Landscape Change and Implications on Protected Areas

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Abstract. The purpose of this study is to detect the characteristics of the landscape change in the protected area environments by using Remote Sensing, GIS and landscape structure indices. Dilek Peninsula Big Meander Delta National Park of Aydin Province, Turkey is the focus of this case study. SPOT 2X and ASTER images are utilized in object oriented classification to detect changes respectively between 1994 and 2005. 5 landscape structure indices are applied to the classified maps. The results have displayed a decrease of the coniferous forests, high maqui, low maqui, grasslands, salt marshes and salt flats, and an increase of the moderately high maqui, garrigue, arable lands and permanent crop fields. Artificial surfaces have slightly decreased. Major drivers of the landscape change includes urbanization, grazing, fire, and clearing of original vegetation for agriculture. Subsequently, coniferous forests, and high and low maquis have been most negatively affected from fragmentation. Matrix utility index has yielded that Dilek Peninsula Big Meander Delta National Park has been subjected to increasing edge effects.

Keywords. Landscape change, object based classification, landscape structure indices, protected areas

Introduction

Conservation of biodiversity holds greater importance as the environmental problems escalates to global level. Accordingly, ecologically important areas are established as national parks. Out of 39 national parks of Turkey, Dilek Peninsula-Big Meander Delta (DPBMD) National Park in Aydin is one of the most important parks in terms of biological diversity. Despite its conservation status the park faces, primarily, fire and water pollution problems along with unsustainable grazing and gaming, exceeding visitor capacity in summer months and increasing road networks. Moreover, the anthropogenic pressures from the surrounding landscape are threatening the resource value of the park. Urbanization of the touristic town of Kusadası on the north, and the intensive agricultural practices taking place in the Soke Plain on the south are such examples of these external impacts. Subsequently, the landscape values of the park have been changing. Determination of the magnitude of this change can help resource managers in taking sustainable protection measures.

The purpose of this study is to detect the characteristics of the landscape change in the DPBMD national park by using Remote Sensing, GIS and landscape structure indices. Analyzing landscape change helps in identifying some of the most critical implications of complex interactions between social and environmental processes [1,2]. Recent developments in landscape ecology paradigm, remote sensing and GIS technologies have been offering new insights into the ecological integrity of landscapes. Especially the use of landscape indices has become popular in this endeavour. Landscape indices enable the quantitative characterization of landscape patterns. They can be used as variables for models that support objective planning actions.

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Caution should be exercised in the utilization of the indices: the selected indices should not be redundant and capture the major properties of the investigated landscape [3]; appropriate spatial observational units should be used as the indices are sensitive to the extent [4]; and also, cautions should be taken when defining land cover categories [5]. The same land cover classes should be utilized when using different spatially scaled remote sensing data [6]. Land cover classes should be meaningful to the planner of that particular landscape, so that the analysis of landscape through landscape indices will yield findings that are directly relevant to planning [2].

When applying landscape indices to land cover maps, the accurate representation of landscape pattern plays an important role. Object based methods have the advantage of incorporating spatial neighbourhood properties into the classification process, thus counteracting sensor limitations and producing a more accurate representation of landscape patterns compared with pixel-based methods [7]. Object based approach produces a thematic map composed of geographical entities labelled with actual land cover classes. This allows obtaining meaningful objects of ground features for analyzing landscape pattern with landscape indices, describing the spatial complexity of the objects, and better utilizing complicated GIS functions in analyzing the data.

1. Study area

Our study area, Dilek Peninsula-Big Meander Delta National Park (Figure 1), is located in the Aegean coast of Aydın, Turkey (27°02' and 27°15' east - 37°36' and 37°42' north). It covers an area of 27675 hectares. In 1966, part of Dilek Peninsula’s was declared as the national park (10985 ha.). Later in 1994, Big Meander Delta, on the south of the peninsula, was added to the park (16690 ha). DPBMD National park is among the important natural reserves of Turkey and Europe. The delta part of the park is an “A Class Wetland”, and the peninsula is a “Flora Biogenetic Reserve” based on the European Council’s European Biogenetic Reserve classification [8].

The national park is neighbouring with a touristic town of Guzelcamli (southern end of Kusadasi) on the northeast, and the agricultural settlements of Tuzburgazi on the southeast, and Batiköy, Balat and Akkoy on the east. Doganbey, the only settlement in the park, is located at the transition zone from the peninsula to delta. In terms of the soil capability classes, the peninsula generally comprises Class VI and VII soils, and the delta section has Class IV, VI and VII soils. A typical Mediterranean climate prevails in the area. Average temperature is 26°C (47-48% humidity) and 25°C (61-64% humidity) in the southern and northern aspects, relatively. There are 804 plant species belonging to 95 different families [9]. 24 of these species are endemics; however, 22 of the endemics are listed in the endangered species lists. The park also has rich fauna: 28 mammal, 27 reptile and vast number of marine species. Anatolian panther and Mediterranean seal, both of which is about to extinct, is listed in the park’s fauna. Delta section is rich in bird diversity (250 bird species).

2. Material and methods

The main research materials of this study included ortho-rectified Spot 2X (dated March 03, 1994) and Aster (dated April 27, 2005) images. Also, already rectified Quickbird satellite image (dated March 05, 2006), and 1: 35 000 scale black and white aerial photographs (dated August 1993), were used for the visual interpretations and the accuracy assessment. Data collected by hand held GPS, and notes generated during our field studies were also used in the analysis as ground truth data. 1/5000 scale city plan of Guzelcamli settlement was employed for studying the possible impacts of neighbouring urban development.
2.1. Image pre-processing

First, the subsets of the satellite images were obtained and then the atmospheric correction was done on the subsets. We used ASTER visible near-infrared region (bands 1, 2, 3) with 15 m spatial resolution and SPOT 2X (bands 1, 2, 3) with 20 m spatial resolution. Second, we re-sampled the SPOT 2X image into 15 m spatial resolution using nearest neighbour method in ENVI (version 4.1). Third, we added the DEM and Aspect (derived from DEM) layers to layer stack to increase the classification accuracy.

Based on our expertise on the study area and the spectral attributes of the available data, we defined 15 LUC classes: 1- Coniferous (Coniferous forest), 2- High maqui (<70% coverage, taller than 2m.), 3- Moderately high maqui (50-70% coverage, around 2m. or less in height), 4- Low maqui (10-50% coverage, less than 2m), 5- Garrigue (discontinuous, 30-60 cm. bushy associations), 6- Transitional woodlands (naturally growing new forest), 7- Sparsely vegetated (steppes, areas with scattered low bushes), 8- Arable land, 9- Permanent crops (Olive, Citrus, Plum plantations), 10- Artificial surfaces (buildings and other impermeable surfaces), 11- Salt marshes (vegetated areas above the high tide line) 12- Saline areas 13- Grasslands (Grasslands, moors and pasturelands) 14- Bare rock, and 15- Water.

2.2. Segmentation, classification and accuracy assessment

Object based technique focuses on the meaningful objects of ground features rather than a uniform pixel, and involves two steps: segmentation and classification [10]. For the procedures, we used the
Definiens Imaging (version 5). In the first step we used a multi resolution segmentation algorithm, which is a kind of region growing methods [11]. Table 1 displays the scale parameters and homogeneity criteria (the ratio of color and shape, and the ratio of smoothness and compactness parameters) utilized in this study. Depending on the scale, there are three levels of segmentation quality: (1) over segmentation, (2) optimal segmentation, and (3) under segmentation. Individual ground features will be guaranteed by segmentation with optimal scale parameters.

<table>
<thead>
<tr>
<th>Images</th>
<th>Segmentation level</th>
<th>Scale parameters</th>
<th>Homogeneity criteria</th>
<th>Shape ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPOT2X</td>
<td>Level I</td>
<td>10</td>
<td>Colour (%)</td>
<td>80</td>
</tr>
<tr>
<td>ASTER</td>
<td>Level II</td>
<td>20</td>
<td>Shape (%)</td>
<td>70</td>
</tr>
</tbody>
</table>

After obtaining the image objects through segmentation at the optimal scale, we applied the nearest neighbour classifier to describe the land cover classes by user defined sample objects (training samples) for each class. Based on the ground data gathered by GPS and Quickbird images, we defined sets of training samples for each class (more than 100 samples per class). We were not able to obtain satisfactory results for distinguishing artificial surfaces from non-vegetated arable and bare lands, and in some areas from salines, therefore we applied manual editing to these classes. Subsequently, each object was assigned to one of the fifteen LUC classes, hence generating the final thematic maps for each study period. The details of the segmentation and classification can be found in Esbah et al. [2].

Finally, we conducted an accuracy assessment by using ground truth reference data. Also the Quickbird images and the black and white aerials were used to test the classification of ASTER and SPOT2X images, respectively. Random points are generated by stratified random sampling method in the Erdas Imagine (version 8.7). The overall, user and producer accuracies and the kappa statistics are calculated.

2.3. **NDVI analysis**

The NDVI is an indicator of vegetation activity such as plant growth of vigour and vegetation cover. NDVI algorithm produces output values in the range of -1.0 to 1.0. Vigorously growing healthy vegetation has low red-light reflectance and high near-infrared reflectance, and therefore yields high NDVI values. Near zero and increasingly negative NDVI values indicate non-vegetated areas such as barren surfaces, water and clouds. We applied the NDVI tool provided by the Erdas Imagine 8.7 software.

2.4. **Landscape structure indices**

We used four class level landscape indices namely (1) percentage of landscape (PLAND), (2) patch number (PN), (3) mean patch size (MPS), and (4) mean shape index (MSI). In addition, the overall impact of surrounding land uses calculated via matrix utility index (MU).

PLAND allows quantifying the extent of each land cover class and discerns the presence of a matrix. It characterizes the overall evenness of the landscape [3]. PLAND changes between zero and one hundred, lower values indicate less representation of the corresponding class. PN represents the number of discrete patches of a particular land cover class. PN reveals the subdivision aspect of fragmentation, which is listed as the greatest threat to biodiversity [12]. MPS measures the size of discrete patches summarized across all patches of a particular land cover class. Area information is important as size affects biomass, primary production, nutrient storage per unit area, and the population of supported species, hence serving as a rough indicator of landscape function [2]. MSI measures the average patch shape for a particular land cover class and indicates the geometric complexity of a patch. Patch shape influences the magnitude and the nature of the interaction with the surrounding neighbourhood. MSI varies between zero and one. As shape complexity increases towards 1, the pro-
portional abundance of edge influenced habitat increases, hence lower ecological integrity. The formulas and greater details of these indices are provided in Leitao et al. [39]. Our last index was matrix utility index. MU varies between zero and one. If a patch is surrounded by compatible land uses the MU value approaches to one, indicating higher ecological integrity. More information about this index can be found in Esbah et al. [13].

3. Results

Our classification yielded 77.30% and 78.42% overall classification accuracy for SPOT2X (1994) and ASTER (2005) maps, respectively. We obtained high user’s and producer’s accuracies for coniferous forest, saline areas, arable lands, artificial surfaces and water. The manual editing of some of these classes accounts for their higher accuracy.

The results have displayed that coniferous forests, high and low maqui cover has experienced the most decline (Table 2). The NDVI result in Figure 2 also displays decreasing value for the areas mainly covered by these classes. Increasing PN and decreasing MPS show that these covers are in the fragmentation stage of land transformation. The area of salt marshes and saline flats has also declined. The change in saline areas is attributable to the agricultural practices encroaching upon these areas. As a result the shape of remaining saline patches has become more complex. NDVI results also confirm the improvement of vegetation cover in saline areas at the delta part. (possibly due to agricultural production).

Our results have yielded diminishing PLAND values for grasslands. Even though, the MPS of remaining grassland patches didn’t change significantly, the number of patches declined considerably, hence indicating the dissection of these habitats. Artificial surfaces have slightly decreased in the park. The settlement pattern has become more convoluted as indicated by increasing MSI, and more fragmented as indicated by MPS and PN values in 2005. No population fluctuation has occurred in Doganbey for two decades; therefore this is not a sign of out-migration. It is, rather, the outcome of regulations controlling the building style, type, etc. in the park.

Table 2. Results of the landscape change with landscape structure indices.

<table>
<thead>
<tr>
<th>LUC*</th>
<th>PN</th>
<th>MPS</th>
<th>PLAND</th>
<th>MSI</th>
<th>LUC*</th>
<th>PN</th>
<th>MPS</th>
<th>PLAND</th>
<th>MSI</th>
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<td>50</td>
<td>6.04</td>
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</table>

Land use/cover (LUC*): 1- Permanent crops, 2- Garigue, 3- Transitional woodland, 4- Conifer, 5- Salt marshes, 6- High maquis, 7- Moderately high maqui, 8- Low maqui, 9- Grassland, 10- Sparsely vegetated, 11- Water, 12- Arable land, 13- Saline areas, 14 Artificial surfaces, 15- Bare rock.
On the other hand, the results have showed expansion of permanent crop fields and arable lands. However, the resulting pattern indicates greater patch number with smaller patch sizes. While the shapes of permanent crop fields become less complex, the shapes of arable lands become more convoluted. This is due to the clearing of natural vegetation cover for gaining agricultural land. The increase of transitional woodland is attributable to the fire occurred in 1996 at the southern slopes of the park. The landscape is in a succession period, hence increasing PLAND, PN and MPS values. NDVI also supports the succession on southern slopes (Figure 2). Transformation of low maqui cover to less dense vegetation cover accounts for the increase in PLAND and MPS of garrigue class. This type of transformations possibly occurs as a result of edge effects generated by anthropogenic activities.

Thus, the Matrix utility index has yielded that Dilek Peninsula Big Meander Delta National Park has been subjected to increasing edge effects. The investigation of neighbouring land uses illustrated that in 1990’s the park was surrounded primarily by the natural areas and agricultural fields, and secondarily by open spaces, river and canals. By mid 2000’s the neighbourhood with natural patches diminished while the amount of arable lands increased. There was a slight increase in the settlement areas along the periphery of the national park. As a result of all these developments, the MU value declined from 0.83 in 1994 and 0.76 in 2005 (6% decline). Investigation of the 1/5000 city plan of Guzelcamli, most major settlement on the border of the park, illustrates that the current
plan would result in 40% decline in the MU values, hence increasing edge effects on the ecological integrity of the DPBMD national park.

4. Conclusion

In our work, we have pursued a landscape ecology approach and utilized a set of landscape metrics to understand the changes in the landscape pattern. Landscape patterns are complex; seldom one single metric is useful to explain spatial patterns. Landscape metrics are better used in conjunction. All together, the metrics enabled a comprehensive interpretation of the landscape pattern in our study area.

Our nomenclature was useful to detect the variation in the vegetation cover, and to capture the finer details of the transformations. Therefore, we recommend its use in similar cases. Our results suggest that object based classification of Aster and Spot images has considerable potential in generating data that can be used with landscape structure indices to understand landscape change dynamics in the complex Mediterranean ecosystems.

Major drivers of the landscape change in the study area include urbanization, grazing, fire, and expansion of agricultural activities. As a result of all these, the resource value of the DPBMD National Park has been changing for two decades. Coniferous forest, high and low maqui covers, saline areas and grassland have been most negatively affected from this change. Moreover, the national park has been dealing with the edge effects of its surrounding settlement. All of these calls for taking landscape management measures not only for inside but also for outside of the park.

References
