initiation of a large-scale campaign to increase the amount of croplands used for food production in the Amik plain in the 1940s, the Amik lake was channeled into the Orontes river. The increase in croplands took place at the expense of the irreversible losses of the lake and its related wetlands. The destructions of the Amik lake and its related wetlands have led to the losses of vital ecosystem goods and services ranging from biodiversity to regulation of hydrological cycle used to be provided for the region. When the structures and functions of the Amik lake and its related wetland ecosystems were destroyed, the emerging ecological impacts have decreased some species in abundance, altered the identity of species and caused local extinctions of some species, some of which are keystone species.

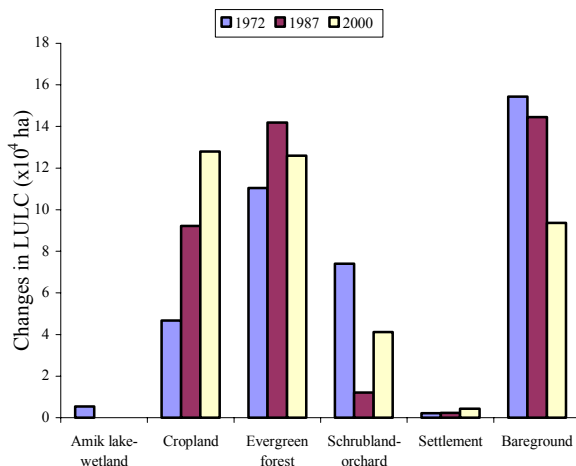


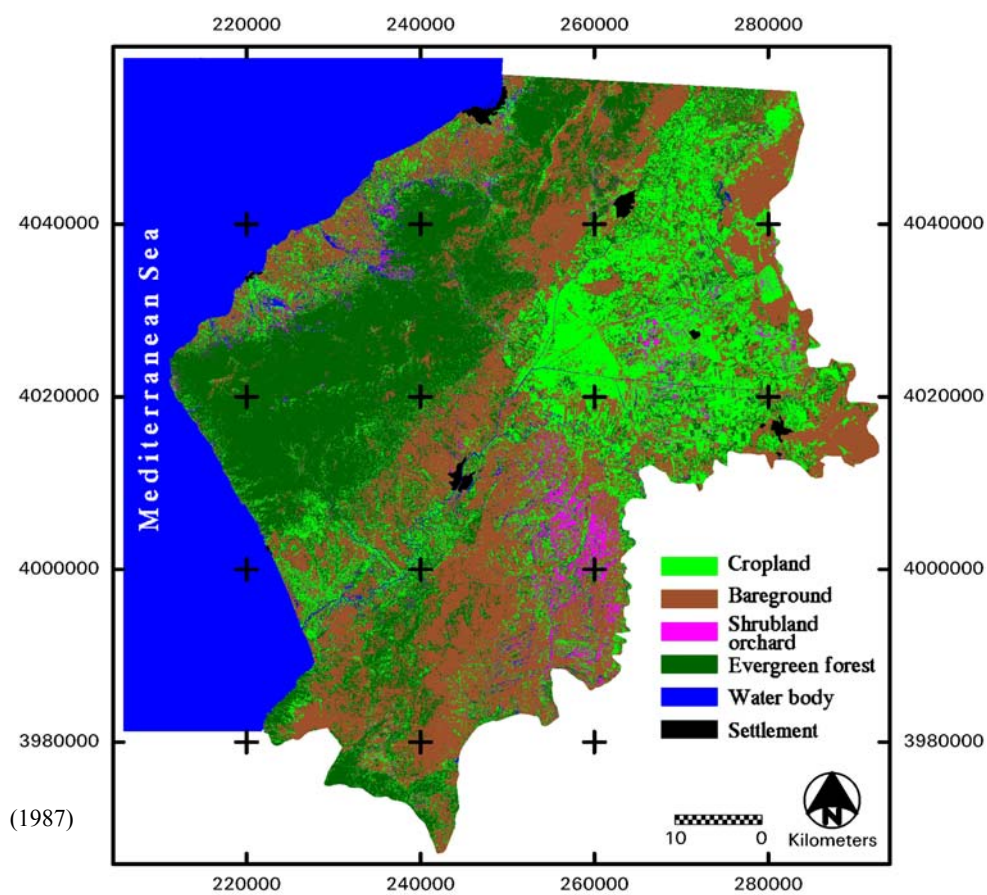
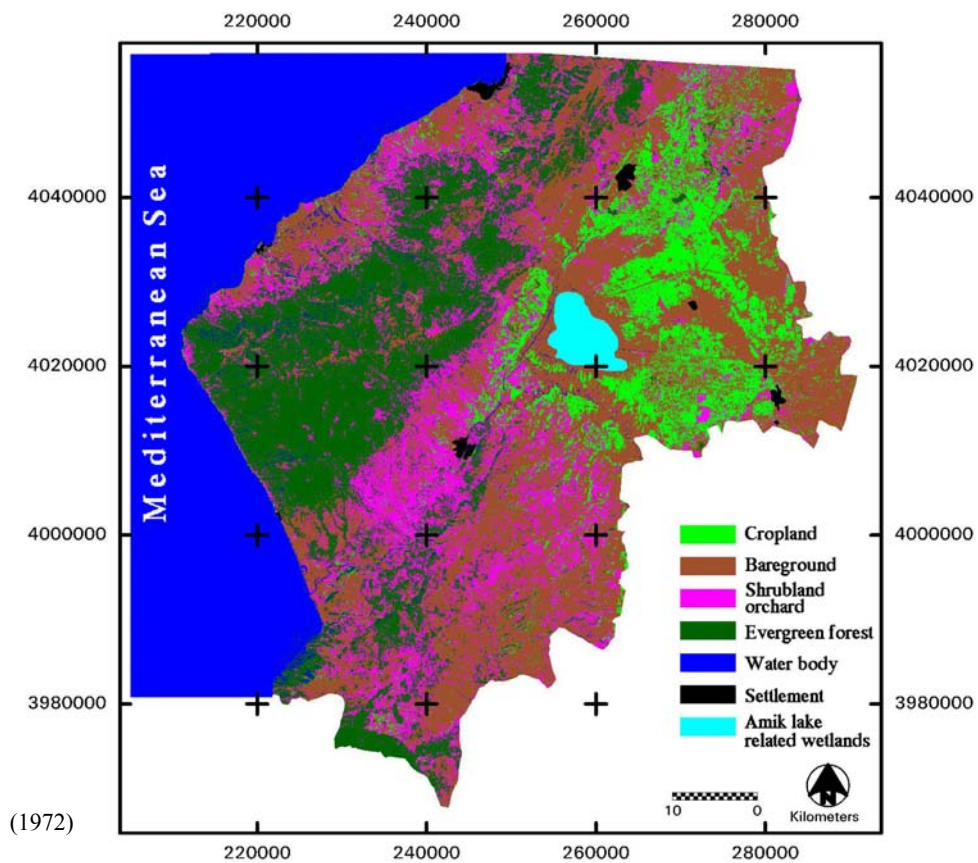
Figure 2. Changes in land use/cover (LULC) between 1972 and 2000 in the province of Hatay

In both periods, croplands and settlements increased in parallel to the decrease in bareground. Settlements and bareground were negatively correlated ($r = -0.9$; $p < 0.05$). The increase in settlements occurred mostly to the detriment of croplands. There was a significantly negative correlation between evergreen forest-orchards and shrublands ($r = -0.9$; $p < 0.05$). Between 1972 and 2000, the land area of croplands increased

by 174% at the rates of 3029 ha yr⁻¹ between 1972 and 1987 and of 2753 ha yr⁻¹ between 1987 and 2000. The area of settlements almost doubled in the period 1972 to 2000, at rates of 12 ha yr⁻¹ between 1972 and 1987 and of 155 ha yr⁻¹ between 1987 and 2000. Forest area increased by 29% in the period 1972 to 1987 and decreased by 11% at a deforestation rate of 1226 ha yr⁻¹ in the period 1987 to 2000. The increase in evergreen forest in the first period can be attributed to the then-accelerated rates of afforestation and reforestation plantings conducted. The area of shrublands and orchards decreased by 44% during the entire period, with an 84% decrease between 1972 and 1987 and a 237% increase between 1987 and 2000. Bareground area decreased by 39% from 154,424 ha in 1972 to 93,696 ha in 2000 (Figure 3). One of the major LULC changes as detected from the imagery in 2000 was the construction of Yarseli Dam and the formation of its reservoir of *ca.* 4 km².

4. CONCLUSIONS

Rate- and stock-limitations of ecological goods and services for human uses, historical reconstructions of ecosystem disturbance dynamics, irreversibility, time lags, interdependency, temporal/spatial scales, and uncertainties constitute the most important components of understanding land-transformation processes, and ecosystem structures and functions worldwide. Today, urbanization, population growth, and consumption growth are the dominant local forces which cumulatively lead to global environmental change. For example, slightly less than half (2.9 billion) of the world's population resided in cities in 2000, but this proportion is projected to rise to 60% by 2030, and the largest cities, and the largest growth in city size are projected to occur in developing nations (UN, 2001). LULC changes have produced about 36% of CO₂ emissions since 1850, the beginning of the Industrial Revolution, thus contributing to global climate change. The integration of ecosystem management and economic development can only be achieved by a holistic, interdisciplinary, goal-oriented and participatory approach. This approach should aim at having people recognize that their well-being is dependent upon the sustenance of ecological goods and services and at improving coordination among related administrative and institutional bodies. The magnitude of uncertainties associated with the



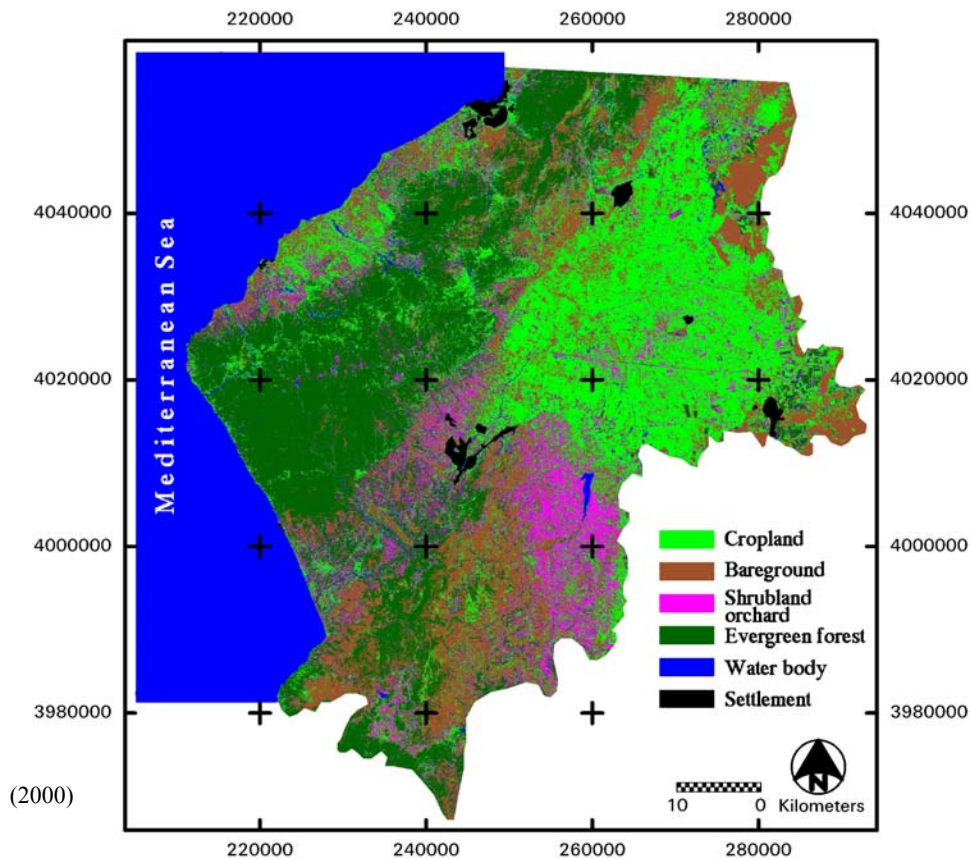


Figure 3. Classification and dynamics of land use/cover changes in the province of Hatay based on a time series of Landsat satellite images from 1972, 1987, and 2000

quantification of the LULC changes needs to be reduced and integrated with dynamic process-based models in order to enable management and planning institutions and public to make informed decisions.

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