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Research Paper

The Biotope Area Factor Method for Sustainable Urban Landscapes: The Cases of the Bornova and Bayraklı Districts, İzmir

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Abstract: In this study, the Biotope area Factor (BAF) methodology was modified and applied in three selected neighborhoods of the Bornova and Bayraklı districts. The aim is to find the ecologically effective area of the three selected neighborhoods and to determine how far this value is from the targeted BAF value (0.5). The BAF method basically calculates the amount of ecologically effective area by giving points for different types of land cover in a given area and then multiplying these scores by the size of that land cover. It then calculates the total amount of ecologically effective area by making this calculation in the whole area. In other words, the BAF index is determined by dividing the total amount of ecologically effective area found here by the total amount of land. The findings of the present study showed that an average BAF index value was 0.33 for the entire study area. This is lower than the minimum BAF target defined of 0.5 for this study. Although the BAF value (0.35) in Evka 3 neighborhood is higher than the district average, it is still lower than the minimum BAF target of 0.5 defined for this study. In Manavkuyu and Mansuroğlu, an average BAF value was calculated to be 0.20. Naldoken has the highest BAF index score with 0.45 among the neighborhoods.
Key words: *BAF index, biotope area factor; land use–land cover, İzmir.*

Introduction

Making cities safe, resilient and sustainable is a goal set by the United Nations (UN, 2021). It is necessary to work in many contexts and sectors to reach this goal in urban landscapes. Undoubtedly, urban open-green spaces are very important ingradients of urban landscapes due to their indispensable functions (Tzoulas et al., 2007). From improving the quality of life in cities to protecting biodiversity, creating a habitat for urban wildlife (Fung et al., 2008, Esbah et al., 2009, Hostetler et al., 2011, Hepcan, 2013) and providing countless ecosystem services, they fulfill many functions. For example, Tzoulas et al. (2007), Jayakaran et al. (2020) and Kumar et al. (2019) states that green spaces and green infrastructure are also very important for human and public health.

While urban vegetation contributes to the improvement of urban air quality in various ways (Tomson et al., 2021), it is also recognized as a sustainable means of minimizing runoff (Jayakaran et al., 2020; Omitaomu et al. 2021). Daeyoung et al. (2021) proposes to create a green network against increasing natural disaster risks, especially in coastal cities. Many countries and cities are working to reduce stress sources on natural ecosystems and ecosystem services (European Commission, 2011).

Here, individually, the benefits of urban green spaces and vegetation are undeniable, but when they create a green network or infrastructure, their functions and ecosystem services will be much greater.

Green infrastructure is defined as an interconnected network of open and green spaces that preserves natural ecosystem values and functions and provides various benefits to people in this context (Benedict and McMahon, 2006). In urban landscapes, both natural ecosystems and man-made green areas and various water surfaces are involved in this process. In recent years, an increasing importance has been attached to urban green infrastructure in terms of both making cities more resilient to climate change and protecting the ecosystem services provided.

However, the way in which urban green spaces are considered in the spatial planning and design process is often arbitrary rather than systematic (Steiner, 2011; Hepcan, 2013). For this reason, urban green areas established on vacant land are not fully functional most of the time (Steiner, 2011;

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Hepcan, 2013) do not have the expected ecological quality. Therefore, they cannot providing edaquate ecosystem services.

In order to guide the spatial planning process, several studies have been conducted to measure the biophysical value of green spaces in different European cities. In this context, the Biotope Area Factor (BAF) is one of the first methodologies. Berlin was the first city to conceptualize and implement BAF in the 1990s to balance the open space deficit in the inner city by improving privately owned areas ecologically (Becker and Mohren, 1990). BAF is applied in existing built environments, revealing the proportion of ecologically efficient land up to some extent. From this point of view, it is aimed to reach the targeted BAF values by transforming existing land and/or planning and designing new land (Becker and Mohren, 1990).

BAF was later adapted and applied in cities such as Malmö, Helsinki and Padua in Europe and in Seattle, USA with the name of Green Area Factor (Juhola, 2018; Peroni et al., 2020). Similarly, the purpose of the green factor method is to increase the total amount of green space and permeable surface in order to make the built environment ecologically more sustainable (Juhola, 2018).

In the present study, the BAF methodology was modified and applied in line with the requirements in three selected neighborhoods in the Bornova and Bayraklı districts. The aim is to find the ecologically effective area of the three selected neighborhoods separately and to determine how far this value is from the targeted BAF value.

Materials and Methods

Study Area

The BAF method was employed three selected neighborhoods in the Bornova and Bayraklı districts of İzmir, Turkey (Figure 1). These districts used to be unified and called Bornova in the past. It was divided into two districts as Bornova and Bayraklı by law. Therefore, their development pattern and urbanization character are very identical.

When the urbanization history is revisited, it is obvious that Bornova with its rustic character was a suburb of the city of İzmir until the early 1900s. The rapid urbanization process experienced in İzmir since the 1960s affected Bornova in a similar way and transformed city's landscape chacter from large agricultural areas and residences with gardens to a densely settled form with tall apartment blocks (Hepcan et al. 2013). Nowadays, residential and industrial areas are dominant in the districts. The building typology in the centers of the districts and their immediate surroundings are characterized by apartment buildings in an adjacent order. On the other hand, in the new development areas of both districts, multi-storey apartments or two or three storey-detached houses surrounded by small gardens are being encountered (Çoşkun Hepcan and Hepcan, 2018).

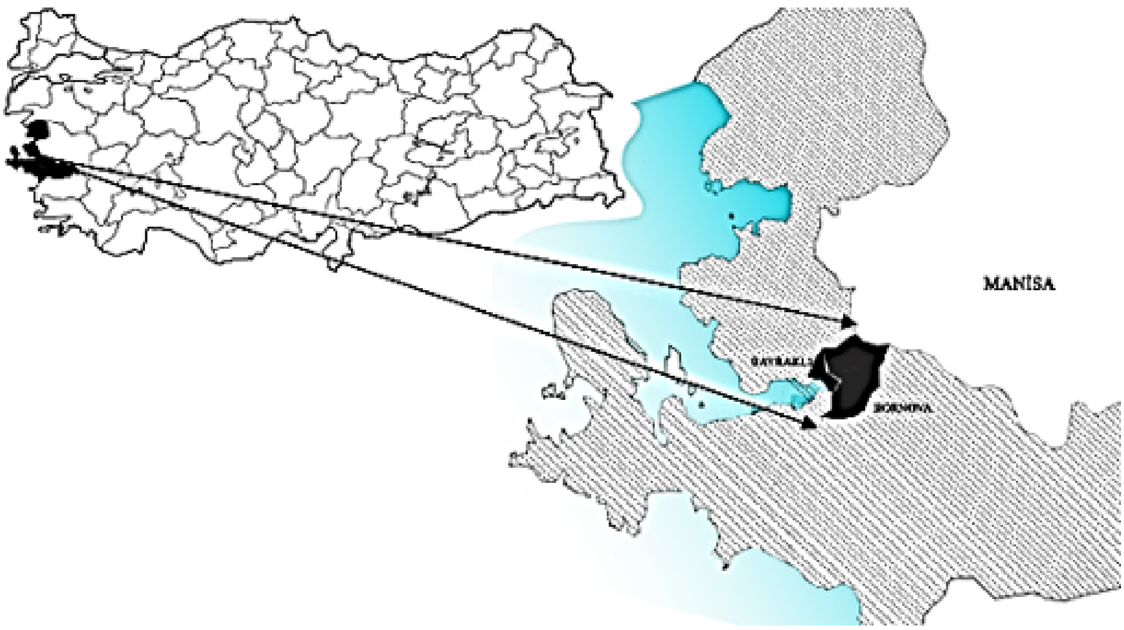

Figure 1. Geographical framework: the municipality of Izmir

Among these neighborhoods, Mansuroğlu and Manavkuyu are located in the Bayraklı district, while Evka 3 and Naldöken are located in the Bornova district. They were chosen based on urbanization typology to represent the districts' urban character. Development typology in Evka 3 is composed of both tall apartmen blocks and single-family houses with gardens. There are also some natural areas at the neighborhood's fringes. Within the scope of the study, Mansuroğlu and Manavkuyu neighborhoods were analized and evaluated together. The urban fabric in this area is mostly represented by buildings in the form of high-rise apartment blocks. On contrary of Mansuroğlu and Manavkuyu, Naldoken is prodominetly composed of natural areas and unsealed surfaces. It represents a different typology of the Bornova and Bayraklı districts (Figure 2).

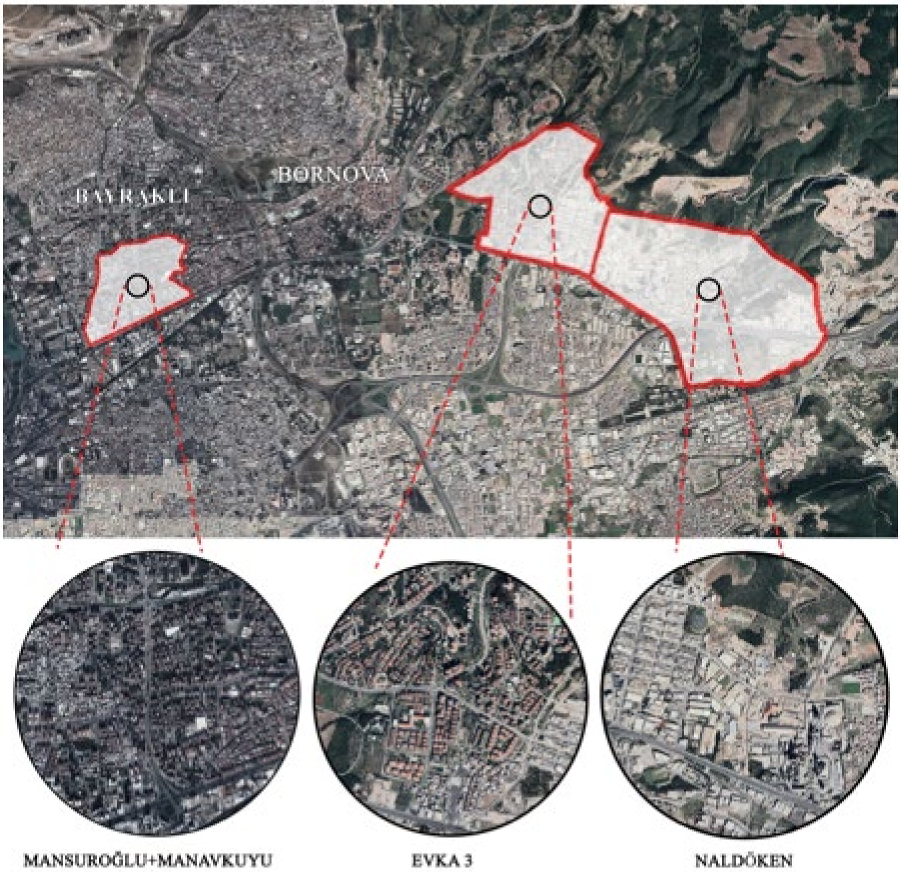

Figure 2. The boundaries of the three neighborhoods

Method

The BAF method basically calculates the amount of ecologically effective area by giving points for different types of land cover in a given area and then multiplying these scores by the size of that land cover. It then calculates the total amount of ecologically effective area by making this calculation in the whole area. The BAF is determined by dividing the total amount of ecologically effective area found here by the total amount of land (Becker and Mohren, 1990).

The method of the present study was obtained by modifying the BAF index (Becker and Mohren, 1990) according to the land cover/land use conditions and requirements of the Bornova and Bayraklı districts. In this direction, the weighting scores given to the land cover types were also reinterpreted. In other words, the BAF equals ecologically effective areas (m^2)/total land area (m^2) (Becker and Mohren, 1990). More spesifically, the BAF index is calculated using the following equation (Casella et al. 2016):

$$\mathrm{BAF} = \frac{\sum_{i=1}^{n} A_i \times w_i}{\sum_{i=1}^{n} A_i}$$

Here, A_i corresponds to each surface of the study area that is homogeneous in terms of BAF value, multiplied by w_i, which corresponds to the BAF coefficient (weighting score varying between 0-1). The result corresponds to the ecologically effective surface area (EESA). The BAF value for the whole study area is equal to the sum of all EESA divided by the sum of the areas (Casella et al. 2016).

In the present study, the minimum BAF target was defined as 0.5 (Kruuse, 2011, Vartholomaios et al., 2013). And weighting scores for the study areas were defined based on the relavant literature (Becker and Mohren, 1990, Kruuse, 2011, Vartholomaios et al., 2013) (Table 1).

The methodology for testing the BAF index relies on two phases: (1) extracting land use features from high resolution satellite images and classifying the same features according to the land use classification using Corine cover, and (2) BAF index values (0 to 1) to score each land use feature.

Table 1. Interprated weighting scores for the neighborhoods in the study area

Land Use / Land Cover Type	Weighting Score
Urban Forests	1
Buildings	0
Parks	0.8
Water Surfaces	0
Shrubland	1
Sports Facilities	0
Sealed Surfaces-Parking Areas	0
Roads	0
Private Gardens	0.7
Agricultural Areas	1
Unpaved Surfaces	0.5

Data Preparation and Data Analysis

At this stage, a digital database containing land cover data in the study areas were produced. Spatial analyses (land cover and the BAF) were made with Arcmap 10.2 software. First, a land cover map was created as a result of the interpretation and classification of the Wordwiev-2 satellite image dated 2015, and then datas were interpreted and the BAF values for each land class were determined.

Results and Discussion

Land use/Land cover values in the neighborhoods

In Evka 3 neighborhood, the buildings constitute the most land use (20.85%), followed by the private gardens (residential gardens) (20.45%). The lowest area usage percentage is water surfaces (0.1%) (Table 2 and Figure 3). Evka 3 is still dominated by open and green spaces (Table 2 and Figure 3).

Table 2. Land use types and proportions in Evka 3 neighborhood

Land Use Type	**Proportion (%)**
Urban Forests	5.29
Buildings	20.85
Parks	6.87
Water Surfaces	0.10
Shrubland	2.57
Sports Facilties	0.32
Sealed Surfaces-Parking Areas	10.8
Roads	19.32
Private Gardens	20.45
Agricultural Areas	2.13
Unpaved Surfaces	11.31

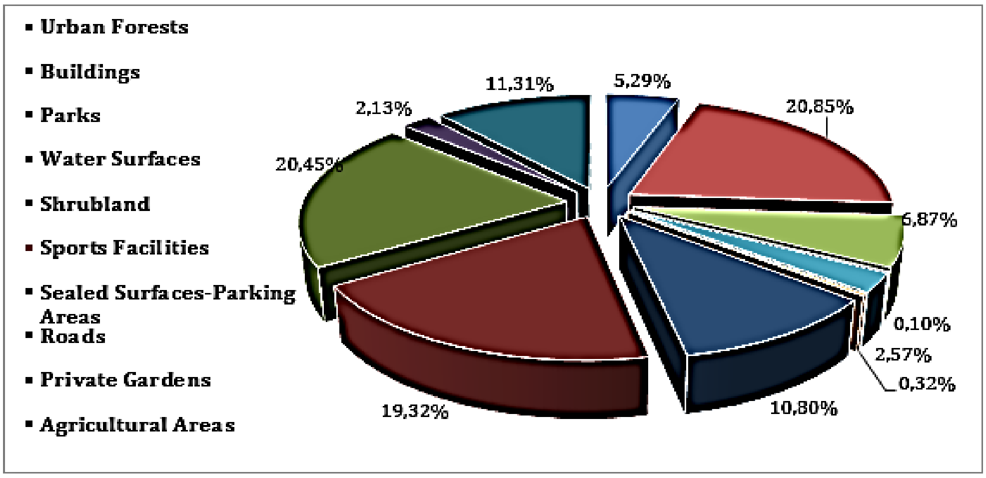

Figure 3. Land uses/land covers in Evka 3

In Mansuroğlu and Manavkuyu neighborhoods the largest land use is roads/asphalt surfaces (42.11%). This is followed by buildings (21.73%) and private gardens (residential gardens) (12.04%). This neighborhood is mostly occupied by surfaces with an impervious character (Table 3 and Figure 4).

Table 3. Land use types and proportions in Mansuroğlu and Manavkuyu neighborhoods

Land Use Type	Proportion (%)
Urban Forests	0.00
Buildings	21.73
Parks	11.44
Water Surfaces	0.23
Shrubland	0.00
Sports Facilties	0.54
Sealed Surfaces-Parking Areas	7.40
Roads	42.11
Private Gardens	12.04
Agricultural Areas	0.20
Unpaved Surfaces	4.32

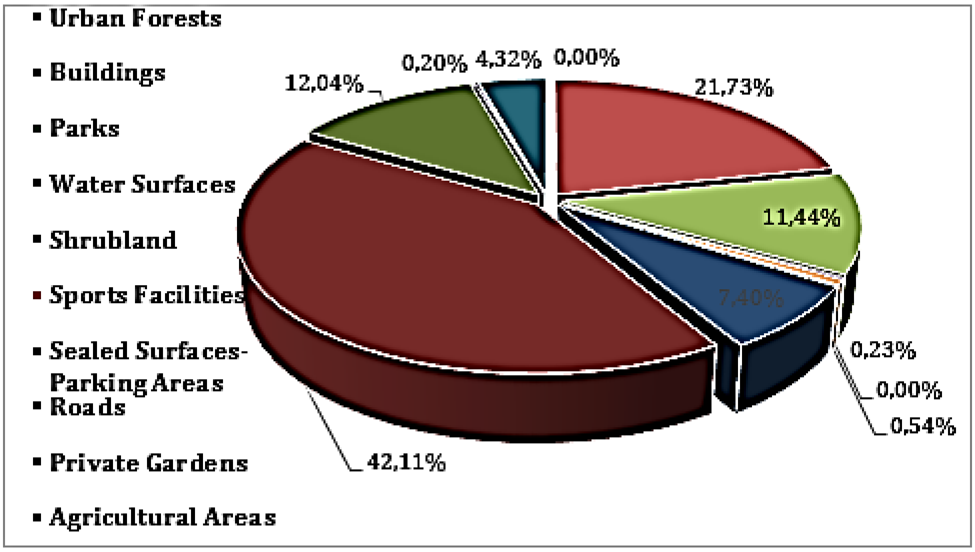

Figure 4. Land uses/land covers in Manavkuyu and Mansuroğlu

The largest land use percentage in Naldöken neighborhood is unpaved surfaces with 22.64%. This is followed by shrubland with19.92%. The lowest land use is water surfaces. Naldöken is a neighborhood with a countryside character where there are a large amount of unsealed surfaces. Naturally, urbanization pattern is quite different than the other two study areas (Table 4 and Figure 5).

Table 4. Land use types and proportions in Naldöken neighborhood

Land Use Type	**Proportion (%)**
Urban Forests	6.56
Buildings	11.47
Parks	2.27
Water Surfaces	0.00
Shrubland	19.92
Sports Facilties	0.08
Sealed Surfaces-Parking Areas	11.46
Roads	19.90
Private Gardens	1.99
Agricultural Areas	3.70
Unpaved Surfaces	22.64

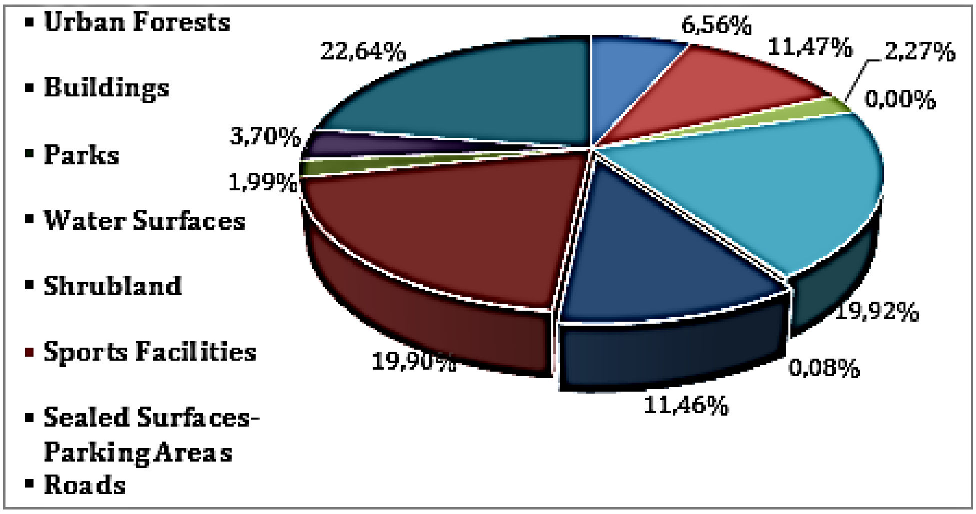

Figure 5. Land uses/land covers in Naldöken

The BAF values in the neighborhoods

The findings showed that an average BAF index value was 0.33 for the entire study areas (Table 5). This is lower than the minimum BAF target of 0.5 for this study (Kruuse, 2011, Vartholomaios et al., 2013).

Table 5. Average BAF values in the neighborhoods

Neighborhood	Average BAF Values
Evka 3	0.35
Manavkuyu and Mansuroğlu	0.20
Naldöken	0.45
Average	*0.33*

Although the BAF value (0.35) in Evka 3 neighborhood is slightly higher than the district average, it is still lower than the minimum BAF target of 0.5 defined for this study. While completely permeable surfaces (BAF = 1) cover 9.98% of the entire Evka 3, completely sealed surfaces (BAF=0) occupies 51.39%. In Manavkuyu and Mansuroğlu, an average BAF value was calculated to be 0.20. This is the lowest score compared to other two and lowers than the average More importantly, it was way lower than the minimum BAF target of 0.5. Completely sealed surfaces in the neighborhood cover almost 72% of entire land. 0.2% is just the amount of completely pervious land cover. Naldoken has the highest BAF index score with 0.45 among the neighborhoods. The total of the surfaces with a

BAF value of 1 in the neighborhood is 30.19%, and the areas with a BAF value of 0 occupy 42.92% (Figure 6).

The BAF values mentioned above also show the urbanization nature of the study areas in a sense. Mansuroğlu and Manavkuyu neighborhoods, which have the lowest BAF values among the three neighborhoods (0.20), are a neighborhood with a high density of high-rise apartments and have an urbanized character up to a large extent. Semi-permeable surfaces occupying approximately 28% of the neighborhood are extremely inadequate. Although Naldöken neighborhood had the highest BAF score among the three neighborhoods (0.45), this score is still lower than the minimum target value of 0.5. For instance, in a study conducted using the BAF index in four different neighborhoods of Padua (Italy), the results indicated different BAF index scores between 0.35 and 0.69 (Peroni et al., 2020).

The BAF scores are of course not everything and do not fully reflect the ecological situation in the study areas, but the calculated scores help set some treshholds in terms of permeability that can often be related to providing several ecosystem services in urban landscapes. For instance, BAF or green area factor tool can be employed to demermine and/or extend quality of green spaces for specific ecosystem services (Juhola, 2018).

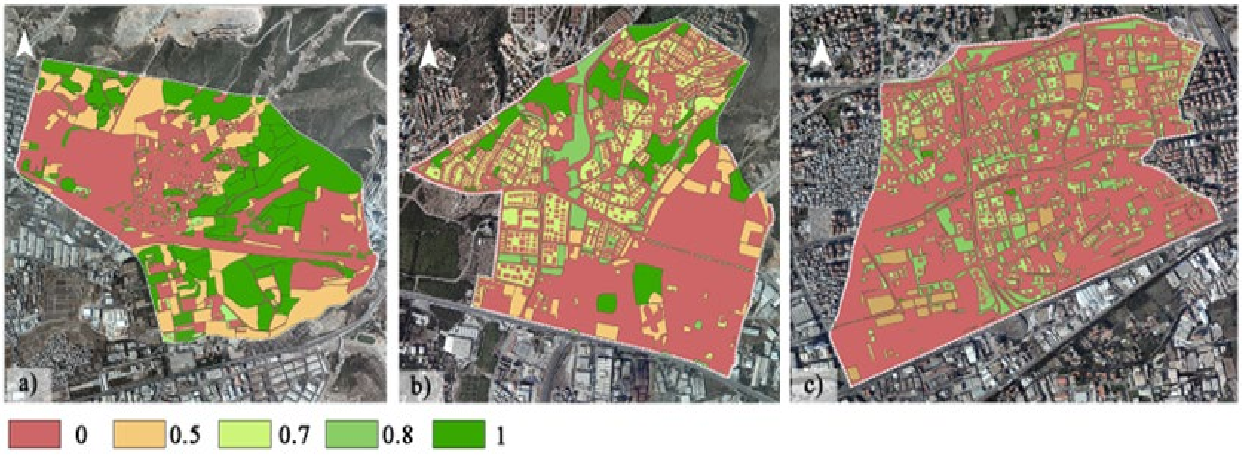

Figure 6. Biotope area factor (BAF) analysis, showing different degrees of permeability, from 0 to 1: (a) Naldöken, (b) Evka 3 (c) Mansuroğlu and Manavkuyu of BAF analysis.

Conclusions

In the present study, the BAF methodology was modified and applied in three selected neighborhoods in the Bornova and Bayraklı districts. The aim is to find the ecologically effective area of the 3 selected neighborhoods and to determine how far this value is from the targeted BAF value (0.5). The findings of the present study showed that an average BAF index value was 0.33 for the districts (Table 5). This is lower than the minimum BAF target defined as 0.5 for this study.

As a result, the neighborhood with the highest BAF value is Naldöken, and the lowest is Manavkuyu and Mansuroğlu. Although three neighborhoods scored lower than the minimum average, spatial attention should be given to the densely settled Manavkuyu and Mansuroğlu neighborhoods because there are things need to be done to increase the current BAF value and reach the target BAF value of 0.5. One of them is to increase the amount of urban green spaces. Green roofs and walls should be part of efforts to increase BAF values. These are the neighborhoods that heavily affected by the recent earthquake hit İzmir in 2020. Incerasing amount of open and green spaces are outmost important for these neighborhoods. Using permeable asphalt and concrete is another option to increase permeable surfaces. In short, different nature-based solutions are needed to be implement here to increase the BAF values permenantly and sustainability.

At the end of the day, the goal is to identify permeable and impermeable land cover by using of the BAF index so as to promote the increase the total amount of green spaces and permeable surfaces in the study areas (Becker and Mohren, 1990, Juhola, 2018). The BAF and similar planning tools are important to increase the functionality of green spaces for several particular ecosystem services (Juhola, 2018). These kinds of tools are also required to formulate important objectives and measures to promote sustinable urban development and secure the qualities of green areas (Becker and Mohren, 1990). According to Stenning (2008), this tool allows spatial planners and managers to estimate the impact of green spaces and structures in various typologies (Juhola, 2018).

The BAF method of course has some weaknesses and needs to be improved and modified for different cases and purposes by adding more ecological parameters and variables. Weakness of the BAF is that the method may not be a suitable in terms of ecological evaluation. For future studies, it would be appropriate to re-adjust the application scale and weighting the system (Huang et al. 2015).

In conclusion, application of the BAF method in a case study is one of the firsts in Turkey. Therefore, more studies or tests are required to improve the accuracy and replicability of the method. But despite its weakneses, the BAF method sets some target scores for spatial planners, designers and contractors to include new green components in their implementations (Juhola, 2018) and also makes it easier to provide a regulatory framework in the spatial process in order to increase the amount of urban green spaces.

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