

Monitoring the urban green spaces and landscape fragmentation using remote sensing: a case study in Osmaniye, Turkey

Murat Atasoy 

Received: 26 May 2018 / Accepted: 7 November 2018 / Published online: 10 November 2018
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Abstract Urban green spaces play a significant role in management of physical activity, psychological well-being, and public health of urban residents. With the expansion of urban areas in Turkey during the past decades, urban green spaces have been fragmented and dispersed causing impairment and environmental degradation. The purpose of this study is to model urban green space distribution by focusing on the landscape fragmentation in city of Osmaniye using remote sensing and geographic information system technology. Normalized difference vegetation index (NDVI) and urban landscape ratio (ULR) were used to assess the proximity and spatial arrangement of urban green spaces within the neighbor landscapes to quantify the urban land use effect. The geospatial analysis results showed that increase in total built-up area and population has significantly decreased the urban green space cover because of high levels of landscape fragmentation in urban city center. Also, due to high levels of landscape fragmentation, approximately 45% of the Osmaniye city is estimated to become urbanized by 2030. This study demonstrated the benefits of directional vegetation index application with geospatial analyses in characterizing the environmental quality for planning and management of urban green spaces. This approach could be used for determining the future urban land development scenarios correlating with regional planning procedures.

Keywords Landscape fragmentation · Remote sensing · Urban green space · Environmental monitoring

Introduction

Urban green spaces provide various social, economic, and ecological roles with a landscape to urban dwellers and these spaces consist of varying sizes of patches with diverse vegetative cover. They have characters regarding distance to public transportation, facilities, ecosystem services, and environmental quality for city dwellers (Sister et al. 2010; Wolch 2014). Public parks, protected and unprotected forest lands, and neighborhood landscapes covering the surrounding houses are the main components of urban green spaces (Mansfield et al. 2005). Public green spaces enhance the air quality, provide a rich biodiversity to urban areas, replenish groundwater, and balance the surface land temperature (Shin and Lee 2005). In fact, residents with enhanced and abundant green spaces tend to have a better health with a proper urban green space planning and management (Lwin and Murayama 2011).

In addition to their positive effects on public health, urban green spaces can facilitate a natural ecosystem, such as forest-like vegetative composition for many species, by helping control soil erosion, decreasing surface runoff, and reducing urban heat island effect (Miller 1997). Because the benefits of urban green spaces have been increasingly accentuated, large cities have initiated urban greening programs including planting of more trees, increasing the number of urban parks, and

M. Atasoy (✉)
Faculty of Architecture, Design, and Fine Arts, Osmaniye Korkut Ata University, 80000 Osmaniye, Turkey
e-mail: muratatasoy@osmaniye.edu.tr

expanding the urban green roofs (Li et al. 2015). While the positive effects of urban green spaces on city dwellers and environment are increasingly observed and studied, green spaces are not distributed equally and formally within the cities. The main reason for this unequal distribution includes the variety of urban park design, differences in ideas of recreational landscape planning, increase in population around city centers, and inequality in ethnicity classes during the history of urban development that may cause fragmented green areas (Byrne 2012).

The landscape fragmentation is defined as the absence of connectivity between the patches of a landscape in which the separation results to significant alterations through the ecological process (Serrano et al. 2002; Jaeger et al. 2008). From this perspective, a landscape can be characterized as continuous or fragmented, where the fragmentation is the end of sprawl within a landscape (Fahrig 2003). Also, the breaking up of the urban green space into small parcels has been considered as a worldwide environmental degradation in recent years (Bogaert et al. 2000). Landscape fragmentation can cause detrimental issues to urban green spaces, such as reducing the dispersal ability of species, increasing the establishment of buildings and roads, reducing the surface runoff, contaminating the drinking water, and reducing the esthetic quality of public green spaces (Miller 1997; Shin and Lee 2005; Cushman 2006). Therefore, it is important to determine the havoc degradations of landscape fragmentation on urban green spaces.

There is a gap in the literature investigating the effect of landscape fragmentation on urban green spaces and mismanagement of the said spaces in the city of Osmaniye, Turkey. Thus, this study aims to evaluate the impacts of landscape fragmentation on the urban green spaces using remote sensing (RS) and geographic information system (GIS) technology in Osmaniye, Turkey. This is the first prospective research that examined the relationship between landscape fragmentation and urban green spaces in the said city. The population of the city is estimated at 527.724 and 164 people per km² (TUIK 2018). More importantly, the population growth of the city is higher than the general population growth rate of Turkey. Due to its geographical location, Osmaniye accommodates immigrants from the rural areas of its neighboring cities, which leads to internal migration (TUIK 2018). As a result, it is important to evaluate how urban green spaces have been impacted by

landscape fragmentation in the study area. To achieve the aim of this study, fragmentation index, which is based on basic types of urban vegetative cover and associated characteristics, is used. The fragmentation index can be derived from RS images to assess the differences of fragmentation between urban city center and surrounding landscapes of urban green spaces.

Methods

Study area

The city of Osmaniye is located in the east Mediterranean Region of Turkey. Neighboring cities are the city of Kahramanmaraş to the north, Hatay to the south, Gaziantep to the east, and Adana to the west. There are seven towns located in Osmaniye, including Merkez (city center), Bahce, Duzici, Hasanbeyli, Kadirli, Sumbas, and Toprakkale (Fig. 1). The topography of the city is lowland and flat with a mountainous surrounding landscape. The altitude of the city is 121 m and the distance to the coast is 20 km. The weather in Osmaniye varies depending on the topography and the climate is classified in the Mediterranean Region. The summer is hot and humid, whereas it is warm and rainy in the winter. The annual average temperature is 18.2 °C and the highest annual temperature is 42.8 °C. The flora of Osmaniye consists of various plant species, including Turkish pine (*Pinus brutia*), Aleppo pine (*Pinus halepensis*), black pine (*Pinus nigra*), oak (*Quercus*), fir (*Abies*), cedar (*Cedrus*), juniper (*Juniperus*), beech (*Fagus*), elm (*Ulmus*), and alder (*Alnus*) trees (Osmaniye Belediyesi 2018).

The population of Osmaniye is estimated at 527.724 and 164 people per km². Due to its geographical location, Osmaniye accommodates immigrants from the rural areas of its neighboring cities, which leads to internal migration. More importantly, the highest distribution rate of population in Osmaniye is estimated in urban center with a rate of 49.86% (TUIK 2018).

Geospatial analysis

Vegetation indices provide detailed information from the multispectral data. These data are applied on the geospatial analysis based on the differences in absorption and reflectance of energy derived from vegetative cover in the red and near-infrared bands (Fung and Siu

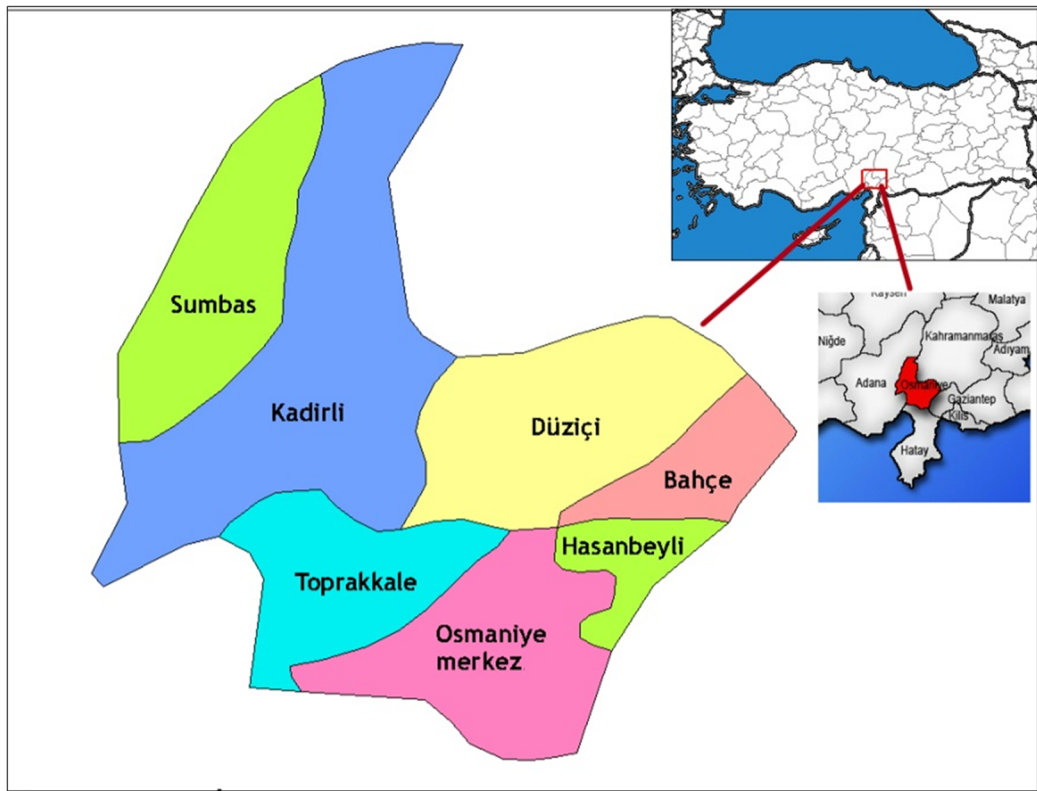


Fig. 1 Location of the Osmaniye city and its towns

2000). One of the most commonly used vegetation indices is the normalized difference vegetation index (NDVI). NDVI is formulated as follows:

$$NDVI = \frac{NIR - R}{NIR + R}$$

where NIR represents near-infrared reflectance and *R* represents visible red reflectance. NDVI analysis can provide enhanced vegetation dynamics monitoring in comparison to other vegetation indices using Landsat images (Fung and Siu 2000).

In this study, NDVI is used to estimate the most current urban green space density and distribution in Osmaniye city. To calculate the urban green space density, Landsat 7 Enhanced Thematic Mapper Plus (ETM+) images of the city derived on January 11, 2018 were used. The Landsat 7 ETM+ images were projected with UTM projection at 30-m resolution using ArcGIS 10.3 software. NDVI index provides values between -1.0 and +1.0 representing the green landscape cover. The negative values show decrease in vegetative cover, whereas positive values indicate a rise in vegetative

cover on the resultant image of NDVI (Rafiee et al. 2009). The values 0.1 and below represent absence of greenness, moderate values between 0.2 and 0.3 show shrub and grassland, and values between 0.6 and 0.8 represent temperate and tropical rainforests on the resultant image. The values do not show the decreases in vegetative cover.

In order to quantify the landscape fragmentation, the landscape elements associated with the fragmentation are included on the urban scale maps which cover the boundaries of city centers. These elements can be classified as urban development areas, suburban areas, roads, railroads, industrial zones, and agricultural areas (Girvetz et al. 2008). Urban landscape ratio (ULR) is the ratio of total built-up area (buildings, roads, parking lots, etc.) and urban landscape area of a city (Forman 1995). In this study, ULR was used to assess the proximity and spatial arrangement of urban green spaces within the neighboring landscapes to quantify the urban landscape fragmentation. The ULR is formulated as follows:

$$ULR = TBA/TULA$$

where ULR represents the urban landscape ratio, TBA indicates the total built-up area, and TULA represents the total urban landscape area (Angel et al. 2012). The fragmentation levels of urban landscape within the city boundaries of Osmaniye city were classified using the European Environment Agency (EEA) classification model as very low, low, medium, high, and very high using ArcGIS 10.3 software. The data was derived from European Environment Agency on January 10, 2018.

A map of probable future urban city center expansion was created and delineated using ArcGIS 10.3 software to provide the effects of current landscape fragmentation within the city boundaries. Global Grids of Probabilities of Urban Expansion to 2030 data set derived from NASA Socioeconomic Data and Applications Center (SEDAC) was used for the future urban expansion estimate. Since this is the first study that examines the negative impacts of urbanization on urban green spaces in Osmaniye, the global forecast of urban areas data derived from NASA was used. The data provides a forecast of urban land cover expansion and estimates the sprawl of urbanized areas by 2030 worldwide. The data also includes empirical distribution of regional urban population densities and probability density functions of projected regional population for 2030 (Seto et al. 2015).

Results

Since it has been considered that NDVI analysis provides one of the most accurate vegetative cover calculation results (Fung and Siu 2000), the resulting image of NDVI basically shows the level of vegetative cover within the city boundary (Fig. 2). On Fig. 2, the color difference between light and dark green represents the level of vegetative cover distribution within the study area. The areas depicted by light green represent low vegetative cover, whereas areas colored by dark green show the highest vegetative cover. It has been found that Osmaniye city center had the lowest vegetative cover with a NDVI range between -0.13 and -0.06 . In addition to urban city center, the lowest NDVI values indicating absence of greenness were also found on the western side of the study area. As radiating out from urban city center, the vegetative cover increased by NDVI values between 0.013 and 0.20 , representing the presence of shrub and grassland. The highest NDVI values between 0.28 and 0.51 were found within the

mountainous landscapes on the north side of the city, representing forested land cover.

The range of vegetative cover values 0.1 and below represent absence of greenness, moderate values between 0.2 and 0.3 show shrub and grassland, and values between 0.6 and 0.8 represent temperate and tropical rainforests.

The ULR results of Osmaniye showed that urban city center and surrounding area had the highest fragmentation levels (Fig. 3). Also, as radiating out from city center, the fragmentation level significantly decreased. The results of ULR were consistent with the NDVI analysis, which indicate that urban city center had the lowest vegetative cover with the highest fragmentation level. Moreover, lower fragmentation levels were found for the landscapes with higher NDVI values and more vegetative cover (Figs. 2 and 3). The future urban expansion estimate and probability density functions of projected regional population showed that urbanization can substantially expand within the city center and towns of Osmaniye city. Based on land cover estimate, approximately 45% of Osmaniye city may be affected by urbanization in 2030 (Fig. 4).

Discussion

This study investigates the effects of landscape fragmentation on urban green spaces of Osmaniye city by showing the most current level of vegetative cover within the city boundary and landscape fragmentation levels over the vegetative cover. In an attempt to improve the wide range of validity, geospatial analysis such as NDVI and ULR can provide detailed information on how urbanization is linked with landscape fragmentation (Balram and Dragicevic 2005; Ozyavuz et al. 2015). In recent decade, researchers implicate vegetation indices with high-resolution data of satellite images to measure consequences of urban sprawl (Gupta et al. 2012). In this study, NDVI analysis and ULR results showed that urban green space of Osmaniye city is negatively impacted by landscape fragmentation. On both NDVI and landscape fragmentation maps, vegetative cover is estimated sparse on urban areas where calculated fragmentation level is also very high. The main cause of fragmentation may be the increase in population of urban areas driven by internal migration in recent years. More importantly, the population growth of Osmaniye is higher than the general population growth rate of

Fig. 2 Normalized difference vegetation index (NDVI) analysis results of the study area

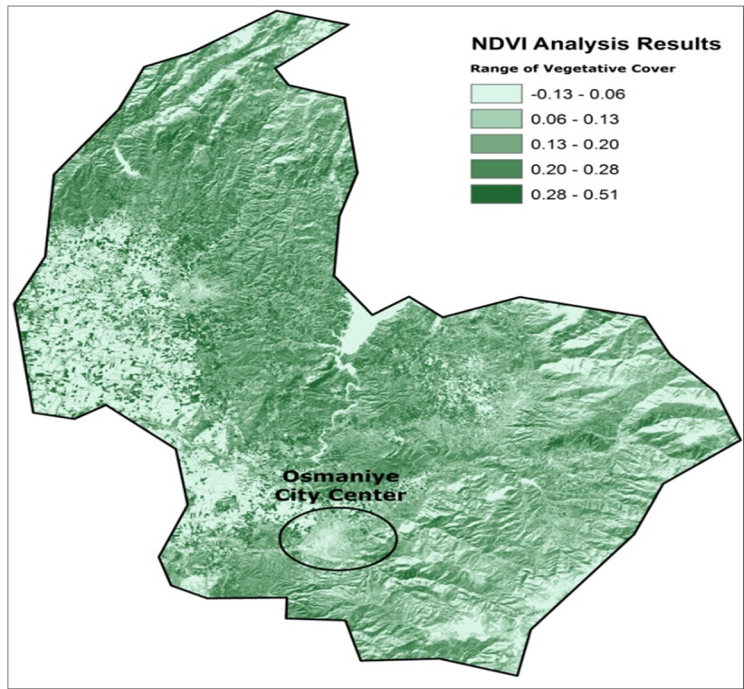


Fig. 3 Fragmentation levels of the study area calculated by using urban landscape ratio (ULR)

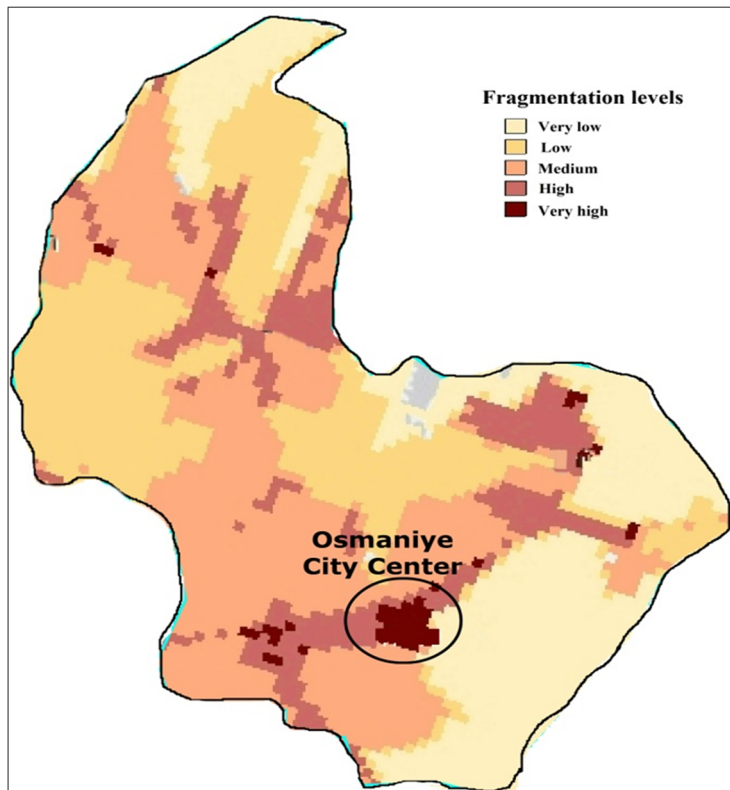
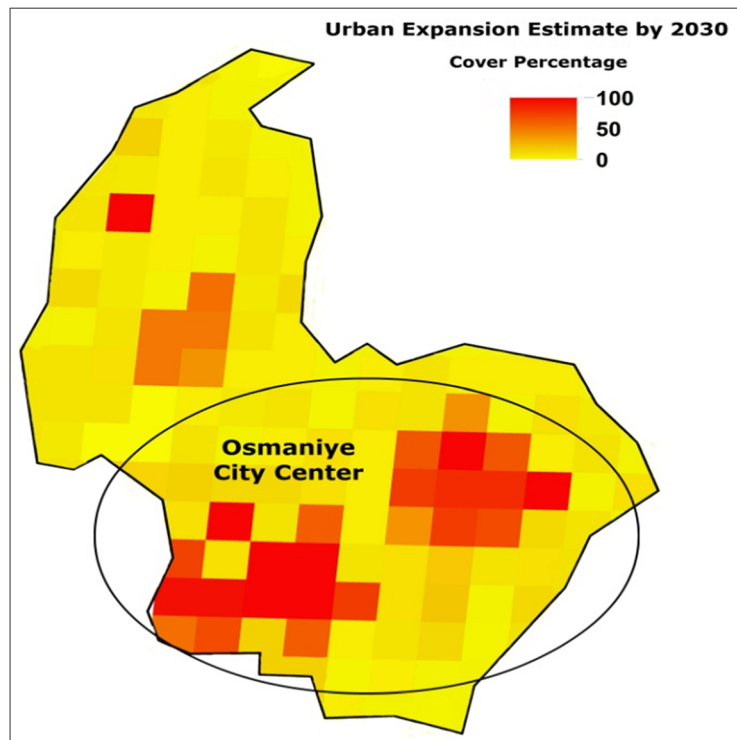


Fig. 4 The future urban expansion estimate and probability density functions of projected regional population of study area by 2030. Red color represents the most probable urbanization, and yellow color represents the lowest urbanization estimate



Turkey. Due to its geographical location, Osmaniye accommodates immigrants from the rural areas of its neighboring cities, which lead to internal migration (TUIK 2018). Another leading factor for this environmental degradation may be that urban landscape ratio is disregarded in Osmaniye city due to increase in total built-up areas and impervious surface cover.

Urban green spaces with high green vegetative cover distributed by small patches can reflect the same fragmentation levels with large patches having low vegetative cover (Tian et al. 2011). In this study, both NDVI and ULR maps of Osmaniye city showed that the vegetative cover was unevenly distributed with small patches (Figs. 2 and 3). This uneven distribution of urban green space can consequently decrease the species richness, and after a certain threshold is reached, edge effects of fragmentation may lead to habitat loss in urban ecosystem (Llausàs and Nogué 2012). Furthermore, the lowest vegetative cover index values of NDVI were found within the urban city center. One of the driving forces of the decrease in green space is that urban forests might have shrunk and become fragmented by road and built-up construction. However, due to insufficient data, the impacts of roads and built-up construction could not

be evaluated in this study. By implementing road and total built-up measures, the deterioration of urban green spaces in Osmaniye city can be comprehensively identified and the disturbance of urban landscape planning can be highlighted.

Conclusion

In recent years, landscape managers have been seeking for reliable information and solution factors to decrease vegetation loss and solve issues regarding inadequate vegetative cover data in urbanized areas. Despite the complexity of NDVI index interpretation and limitations in data acquisition of ULR calculation, the results of this study can facilitate understanding of negative consequences such as reduction in green space distribution driven by urban green space fragmentation. Because this is the first prospective research that examined the relationship between landscape fragmentation and urban green spaces in the city of Osmaniye, the data is constrained regarding how much of the urban green spaces have changed over time.

The solution factors for the negative impacts of urbanization on urban green spaces can be listed as informing people about the importance of green spaces and their benefits to social life, collaborating with government associations to create a comprehensive database for green space calculation and landscape fragmentation in urban city centers, and implementing a conservation plan for urban vegetative composition in the future. Therefore, the most available data is used to guide any other future studies about city of Osmaniye. Through this, urban dwellers can enhance their quality of life should urban green spaces be conserved and should a simplified management plan be implemented by planners and decision-makers in the future.

Acknowledgements The author would like to thank anonymous reviewers for their constructive comments.

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References

- Angel, S., Parent, J., & Civco, D. L. (2012). The fragmentation of urban landscapes: Global evidence of a key attribute of the spatial structure of cities, 1990–2000. *Environment and Urbanization*, 24(1), 249–283. <https://doi.org/10.1177/0956247811433536>.
- Balram, S., & Dragičević, S. (2005). Attitudes toward urban green spaces: integrating questionnaire survey and collaborative GIS techniques to improve attitude measurements. *Landscape and Urban Planning*, 71(2–4), 147–162.
- Bogaert, J., Van Hecke, P., Eysenrode, D. S. V., & Impens, I. (2000). Landscape fragmentation assessment using a single measure. *Wildlife Society Bulletin*, 875–881.
- Byrne, J. (2012). When green is White: the cultural politics of race, nature and social exclusion in a Los Angeles urban national park. *Geoforum*, 43(3), 595–611. <https://doi.org/10.1016/j.geoforum.2011.10.002>.
- Cushman, S. A. (2006). Effects of habitat loss and fragmentation on amphibians: a review and prospectus. *Biological Conservation*, 128(2), 231–240. <https://doi.org/10.1016/j.biocon.2005.09.031>.
- Fahrig, L. (2003). Effects of habitat fragmentation on biodiversity. *Annual Review of Ecology, Evolution, and Systematics*, 34(1), 487–515. <https://doi.org/10.1146/annurev.ecolsys.34.011802.132419>.
- Forman, R. T. (1995). Some general principles of landscape and regional ecology. *Landscape Ecology*, 10(3), 133–142. <https://doi.org/10.1007/BF00133027>.
- Fung, T., & Siu, W. (2000). Environmental quality and its changes, an analysis using NDVI. *International Journal of Remote Sensing*, 21(5), 1011–1024.
- Girvetz, E. H., Thome, J. H., Berry, A. M., & Jaeger, J. A. (2008). Integration of landscape fragmentation analysis into regional planning: a statewide multi-scale case study from California, USA. *Landscape and Urban Planning*, 86(3–4), 205–218.
- Gupta, K., Kumar, P., Pathan, S. K., & Sharma, K. P. (2012). Urban neighborhood green index—a measure of green spaces in urban areas. *Landscape and Urban Planning*, 105(3), 325–335. <https://doi.org/10.1016/j.landurbplan.2012.01.003>.
- Jaeger, J. A., Bertiller, R., Schwick, C., Müller, K., Steinmeier, C., Ewald, K. C., & Ghazoul, J. (2008). Implementing landscape fragmentation as an indicator in the Swiss Monitoring System of Sustainable Development (MONET). *Journal of Environmental Management*, 88(4), 737–751. <https://doi.org/10.1016/j.jenvman.2007.03.043>.
- Li, W., Saphores, J. D. M., & Gillespie, T. W. (2015). A comparison of the economic benefits of urban green spaces estimated with NDVI and with high-resolution land cover data. *Landscape and Urban Planning*, 133, 105–117. <https://doi.org/10.1016/j.landurbplan.2014.09.013>.
- Llausàs, A., & Nogué, J. (2012). Indicators of landscape fragmentation: the case for combining ecological indices and the perceptible approach. *Ecological Indicators*, 15(1), 85–91. <https://doi.org/10.1016/j.ecolind.2011.08.016>.
- Lwin, K. K., & Murayama, Y. (2011). Modelling of urban green space walkability: eco-friendly walk score calculator. *Computers, Environment and Urban Systems*, 35(5), 408–420. <https://doi.org/10.1016/j.compenvurbsys.2011.05.002>.
- Mansfield, C., Pattanayak, S. K., McDow, W., McDonald, R., & Halpin, P. (2005). Shades of green: measuring the value of urban forests in the housing market. *Journal of Forest Economics*, 11(3), 177–199. <https://doi.org/10.1016/j.jfe.2005.08.002>.
- Miller, R. W. (1997). *Urban forestry: planning and managing urban green spaces* (2nd ed.). New Jersey: Prentice-Hall.
- Osmaniye Belediyesi (2018). *The municipality of Osmaniye City*. Retrieved from <http://osmaniye-bld.gov.tr/>.
- Ozyavuz, M., Bilgili, B. C., & Salici, A. (2015). Determination of vegetation changes with NDVI method. *Journal of Environmental Protection and Ecology*, 16(1), 264–273.
- Rafiee, R., Mahiny, A. S., & Khorasani, N. (2009). Assessment of changes in urban green spaces of Mashad city using satellite data. *International Journal of Applied Earth Observation and Geoinformation*, 11(6), 431–438. <https://doi.org/10.1016/j.jag.2009.08.005>.
- Serrano, M., Sanz, L., Puig, J., & Pons, J. (2002). Landscape fragmentation caused by the transport network in Navarra (Spain): two-scale analysis and landscape integration assessment. *Landscape and Urban Planning*, 58(2–4), 113–123.
- Seto, K. B., Güneralp, B., & Hutyra, L. R. (2015). *Global grid of probabilities of urban expansion to 2030*. Palisades: NASA Socioeconomic Data and Applications Center (SEDAC). <https://doi.org/10.7927/H4Z899CG>.
- Shin, D. H., & Lee, K. S. (2005). Use of remote sensing and geographical information systems to estimate green space surface-temperature change as a result of urban expansion. *Landscape and Ecological Engineering*, 1(2), 169–176. <https://doi.org/10.1007/s11355-005-0021-1>.

- Sister, C., Wolch, J., & Wilson, J. (2010). Got green? Addressing environmental justice in park provision. *GeoJournal*, 75(3), 229–248. <https://doi.org/10.1007/s10708-009-9303-8>.
- Tian, Y., Jim, C. Y., Tao, Y., & Shi, T. (2011). Landscape ecological assessment of green space fragmentation in Hong Kong. *Urban Forestry and Urban Greening*, 10(2), 79–86. <https://doi.org/10.1016/j.ufug.2010.11.002>.
- TUIK (2018). *Turkish Statistical Institute addressed based population registration system*. Retrieved from www.tuik.gov.tr/PreIstatistikTablo.do?istab_id=1590.
- Wolch, J. R., Byrne, J., & Newell, J. P. (2014). Urban green space, public health, and environmental justice: the challenge of making cities 'just green enough'. *Landscape and Urban Planning*, 125, 234–244. <https://doi.org/10.1016/j.landurbplan.2014.01.017>.