The Effects of Urban Spatial Development on Coastal Ecosystems: The Case of Mersin, Turkey

Merve Yilmaz¹, Fatih Terzi¹
¹ Department of Urban and Regional Planning, Istanbul Technical University, Taskisla, Istanbul/Turkey

yilmaz.merve@itu.edu.tr

Abstract. In the process of urbanization, protection of ecosystems and ensuring the continuity of the services they provide are very important in terms of the functionality of life support systems. Otherwise, degradation in ecosystems can have negative consequences for different dimensions, such as biodiversity decline, over-consumption of resources and climate change. In this context, as a result of urbanization, the loss of surface water drainage areas, the interruption of the continuity of green corridors and the increase in the size of impermeable surfaces cause problems in terms of sustainable development. Therefore, the attempts to ensure urban spatial development in harmony with natural areas in coastal areas are one of the most important issues of the planning agenda. The aim of the study is to reveal the relationship between the urban development pattern and the natural areas in the context of sustainable urban development, in the case of Mersin a coastal city in southern of Turkey. For this purpose, an interdisciplinary approach by using geographic information systems and remote sensing has been applied to understand the urban spatial patterns of Mersin. A multi-temporal change by using a series of satellite images for the three periods of 1987-2000-2015 have been analyzed. Threshold values was employed to detect built-up land and non-built-up land on the images. The results revealed that Mersin has spatially grown more than 6 times since 1980. The spatial growth is observed to increase by 80 % between 1987 and 2000 and by 60 % between 2000 and 2015. Under these circumstances, the development in Mersin has resulted in critical problems about decreasing of natural area in size, disconnecting of green network and degradation of coastal ecosystem. The results of the paper highlight the importance of determining the measurable variables for analyzing problems of urban forms for the future development strategies of cities.

1. Introduction
The future of ecosystems has been based on urban spatial development pattern in the course of time. Sprawling cities cause to destroy in the natural environment especially coastal cities that is located in the interface combined sea and land come about results, which is trigerrer destruction both the hydrologic ecosystems and the terrestrial ecosystems [1, 2, 3, 4, 5, 6]. In the result of adversely influenced ecosystems, cities and natural areas are experienced increasing sea level, increasing heat of sea water, flooding, storm and coastal erosion due to climate change [2]. In addition, losing ecosystems in the coastal regions is experienced increasing risks of climate change and disaster sensitive settlements [7, 8, 9, 10]. Relations between the urban spatial development and natural environment accompanied with the spatial development balance correspond to the sustainable spatial development.
Numerous specialists underline the significance of giving coherence of green framework without interfering with them because of developed territories in the environmentally delicate regions [8, 11, 12, 13]. Ecologically sensitive areas such as riparian zones, timberland zones, surface water seepage zones, green territories, in waterfront urban communities are the fundamental components guaranteeing continuity of the green associations. These regions might be characterized as delicate natural corridors serving to the ecosystem functions (such as forests, agricultural lands, meadows and water ecosystems). Examining the urban morphology that are affected by such changes by methods for the quantifiable factors will make noteworthy commitments to deciding the future improvement procedures of the urban areas.

In the study, urban spatial development and relationships of green corridors connection in Mersin coastal city were analysed by using multi-temporal change in three different periods of 1987, 2000 and 2015. There are many quantitative assessment methods that may be used to analyze the urban spatial development and observe to their effects on natural environment [14, 15, 16, 17, 18, 19]. We have used some quantitative methods for the relationships and the development. As an analysis for ecological corridors under the influence of urban spatial development, coastal green area index and green corridor index were calculated through remote sensing and geographical information system tools.

2. Ecosystem functions of coastal regions and ecologic corridors

Global ecosystems that is chanced by human/people is important in management of sustainable ecosystems. Economic development and human welfare are based on sustainable of the management. The capacities of ecosystem must be known and evaluated in terms of natural lands/areas and natural research use. The sustainable management is for not only people/dwellers but also protected of flora-fauna and ecosystems. The sustainable of ecosystem resource use is important for the future resource use of current capacity, extent and conditions [3]. Coastal ecosystems and sea ecosystems is among the most productive and abundant ecosystems [20, 21].

Coastal ecosystems in the interface of sea and terrestrial area have hosted many species (as flora-fauna) and genetic diversity. The richess is provided to help the water filtration, nutrient cycle, prevention from coastal erosion and protection from storms. Therefore, the coastal regions are an area that have interface between natural environment and built-up area [12]. Water has a main role among people and ecosystems and it is provided to hydrological cycle in ecological cycle. The cycle in water and terestrial ecosystem sustains the cycle of water, nutrient and energy. Regulation of the hydrological cycle is directly related to size of land cover (e.g. forest, riparian area, green valley areas) [22, 23, 24, 25, 26, 27]. In addition, the cycle is the main factor in the sustainablity of the ecosystems and the biodiversity [8].

The size and form of green area related ecosystems have been converted to diffetent functions or forms by shrinking or disconnecting from each other [28]. One of the most effected factors about the chances is increased to the impervious surface, which results in increasing heat island effect and decreasing surface infiltration [20, 21, 29, 30, 31, 32, 33].

Landscape areas have hosted many species (flora-fauna) from macro region (e.g. forests) to micro region (e.g. roadside vegetation). Linear corridors, riparian corridors and green network are among the most integrated characteristics to each other [11, 26]. Network relation comprised of these corridors is modelled as a spatial relations which are natural-vegetation patches, vegetation along major streams, connectivity between patches described in Figure 1 [11, 34].
3. Material and methods

3.1. The study area and the history of urban development

Mersin is a coastal city on the border of Mediterranean in the south of Turkey (Figure 2). Mersin that was a mere village in the 18th century has been developed as a port of Cukurova region that is agriculture area [35, 36]. The city has been affected from urbanization process. The 1950s, it was one of turning points for the urbanization, which are led to increase of urban migration in the 1950s-1960s. Urban spatial development in Mersin up to 1960s had been occurred through the west from the city core and up to 20th from 19th century, the core city protected as spatial form [37, 38, 39]. Mersin has been a port city thanks to agriculture production in Adana region since the past [35].

Mersin has been economically, socially and physically affected from the migration movements since 19th century. The rapid development of Mersin during the 19th century developed relations with other port cities. Railway that has important role in transportation modes and specialization activities was installed in the 1960s and it has been provided to more urban development [40]. Mersin population increased about twenty time from 1950s up to now. In the development, the port activities has been had important roles.

Figure 1. Model of landscape patches and green corridors [34]
3.2. Mapping of multi-temporal change

Satellite imageries in the different periods have been used to analyze how spatial development pattern has came about in Mersin and to analyze the development events that have an impact on natural environment. Landsat 5 TM images of August 12, 1987, Landsat 7 ETM + SCL-on (1999-2003) images of August 16, 2000 and Landsat 8 OLI/TIRS images of August 2, 2015 were obtained in three periods between 1987 and 2015, from high quality images, with the the lowest cloudiness ratio (earthexplorer.usgs.gov). Image classification indexes created in the study were used for the three satellite images. The indexes were used to obtain the built-up area and water surface by the software of Erdas IMAGINE 2014. NNBAI (New Normalized Built-up Area Index) and MNDWI (Modified Normalized Difference Water Index) used in this study were produced indexes provided increasing the ratio of accuracy [41, 42, 43], which became determinant for the image classification indexes.

Band equations of the satellite images used for the image classification indexes by Erdas IMAGINE are as follows (equation 1, 2, 3, 4):

Image classification indexes for Landsat 8 images:

\[
NNBAI = \frac{(Band_7 - Band_6)}{(Band_7 + Band_6)} \bigg/ Band_2
\]

(1)
\[ MNDWI = \frac{\text{Band}3 - \text{Band}7}{\text{Band}3 + \text{Band}7} \]  

**Image classification indexes for Landsat 7 ETM+ SCL-on (1999-2003) and Landsat 5 images:**

\[ \text{NNBAI} = \frac{(\text{Band}7 - \text{Band}5)}{(\text{Band}7 + \text{Band}5)} \]

\[ MNDWI = \frac{(\text{Band}2 - \text{Band}7)}{(\text{Band}2 + \text{Band}7)} \]

Pixel values of the images were set between 0 and 255 and a pixel cell was decided as 100x100 meter. Pixel values of the built-up regions and water surface of the settlements found in distinctive geological positions have diverse edge values due to atmospheric conditions. In this manner, edge values were set for each period. Such values were compared with the satellite images of the respective year and set concurring to the value intervals giving the most plausible built-up zone design.

Undeveloped land, built-up regions and water surface obtained from the limit values were changed over into 0 (undeveloped land) and 1 (built-up area) value (as twofold maps) by means of the ArcGIS 10.3.1. The same strategy was applied to the water surface in arrange to decide the water and land surface. The ‘Built-up Range Index’ created under this study was utilized for the obtained maps. This file is expressed as follows (equation 5):

\[ \text{Built-up Area Index} = \text{NNBAI}_v - \text{MNDWI}_v \]

**Built-up Area Index:**

\[ \text{NNBAI}_v: \text{Built-up area vector data} \]

\[ \text{MNDWI}_v: \text{Water surface vector data} \]

Built-up Area Index was used to obtain images of built-up vector data and water surface vector data combined.

### 3.3. Measuring ecological corridor connectivity

Conversion of natural areas into the built-up areas in the time leads disconnection to the ecological corridors such as the green corridors (e.g. surface water drainages, riparian areas, green areas along coastal zone). In addition, losing the vacant land in the city in the course of time causes to adversely affected the ecologic sustainability of both the settlement and the nature environment. At the same time, typology of urban spatial development (e.g. sprawling development, leapfrog development, infill development) is one of the most determinative factors resulted from inefficient use of the limited natural resources [44, 45, 46].

There are three main green connections serving to evaluate the green network on coastal regions. This includes valley (area of surface water drainage line), riparian areas, green areas along coastal zone [47, 48, 49, 50]. Connections hypothetically described in Figure 3, 3, and 4 have been used for explanations of these connections that are green corridors and green areas along coastal.
Figure 3. The elements of the model of urban spatial development

Green/ecological corridors

It indicates to the value of continuous of the green corridors such as valleys and riparian areas in and around in the city, and forests that have important role on hydrological systems. Ecological systems have important roles in terms of sustainability of natural areas and connections among green corridors. Therefore, it is necessary sustained continuous and relationships of the corridors. Increasing distance between nature areas and undeveloped lands has been adversely affected ecosystem cycles [46].

Increasing rate in the green corridor index, value defines the disconnection green corridors. Urban spatial development area in riparian area and valleys cause inefficient use of the limited resources (Figure 4).

\[
\text{Green corridor index} = \frac{G_{\text{built-up}}}{G_{\text{area}}} 
\]

In the green corridor index (6), \( G_{\text{built-up}} \) indicates the built-up areas (hectare) developed in valleys and riparian areas while \( G_{\text{area}} \) designates the total riparian area (hectare) and the total valley area (hectare). Increasing in the value of green corridor index means high ratio of disconnection green corridors while the more low values implies protected of connection green corridors.

Figure 4. Model of green corridor connection

There is uncompleted areas as urban spatial development in and around the city. The areas may be defined as transition regions to ensure connections among ecological regions (e.g. forests, riparian areas, valleys). In the course of time, conversion of uncompleted urban areas, undeveloped lands and/or natural areas into built-up areas has been destroyed the transition regions/corridors. As the
result of this destruction, absence of the hydrology cycle, negative micro-climatic effect and intense/high heat island effect have been negatively affected the sustainable urban development.

Green/ecological area along coastal

The coastal green area index indicates to the fragmentation green area value of coastal area that is transition area between land and sea as one of sensitive regions in ecosystems. Increasing rate in the index value defines both the decreasing coastal use and weakness connections of natural areas to each other.

\[
\text{Coastal green area index} = \frac{C_{\text{built-up}}}{C_{\text{area}}}
\]

In the coastal green area index (7), \(C_{\text{built-up}}\) indicates the built-up areas (hectare) developed in the coast area while \(C_{\text{area}}\) designates the total coastal green area in 500 meter buffer area from coast (hectare). Increasing in the value of coastal green area index means high ratio of destruction vulnerability in coastal ecosystems and disconnection between land and sea while the more low values implies protected of coastal green corridors and/or more less adversely effects on coastal ecosystems.

Parallel form of sea and land by each other has important role in different type ecosystems and habitat movement. The form increases to interaction of ecosystems [11, 12]. Conversion of the vacant lands and undeveloped area along the coast of city into the built-up areas over time causes destruction of the natural environment and ecological cycles. Therefore, the low built-up rate on coastal region and integration with green network are highly effective factors for sustainable natural environment, economic and social activities.

4. Results and discussion

Urban spatial development which changes and converts in the course of time can be adversely affected natural environment. The effect can be defined using the quantitative methods. This study brings about evaluations regarding conversion of the built-up areas and connection/disconnection green corridors over time. We have used index calculations which are based on the size of the built-up area and ecological corridors. According to these measurements, it is indicated that is disconnection of ecological connections while being urban spatial development. In order to connections the ecological corridors, we have used images obtained kernel density that is used grid points in per one hectare by forest area, riparian area, valley (100 meter area of both side of surface water drainage line) and coast green area (500 meter buffer area from coast). Sea that has the most important role for hydrologic cycle in the coastal cities, is water drainage collection region in the highest level. Therefore, the
Drainage lines in coastal regions must be connected to sea and must be disconnected by built-up areas; otherwise the sustainability of ecological cycles may not be enabled.

To the urban spatial development, the built-up areas have been acquired through the image classification method by using the satellite images of Mersin. Such areas have been produced by determining edge values according to the ‘Built-up Area Index’ prepared in the context of this study (Table 1, Figure 6).

**Table 1.** Edge values of satellite images

|                  | 1987       | 2000       | 2015       |
|------------------|------------|------------|------------|
| **Edge values of the built-up area** | 89 ≤ NNBAI ≤ 145 | 107 ≤ NNBAI ≤ 145 | 113 ≤ NNBAI ≤ 145 |
| **Edge values of the water surface**  | 193 ≤ MNDWI ≤ 255 | 179 ≤ MNDWI ≤ 255 | 165 ≤ MNDWI ≤ 255 |

**Figure 6.** Urban spatial development pattern of Mersin (1987, 2000, 2015 by top to bottom) (1: city core, 2: port area, 3: main road direction)
According to binary images of the built-up areas and undeveloped land, it is observed that urban spatial development in Mersin has spatially grown more than 6 times since 1980. The spatial growth is observed to increase by 80 % between 1987 and 2000 and by 60 % between 2000 and 2015 (Table 2). The obtained built-up area images are used to acquire the built-up area development in green corridors (valleys, riparian areas, green area along coast). Built-up area trends in green corridor were found gradually increasing trend (Table 2, Figure 7). Natural threshold such as coastal line, port (spot 2 in Figure 6) relationships and transportation networks (spot 3 in Figure 6) are the most determinative factors of spatial development in Mersin. In Mersin, the city developed not only towards the north regions and along the coast, but also developed under effects of transportation.

Table 2. Land conversion rate by years

|                     | 1987 (hectare) | %    | 2000 (hectare) | %    | 2015 (hectare) | %    |
|---------------------|---------------|------|----------------|------|----------------|------|
| Built-up area       | 1113          | 2506 | 6599           |      |                |      |
| Valley area         | 1841 (100 %)  |      |                |      |                |      |
| Built-up area in valley | 9.49         | 0.79 | 5.34           |      |                |      |
| Riparian area       | 1290 (100 %)  |      |                |      |                |      |
| Built-up area in riparian area | 26.02       | 4.73 | 17.29          |      |                |      |
| Coastal area        | 1954 (100 %)  |      |                |      |                |      |
| Built-up area in coastal area | 13.06       | 21.70| 43.69          |      |                |      |

Figure 7. Change of built-up area (hectare) (left) and rate of disconnection green corridor (%) (right) by year

As it is described in Figure 8, green corridors have been disconnected towards and along coast. The disconnection has been triggered by the urban spatial development. In the disconnection green corridors, there is visible weakness in riparian area connection, besides along coast green corridor.

Built-up areas inside the green corridor areas cause shrinking green areas, disconnection and fragmentation of green corridors (Figure 8). In addition, the impervious surfaces have increased in the course of time (Figure 6). The images have been figured out disconnection spots that are due to built-up areas. There are Mersin port, the city core and new development areas in the west.
Figure 8. Images obtained kernel density by green corridors (left) and by built-up in the corridors (right) (circles means points or lines that were disconnected green corridors) (1987, 2000, 2015 by top to bottom)

5. Conclusions
Urban spatial development and green corridors takes place through the conversions of lands and connection of ecological area. Achieving sustainable spatial development is among the significant issues of the conversion of natural environment. This study deals with the phenomena of occurrence and the effects on green corridors of the development. Therefore, the spatial development pattern observed in Mersin has been evaluated in the context of disconnection green corridors from the 1987s onwards.

Conversion of the natural lands into the built-up areas over time causes destruction of the ecological corridors. In addition, losing the vacant land in the city in the course of time causes a disconnection on the corridors adversely affect the ecologic sustainability of the settlement. This situation can be occurred intense built-up pattern, absence of the hydrology cycle, negative micro-climatic effect and intense/high heat island effects.
As the result of the phenomenon, green corridors that have important roles on ecological cycles and coastal ecosystems. Sustainable planning principles must be components of built-up areas harmonized with natural environment.

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