Assessment of Urban Forests by Using Weighted Linear Combination

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SUMMARY

Especially in parallel with the gradual enlargement of urban areas, the concept of urban forest has emerged as a result of the need of people, who are living in urban areas, for green areas. In the project developed in Turkey, the forests near or adjacent to urban areas were organized as urban forests and it was aimed to establish the areas, where the people can be alone together with the nature. With this project put into practice in 2003, totally 63 urban forests (54 in cities and 9 in districts) were put at service of people as of the end of year 2008.

Analyzing the urban forests in details and making certain decisions are difficult tasks and it takes long time to investigate. But the assessments can be made via main factors that have been determined by the specialists. These factors (criteria) can be listed as location, altitude, size of forest area, flora, fauna, artificial and natural facilities in the area, and oxygen production. Weighted Linear Combination, one of the location-based assessment methods, is based on the concept of weighted mean, in which the criteria are standardized within a common numeric range.

In this study, 63 urban forests were marked on the map of Turkey by using ArcGIS software. The characteristics of 63 urban forests in terms of 8 criteria were entered in feature table. By using WLC method in the software, the raster maps were created for each criterion and, by entering the weights, the suitability values of WLC method were obtained. Thus, the urban forests were put in an order.

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1. INTRODUCTION

As a result of the increasing urbanization of today, the interest in green areas and forests within and near the urban areas increased and the expectations of people from the nature got diversified and differentiated. The concept of urban forest has emerged from the increase in local peoples' need for green areas in parallel with the gradually enlarging urban areas. In a research carried out by World Health Organization, minimum 9 m^2 green area per capita is recommended. The forests have remarkable positive effects on the peoples' mental and physical health. In the project developed in Turkey, the forests near or adjacent to urban areas were organized as urban forests and it was aimed to establish the areas, where the people can be alone together with the nature. With this project put into practice in year 2003, totally 103 urban forest establishment was made until the end of 2008, and totally 63 urban forests (54 in cities and 9 in districts) were put into service for the public.

The increase in population on the earth leads to significant changes in land use. As a result of the land transformation including the destruction of lands and forests, severe natural disasters such as biodiversity, overflow, landslide, and drought occur (Environmental Agency, 2011). Such a change in land surface also causes climate change (Sumirat and Solehudin, 2009). A solution for minimizing such negative consequences is to appropriately establish the urban forest (Asyaebani, 2013). In many European countries, the percentage of urban forest within urban areas was set to be minimum 10%. In literature, the urban forest is reported as the source of mental and physical health, in addition to being recreational areas for local people (Tyrvainen et al., 2005; Jay and Schraml, 2009). Tyrvainen (1999) emphasized the natural beauties and recreational values of urban forests (Tahvanainen et al., 2001). In study of Narulita et al. (2016) by using Geographical Information System, the analyses were performed in order to determine the urban forest areas in Bandung province and the spatial distribution of existing forest areas on the plans. In this study, the selected parameters are altitude, slope, land cover, population density, and distance to road. AHP method was used in order to analyze these parameters together. It was determined that the place to establish first urban forest in Bandung province is Mandalajati, followed by Cibiru and Ujung Berung.

In study of Mutlu and Cengiz carried out in year 2017, the natural and recreational usage characteristics of Bolu Urban Forest were determined using Geographical Information System. In this study, the survey forms involving ecological, aesthetical, architectural, physical, social, climatic, and economic functions that are the milestones of urban green infrastructure were analyzed using Correlation analysis of SPSS software. In conclusion, although Bolu Urban Forest has a significant potential in terms of multifunctional usage characteristics, the urban forest couldn't achieve the desired level of interest since majority of Bolu is covered by the forests (Mutlu and Cengiz, 2017).

Analyzing the urban forests in details and making decisions are very difficult tasks and it takes long time to investigate. But, certain analyses can be made by using the main factors determined by the specialists. These factors (criteria) are size of forest area, location, flora, fauna, natural and artificial facilities in the area, precipitation level in region, and oxygen production capacity.

Besides that, the spatial decision support systems integrating location-based Geographical Information Systems (GISs) and decision-making methods are widely used now. Weighted Linear Combination or Simple Additive Weighting method, one of the location-based assessment methods, is based on the weighted mean, in which the criteria are standardized within a common numeric range. The suitability value of each alternative is obtained from the sum of multiplications of the importance weights determined for criterion with the scores calculated within the scale. In this study, WLC method was used in order to GIS-based assessment of urban forests.

2. WEIGHTED LINEAR COMBINATION

The Weighted Linear Combination (WLC) model is one of the widely used GIS-based decision-making rules (Malczewski 2000). Weighted linear combination (or simple additive weighting) is based on the concept of weighted mean value, in which the criteria are standardized within the numeric range. The decision-maker assigns the weights, which have relative importance, directly to a layer of characteristics map. The total score of each alternative is obtained from the sum of multiplications of importance weights determined for criteria and core values calculated. The suitability alternatives are calculated for each alternative, and the alternative having the highest suitability value is selected. This method can be used in both raster and vector GIS media (Drobne and Lisec, 2009). The main formula of this method is presented below:

$$S = \sum Wi \,.\, Xi \tag{1}$$

here:

S= suitability value

Wi= criterion weight

Xi = score

Nowadays, GIS programs offer the main solution instruments for assessing such models (Drobne and Lisec, 2009). Conversion to WLC score values is achieved by using Equation 2.

$$Xi = \begin{cases} \dfrac{a_{ik}^{q} - \min\limits_{i,q}\{a_{ik}^{q}\}}{r_{k}^{q}}, & for\ the\ k-th\ criterion\ to\ be\ maximized \\ \dfrac{\max\limits_{i,q}\{a_{ik}^{q}\} - a_{ik}^{q}}{r_{k}^{q}}, & for\ the\ k-th\ criterion\ to\ be\ minimized \end{cases} \quad (2)$$

3. RESULTS

Together with the increasing urbanization in Turkey, the demand urban population on the urban areas near the cities increased. In order to meet this demand, the Urban Forest Project has been initiated. In this project, it was aimed to establish areas, where the people can be alone with nature, by organizing the areas near or adjacent to urban areas as urban forests. With this project put into practice in year 2003, 103 urban forest projects were carried out until the end of year 2008, and totally 63 urban forests (54 in cities and 9 in districts) were put into service. Within the scope of this study, ArcGIS software was used in order to mark 63 urban forests on the map of Turkey. The data of 8 criteria of 63 urban forests were entered into the table of features (Figure 1).

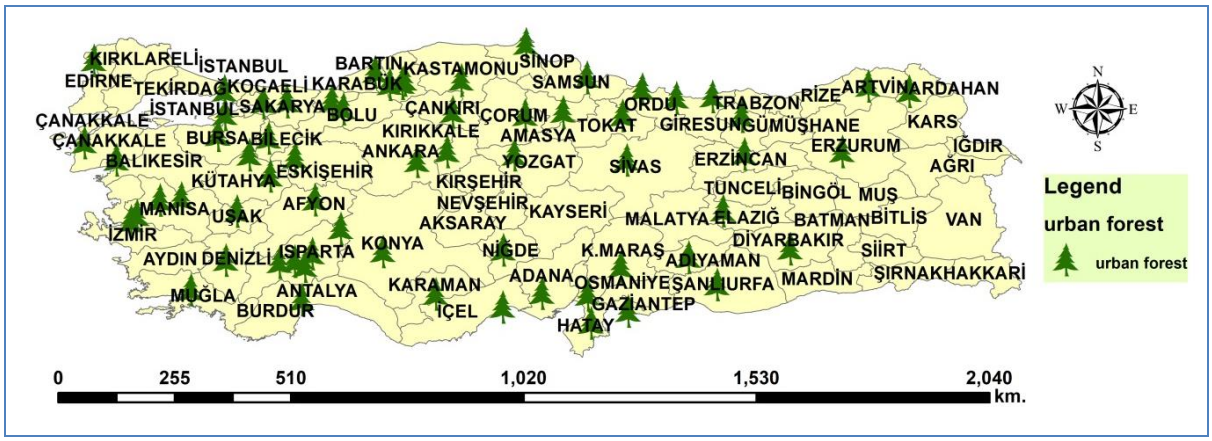

Figure 1. Urban forests established in Turkey

In accordance with the scoring method in this study, 8 criteria were evaluated by the focus group consisting of forest engineers, and the weights were obtained (Table 1).

Table 1. Determining the Weights

No	Criterion	Mean score	Weight
1	Location	6.21	0.1460
2	Size of forest area	4.42	0.1039
3	Mean altitude	3.86	0.0907
4	Fauna	5.13	0.1206
5	Flora	6.05	0.1422
6	Precipitation level of region	4.26	0.1001
7	Oxygen production capacity	7.25	0.1704
8	Facilities within the forest area	5.36	0.1260

By using the weights determined by making use of scoring method, WLC scores of each criterion for 63 urban forests were determined. By using the WLC method in software, the raster maps were created for each criterion. The suitability values in WLC method were calculated by entering the weights. In Table 1, there are the suitability (Si) values of first and last 5 urban forests.

Table 1. Suitability values used in assessing the urban forests

ID	Name of urban forest	Si
5	Antalya Urban Forest	0.6168
52	Osmaniye Urban Forest	0.5037
63	Zonguldak Urban Forest	0.4991
46	Manisa Urban Forest	0.4927
12	Bursa Urban Forest	0.4861
...	...	...
22	Erzurum Urban Forest	0.2674
39	Kırıkkale Urban Forest	0.2673
37	Karaman Yunus Emre Urban Forest	0.2544
4	Ankara Urban Forest	0.2157
2	Afyonkarahisar Urban Forest	0.1563

In this method, the values closer to 1 are very suitable for the decision-maker, whereas the values closer to 0 are not suitable at all. WLC suitability values calculated for 63 urban forests were divided into 5 geometric-based clusters and the results are presented on the map in Figure 2. In the evaluation of urban forests, the points presented in yellow and red are below the average, those presented in yellow are at average, and those in blue and black are above the average.

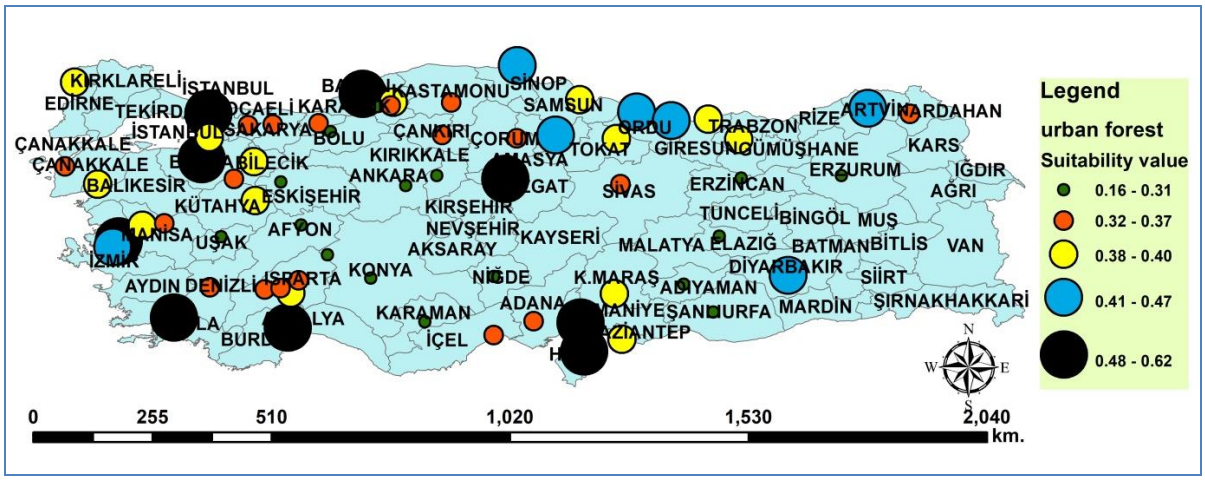

Figure 2. Classification of forests by using WLC method

4. RESULTS AND CONCLUSION

In this method, the weights were determined using the scoring system. Among 8 criteria determined in this study, the most important criteria were found to be the oxygen production capacity, location, and flora. By using GIS-based WLC method, the forests were successfully assessed in terms of 8 criteria.

According to the assessment on map, it can be stated that the forests established in coastal regions are significantly suitable in terms of the examined criteria, and that the suitability values of forests located in inner regions are lower when compared to those located in coastal regions. It can be said that the climate of coastal region is better for urban forests.

The weights determined by making use of various decision-making methods such as Analytical Hierarchical Process, Analytical Network Process, and TOPSIS, the weights can be calculated and then used in WLC method. The weights determined by using these methods can be used in WLC method and the results can be analyzed on the map.

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BIOGRAPHICAL NOTES

Bülent Bostancı was born in Aksehir, Turkey, in 1969. He graduated from Yıldız Technical University, Istanbul, Turkey in 1992, and received MSc and PhD degrees from Yıldız Technical University, Istanbul, Turkey in 1995 and 2008. He worked at Republic of Turkey General Directorate of Highways for 5 years. He received his Assistant Professor degree in Turkey in 2010. He is now working for Erciyes University, Kayseri, Turkey as the Head of the Surveying Technical Division at the Department of Geomatics Engineering. His research interests are special engineering surveying, real estate development and risk analysis.

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