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CHANGE DETECTION IN SOUTHERN TURKEY USING NORMALIZED DIFFERENCE VEGETATION INDEX (NDVI)

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Abstract. This study analyzed landscape changes in the Mediterranean using remotely sensed satellite images. Bi-temporal Thematic Mapper (TM) scenes of Erdemli (Southern Turkey) acquired by Landsat satellites were analyzed to detect landscape changes in the study area, which supports a mosaic of landscapes from coastline to altitudes over tree line. Visible and near infrared bands (i.e. bands 3 and 4) of the near-anniversary (August) images from 1984 and 2006 were used to derive Normalized Difference Vegetation Index (NDVI) images. NDVI images for the earlier and later dates were analyzed. ASTER and Quickbird images, topographic maps, forest stand maps were used as ancillary data. Spatial distribution of change is mapped and interpreted. Results showed that forest regeneration took place especially in upper lands, while deforestation occurred at lower altitudes in relatively smaller patches in close proximity to the coast and to the roads.

Keywords: environmental monitoring, environmental processes modeling, environmental assessment, NDVI.

Introduction

Vegetation is often regarded as the primary indicator of land cover (e.g. Di Gregorio, Jansen 2000). Thus, quantitative analysis of the changes in its composition, biomass and vigor on the basis of multispectral remote sensing helps understand land cover modifications (Keles *et al.* 2007; Cakir *et al.* 2008). This information may then serve as an effective means to solve landscape management questions relating to desertification, vegetation change and forest fragmentation (Zhang *et al.* 2008; Kim, Daigle 2010; Kucas 2010) and erosion (e.g. Šurda *et al.* 2007). Distribution of vegetation in the Mediterranean is determined by many different environmental variables such as altitude, surface aspect, pH and total calcium carbonate (Ozkan *et al.* 2009). Vegetation dynamics in the Eastern Mediterranean ecosystems are mainly driven by an alternation of episodes of various human activities. As a result, a mosaic of plant communities has evolved following different stages of degradation (Fernandez *et al.* 2004). Mediterranean landscapes have been affected by human activities for thousands of years (Alados *et al.* 2004; Falcucci *et al.* 2007; Hilla *et al*. 2008). The perception of people for conservation and use of the resources has a substantial impact for landscape management (Alkan *et al.* 2008; Alkan *et al.* 2009).

The exploitation of coastal environmental resources in the Mediterranean as a result of mismanagement and lack of monitoring has been widely recognized. Agricultural expansion and urbanization are the most prominent forces fueling destruction trends in (semi) natural vegetation cover in the Mediterranean. Agriculture expands over marginal areas while urban areas grow at the expense of highly productive croplands on the coast, leading to even more increased demand for new agricultural areas (Alphan, Yilmaz 2005).

Shoshany *et al.* (1995) noted that classification according to different patterns of vegetation change is highly correlated to the land cover, thus suggesting that the land cover is an important environmental controlling factor in the Mediterranean. Bakr *et al.* (2010) highlighted the importance of monitoring temporal changes of vegetation cover in heterogeneous regions of the Eastern Mediterranean as it provides an effective and accurate evaluation of human impacts on the environment.

Monitoring of environmental resources may be employed using a broad range of techniques from photographic surveys (e.g. Millington *et al.* 2009) to digital image interpretation (e.g. Lillesand, Kiefer 2000). The fact that land use / land cover (LU/LC) change detection has been successfully applied in a rich variety of geographical regions and / or ecosystems from Asia to Africa and Americas suggests that the major outcomes from these analytical procedures help understand ecological systems and processes at landscape level (Alphan, Yilmaz 2005; Nagler *et al.* 2005; Bontemps *et al.* 2008; Fraser *et al.* 2009; Lin *et al.* 2009; Vogelmann *et al.* 2009).

NDVI indicates presence / absence and vigor of the vegetation. Therefore, its comparison may yield information on quantitative and qualitative changes in land cover; given vegetation is the primary indicator of land cover (LC) and its change. This study analyzed landscape changes using NDVI images derived from Landsat TM images to contribute effective monitoring and sustainable use of the Mediterranean- ecosystems, in the case of Erdemli, southern Turkey. Change detection procedures were applied to NDVI datasets derived from Landsat TM images acquired in 1984 and 2006. The earlier and later date images were compared to analyze landscape-level vegetation changes.

1. Study Area

The study area is the district of Erdemli of the Mersin Province, located in the Mediterranean region of Turkey. It is bounded by 36° 30’ 13” and 37° 08’ 18” Northern latitudes and 32° 54’ 57”- 34° 23’ 43” Eastern longitudes, covering an area of 2078 km^2, 62% of which occupied by forests. The study area extends from coastal plain to Taurus Mountains with altitudes reaching up to 2440 m (Fig. 1). Mountainous regions represent areas with undulated terrain and steep slopes, occupying approximately 50% of the study area. Limonlu (Lamas) is one of the major elements of a complex network of streams that flow into the Mediterranean Sea through deep valleys carved from limestone. The population of the town, which is located on the coast of the district, is 40175 persons, while rural population living in villages is 102180. The climate is typical Mediterranean. Winters are mild and rainy, whereas summers are hot and generally humid on the coastal zone. Precipitation and temperature patterns for highlands show differences as compared to those observed on the coast.

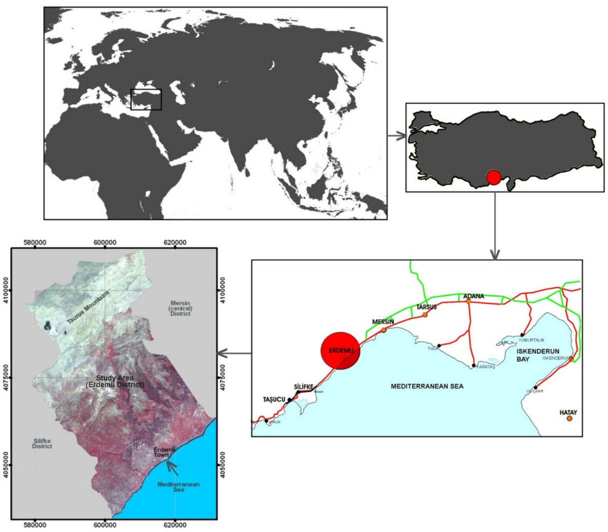

Fig. 1. Location of the study area

Local economy is based on agriculture. Agricultural crop production in the study area may be considered in four categories: (1) open-field agriculture, (2) citrus plantations, (3) greenhouses and (4) vineyards and orchards. Open field agriculture serves for growing a rich variety of fruits and vegetables year-around. It occupies relatively flat areas on the coastal plain, where citrus plantations are also extensive. Plastic and glass greenhouses generally exist on mild slopes of the foothills of Taurus Mountains, while orchards and vineyards create a complex mosaic with forest patches and other semi-natural vegetation at relatively higher altitudes.

Plant communities show high diversity according to morphology and altitude. Approximately 15% of the study area is occupied by forests with canopy cover of more than 40% (Fig. 2). Foothills of the Taurus Mountains are generally covered by sclerophyllus macchia shrubs with *Quercus coccifera* and *Phllyrea latifolia* as being the dominant species. Outcropping limestone is typical for the areas, where this vegetation type occurs. This vegetation type supports very high diversity of annual and perennial plant species.

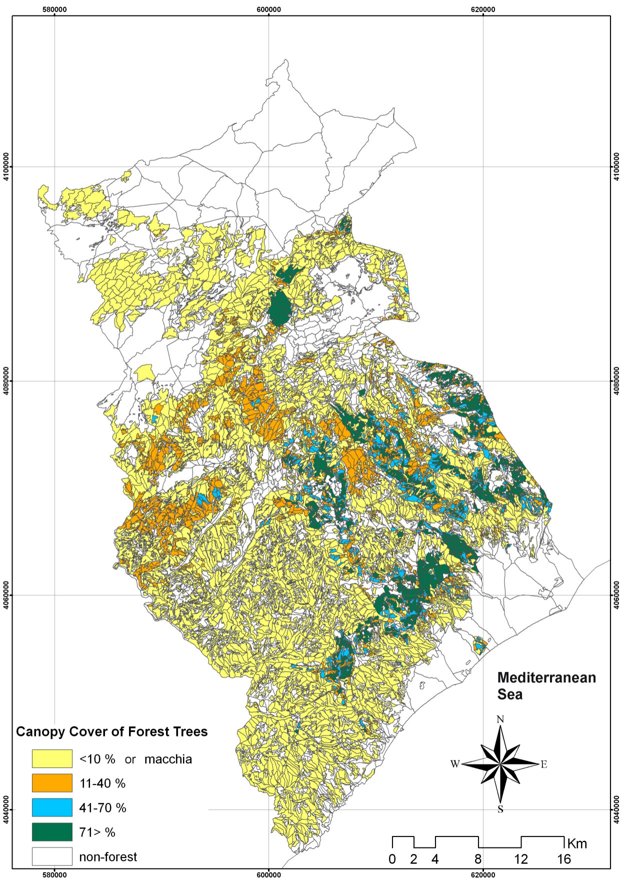

Fig. 2. Per cent canopy cover of forest trees

Turkish pine (*Pinus brutia*) is the most common tree species in this region from coastline to over 1200m. Understory of this forest type is richer at lower altitudes than that of the higher altitudes. Closer to the upper limit of its distribution several broadleaved trees accompany this species. Altitudes over 1000 m ASL support juniper species (e.g. *Juniperus excelsa*) that occur as pure or mixed stands. Lebanon cedar (*Cedrus libani*) and Cilician fir (*Abies cilicica*) accompany junipers. Understory includes several astragalus species, as well as gopher plant (*Euphorbia rigida*), asphodel *(Asphodeline taurica*) and barberry (*Berberis crataegina).* Some other species such as buckthorn (*Rhamnus oleoides*), dog rose (*Rosa canina*), catmint (*Nepeta italica*) and hypericum (*Hypericum spp.*) also exist. Thorny cushion shrublands, which also include low perennial shrubs, occur above the tree line. Dominated by several astragalus species, vegetation formations of these altitudes include daphne (*Daphne oleoides*) and horehound (*Marrubium globosum*) (Anonymous 2009).

2. Datasets and Methodology

Landsat TM scenes of 1984 and 2006 (path/row: 176/34-35) were used for change analysis. These high quality cloud-free image scenes were acquired on the third and sixteenth of August for the earlier (1984) and later (2006) dates, respectively. Images from the dry season were selected so as to reduce negative impacts of plant phenology and pre-acquisition events (e.g. rain) that may lead to false interpretations. The TM datasets include multispectral bands for visible (1, 2, 3), near-infrared (4), mid-infrared (5, 7) and thermal infrared regions of the electromagnetic spectrum (6). Since this study analyzed Normalized Difference Vegetation Index (NDVI) differencing, only two spectral bands (Bands 3 and 4) that are used to derive NDVI images were used for analyses. High-resolution Quickbird images, topographic maps and forest stand maps were used as the source of collateral information.

Green plants absorb solar radiation in the photosynthetically active radiation (PAR) spectral region of the electromagnetic spectrum (EMS), which they use as a source of energy in the process of photosynthesis, while they reflect energy in near-infrared (NIR) wavelengths. Hence, live green plants appear relatively dark in the visible and relatively bright in the near-infrared wavelengths (Gates 1980). These interactions of the solar radiation with live green plants are the basis for calculating NDVI. The NDVI is calculated as follows:

$$NDVI = \frac{NIR - red}{NIR + red}. \quad (1)$$

NDVI is a well-known index and one of the most important means for vegetation monitoring studies. It also helps compensate changing illumination conditions, surface, slope and other extraneous factors (Lillesand, Kiefer 2000). NDVI is often used to retrieve biophysical properties of green vegetation canopy and determine vegetation changes (e.g. Morawitz *et al.* 2006)

Availability of geographically and radiometrically comparable images is one of the most critical issues for a change study. Geographical consistency may be obtained by employing a rigorous geo-referencing procedure, which is expected to keep possible spatial errors within a pixel, while radiometric consistency may be achieved by removing atmospheric effects and normalizing images to a reference scene. Geographically and radiometrically corrected spectral bands were used for deriving NDVIs for the earlier and later dates.

Change detection methodology relied upon comparing NDVI images on a pixel basis. Positive and negative change areas were extracted from difference images and labeled as change by means of a thresholding procedure. The flow of this analytical procedure was given in Fig. 3.

3. Results and Discussion

3.1. Pre-processing

Two input scenes were geo-registered to the UTM Projection. During this process nearest neighbor resampling algorithm was used. Each image was resampled to 30 m ground resolution. Spatial errors (RMSE) during this procedure were less than 0.5 pixel, which indicated an acceptable level of accuracy that remains within a pixel.

Atmospheric effects were removed and images were radiometrically normalized using Cos(t) Model (Chavez 1996) and linear regressions between unchanged features (i.e. pseudo invariant features) in the earlier and later dates. The Cos(t) model uses cosine of solar zenith angle and estimates the effects of atmospheric absorption and Rayleigh scattering. It also takes the advantages of dark object subtraction (DOS), which assumes that any radiance recorded for a dark object is due to atmospheric path radiance. Atmospheric correction parameters for the model were given in Table 1.

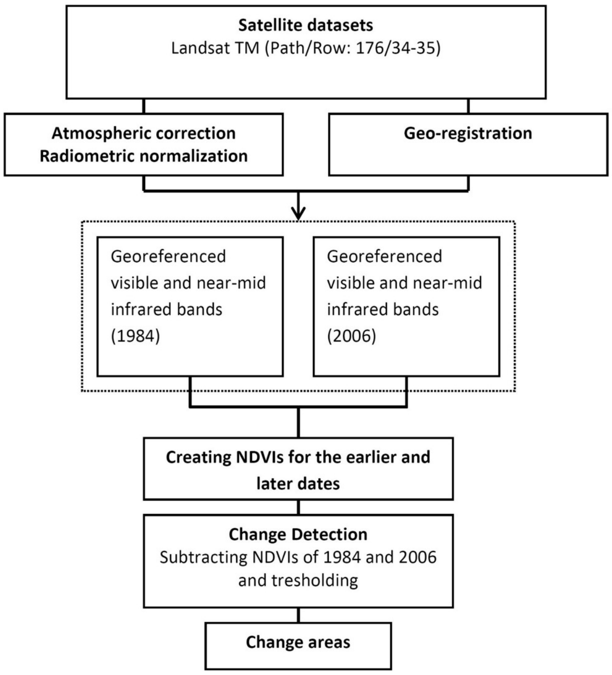

Fig. 3. Flow of the change detection analysis

After atmospheric correction, images were normalized using linear regressions calculated between images. The later date image was used as reference during this calculation. Normalization functions were applied and normalized image was produced.

3.2. Calculating NDVIs and extracting change information

Geographically and radiometrically corrected imagery was used for calculating NDVI images for the earlier and later dates. These two images were then differenced to produce a change image, in which extreme bright and dark values indicate candidate change areas, while average grey levels coincide with candidate no-change areas (Fig. 4).

Table 1. Atmospheric correction parameters (*offset, **gain)

Band	Lmax		Lmin		Sun elevation (°)		Time		Date
	176 / 34	176 / 35	176 / 34	176 / 35	176 / 34	176 / 35	176 / 34	176 / 35	176 / 34–35
3	1.040*	1.040*	–1.170**	–1.170**	57.09	57.52	07:51	07:51	03 Aug 1984
4	0.873*	0.873*	–1.510**	–1.510**					
3	264.0	264.0	–1.170	–1.170	58.48	59.23	08:15	08:15	16 Aug 2006
4	221.0	221.0	–1.510	–1.510					

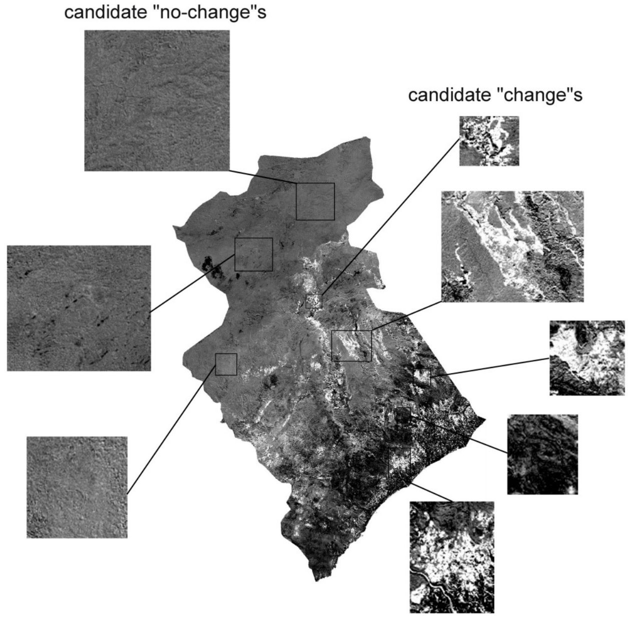

Fig.4. NDVI difference image for the study area and interpretation of the candidate change and no-change areas

The resulting NDVI difference image was analyzed in order to distinguish change from no-change. This analysis was based on thresholds, each leading to change images with varying proportions of change / no change information. Accuracies of these binary-coded change images, in which non-zero (1) values indicated change, while zero (0) indicated no-change were evaluated by calculating and comparing several accuracy measures such as overall percentage and Kappa accuracies. Table 2 shows comparisons of these calculations.

Accuracy results suggested that the threshold level of 1.4, as standard deviation distance from the mean value of the NDVI difference image yielded an overall accuracy of 0.86 with an associated Kappa value of 0.71. Other threshold values also provided relatively high accuracies.

Table 2. Accuracies (PA: producer's accuracy, UA: user's accuracy, OA: Overall accuracy, 1: change, 0: no-change)

Layer	PA (0)	UA (0)	PA (1)	UA (1)	OA	Kappa
NDVI 10σ	0.88	0.60	0.41	0.77	0.65	0.29
NDVI 12σ	0.80	0.89	0.90	0.82	0.85	0.70
NDVI 14σ	0.84	0.87	0.87	0.84	0.86	0.71
NDVI 16σ	0.88	0.85	0.84	0.87	0.86	0.72
NDVI 18σ	0.92	0.83	0.81	0.90	0.86	0.72
NDVI 20σ	0.94	0.80	0.77	0.92	0.85	0.70

4. Interpretation of changes

Spatial heterogeneity of landscapes and extensive human interventions in the study area resulted with complex patterns of temporal change in the study area. Inspection of these change patterns revealed information about the quality of the LC changes that took place between the earlier and later dates. The change map was interpreted using various sources of collateral information (e.g. high resolution satellite images, forest stand maps, etc.) and the field data. Following summarizes the change detection analysis:

(1) Temporal changes on the coastal plain were more evident than those occurred on the higher areas. The changes on the coast were mainly due to expansion of agriculture and urbanization.

(2) Agricultural expansion, which transformed large quantities of (semi) natural vegetation to crop fields, existed on a topographic gradient from coastline to high altitudes up to 2000 m. Agriculture grew at the expense of macchia shrublands at relatively lower altitudes. During this transformation process, agricultural practices and crop pattern also changed especially on the coastal zone. For example, open field agriculture, which was extensively applied in the past, has recently changed to orchards and greenhouses.

(3) Crop patterns varied between the coast and uplands and between the earlier and later dates. The intensity of agriculture also increased due to high demand for growing cash crops two / three times per year.

(4) Urbanization mostly occurred along the coastline and around the town center. Urbanization along the coastline was mainly caused by multistory buildings designed to serve as summer apartments.

(5) Forest-related changes were observed as regeneration of forest stands in the areas that were logged prior to acquisition of the earlier date images. Deforestation mostly took place at lower altitudes in relatively smaller patches in close proximity to the coast and to the roads. This phenomenon was mainly due to new summer apartments expanding over macchia shrublands.

4.1. Drivers of landscape changes

The study area has undergone rapid and extensive changes during the study period due to unprecedented tourism development on prime agricultural lands on the coastal zone and agricultural expansion on the foothills of Taurus Mountains. This process changed spatial configuration of agriculture areas from previously dominant citrus plantations existed on the coast to a mixed pattern of greenhouses and citrus plantations behind the developed coastal land.

The coastal zone of the study area has narrow alluvial plains between the Mediterranean Sea and Taurus Mountains. Formed by the streams flowing into the Mediterranean Sea, these plains provide highly fertile soils for crop production. However, their destruction by multistory buildings created a trend, by which agriculture was forced to move to upper lands, where the land is far less favorable for agriculture than on the coast due to limestone outcrops and thinner top soil. Not to mention that during this transformation, vegetation cover on these relatively higher areas was removed and the relief has changed due to e.g. stone terraces built on sloping hills (Fig. 5).

Land use policies play a central role as they determine the type, extent and magnitude of land cover changes. For example, Sun *et al.* (2010), reported changes in the NDVI, which are indicators of landscape transformations, are closely linked with policy-oriented differences in urbanization in China.

The development on the coastal zone of the study area, which created serious implications for the use of resources, was driven by economic and cultural transformations during the liberalization of Turkish economy in 1980s. Existence of coastal laws and their proper enforcement is also another important factor for environmental resource use and management. The fact that many different changes made in the Turkish coastal legislation starting from early 1980s also created substantial impacts on the landscape transformation processes in the study area.

First Turkish coastal law numbered 3086 was issued in 1984 to determine the conditions of use of the coasts. It described the terms coastline, coastal edge line and the coastal band, which indicate a horizontal width between 10–30 meters from coastal edge line towards the land. According to this law, coastal development was permitted upon a plan decree only for buildings and facilities such as shipyards, factories, and water product premises that conduct their activity at the coast in structures aiming for public interest and comfort. Furthermore, permission for educational, recreational and tourism facilities was also granted (Ceylan 2006).

The Coastal Law numbered 3086 was cancelled by the Constitutional Court in 1986. In order to avoid a legal gap, the Constitutional Court postponed the enforcement of the cancellation decree six months. However, no new coastal law was issued during that period, while the Ministry of Public Works released a circular (circular 110) in July 1987 that took into consideration the Constitutional Court's cancellation decree. The Circular 110 was then cancelled in February 1989. In April 1990, a new Coastal Law numbered 3621 was issued on and its related directives of practice were enforced in August, 1990 (Eke 1995; Tekinbas 2000; Ceylan 2006). Since then, several other revisions have been made on the coastal law numbered 3830.

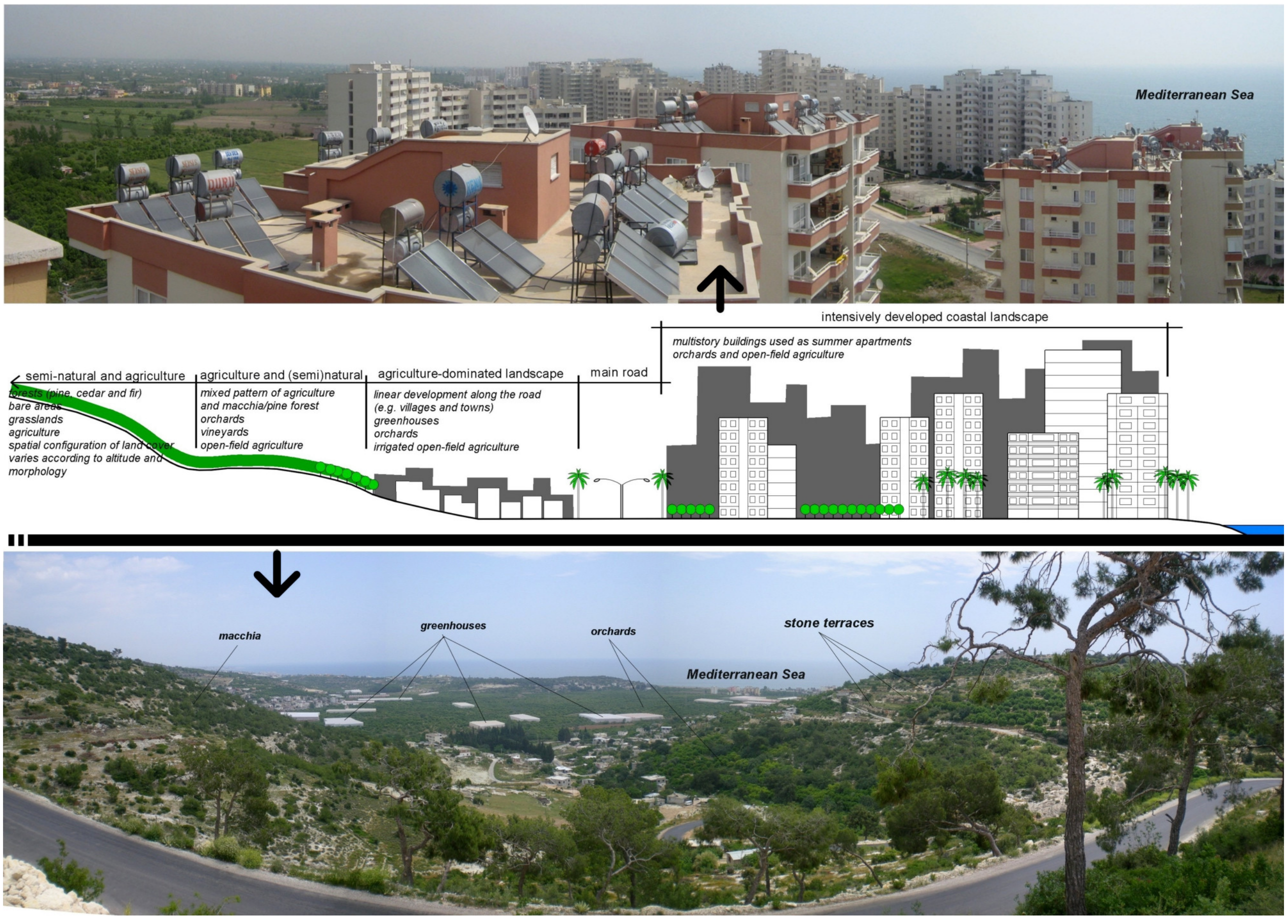

Fig. 5. Typical profile of lower altitudes in the study area. Intensive development along the coastline (above) and the mixed pattern of agriculture areas and (semi) natural vegetation behind the developed coastal zone (below)

In the study area, forest regeneration which corresponds to positive changes in NDVI comparisons existed. This was mainly due to harvested forests just prior to acquisition of the earlier-date imagery. Morawitz *et al.* (2006), used NDVI to detect vegetation changes in Western Washington, USA, and reported that anthropogenic factors were important drivers of positive and negative vegetation change. According to their results, population and road density were highly correlated with negative NDVI change. They also noted that vegetation changes were also due to the forests harvested or preserved. Although, we did not employ rigorous analyses on population dynamics and road network development, based on the knowledge from our field observations and the change map we produced, these two factors caused substantial changes in vegetation cover especially on the coastal zone. In this process, macchia vegetation of lower altitudes (up to 500 m ASL), was destroyed by urbanization.

Conclusions

Human alterations in the landscape cause serious land cover changes at different scales. This change information can be applied for watershed planning / management as well as for environmental modeling and assessment (Wen *et al.* 2011). This study dealt with vegetation changes on a regional basis in the case of Mediterranean landscapes. NDVI images were used for geographically identifying changes. NDVI images were also investigated for their efficiency in representing these changes using several test images that include varying amounts of change / no-change information. As a conclusion:

(1) Lower thresholds applied to the NDVI difference image produced less accurate change images. For example, a threshold of 1.0 applied to the NDVI difference image yielded a change image with an overall accuracy of 65%. Images resulting from relatively upper thresholds (e.g. 1.6), however, yielded better accuracies.

(2) The area under investigation supports typical Mediterranean landscapes that show high spatial and temporal variations on a topographic gradient. In general terms, areas with lower altitudes, mainly characterized by a mixture of agricultural patches, pine forests and high macchia shrubs have undergone extensive changes due to agricultural expansion. The invasive nature of agriculture was also evident in upper lands. Coastline and coastal alluvial plain, on the other hand witnessed rapid urbanization. The town expanded and the coastline was occupied by high multistory buildings serving for domestic tourism.

This study demonstrated a methodology that helps easily locate the areas of LC change using vegetation as an indicator. The areas of disturbance were identified with the help of collateral data. This methodology may help resource planning as it provides a basis to locate and identify areas of disturbance by creating a spatial background for change and disturbance studies, which can be employed on finer spatial and time scales to solve complex questions in the context of landscape ecology.

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