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EVALUATION INDICATORS FOR SUSTAINABLE URBAN FOREST IN TABRIZ CITY, IRAN

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Abstract

The main goal of this study was to achieve a set of the main key to sustainable urban forest indicators by using Fuzzy Delphi method – Iran perspective. The questionnaires were developed based on the ecological (sub-criteria including urban trees biodiversity, trees canopy coverage, flood control, species habitat provision, carbon storage and greenhouse gases sequestration), social (sub-criteria including physical assess to nature, visual assess to nature, increasing growing space in the city, air quality improvement and danger probability of urban trees) and economic criteria (sub-criteria including energy conservation and increase property value) and 13 experts in the field of forest sciences were chosen to sit on the panel of experts. The results of this study showed that carbon storage and greenhouse gases sequestration (final weight = 0.25) in ecological sub-criteria, air quality improvement (final weight = 0.24) in social and energy conservation (final weight = 0.66) in economic criterion has the first level of importance in each criterion. The results demonstrate that urban forests not only beautify the landscape, they even play a major role in ecological, social and economic values. The results of this study will be implemented in urban forests developing projects by helping in suggesting proper tree species to maximize all of the indicators factors investigated in this study.

Key words: criteria and indicators, landscape, Iran, sustainable urban forestry.

Introduction

Urban forests are located in or around dense urban areas and include trees that grow in roadsides, parks, gardens, and remnant forest patches. Urban forest provides sustainable public health and public environmental benefits to urban residents (Gerrish and Lea Watkins 2018, Song et al. 2018, Vujcic and Dubljevic 2018) and offer urban dwellers a higher quality of life by delivering a wide range of benefits including ecological (moderating climate, air quality improvement and reduction in noise levels), economical (providing shade cover and reducing energy costs and increasing property values) and psychological (provide a great potential perceiving general health by reducing stress and making positive emotions) benefits (Wilde and Maxwell 2018).

Recent studies demonstrate that urban forests provide visitors opportunities to various activities such as social interactions, physical activities, outdoor recreation, multiple health benefits, etc. Visitors have diverse motivations for visiting urban forests in every country such as taking a walk in Denmark, barbequing and picnicking in Australia, walking and jogging in Austria and Germany (Zhai et al. 2018, Chen et al. 2018).

Over the past few decades, there have been intensive efforts to green cities because healthy urban forests can produce ecosystem functions and provide goods and services to benefit humans and the environment (McPherson et al. 2017, Song et al. 2018).

The presence of urban forests is constrained by urbanization. The urbanization has many challenges to urban dwellers and creates many problems that can affect human wellbeing and associated air pollution emission with consequent detrimental health effects. Therefore, the evaluation of sustainable urban forest indicators has become an essential need for overcoming these problems and help to create a healthy living environment (Chen et al. 2018, Selmi et al. 2016).

There are many scientific methods to achieve this purpose. The Delphi method is a well-established method that uses experts' consultation and contribute their opinion to obviate a structured problem and develop improves solutions in an urban forest situation (Barron et al. 2016, Ocampo et al. 2018) and generate a majority agreement around the most efficient criteria for improving urban forest planning framework (Toumbourou 2018).

Delphi method has been recognized as a social and policy technique and a valid instrument for assisting decision-making processes on various issues. The selection of a suitability qualified and knowledgeable panel is critical to the success, validity and accuracy results of a Delphi study (Toumbourou 2018). The Fuzzy Delphi method is the modified and improved version of the classical Delphi technique (Amira et al. 2016) that is an analytical hierarchy approach for ranking of effective material section criteria (Kazemi et al. 2015).

The Fuzzy Delphi method established in this study is a highly objective, adaptive assistive decision-making tool that can facilitate subsequent maintenance and applications (Fig. 1) (Hsueh 2015). Fuzzy Delphi as an analytical method used probability theory (instead of absolute mathematical concepts) to address the fuzziness numbers of experts prediction interval values in order to achieve a better conclusion of the expert judgments and decision making (Sensuse et al. 2018, Ho and Wang 2008).

The natural environment and urban

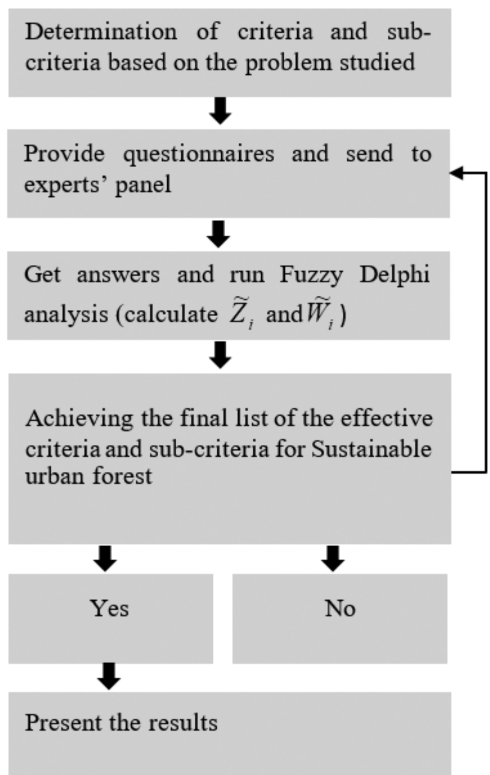

Fig 1. A summary of steps to run the Fuzzy Delphi method.

forests scientific studies by the Fuzzy Delphi approach have been a debate in many publications that attempted to qualify the benefits of urban forests. Filyushkina et al. (2018) applied the Delphi method to identify the impacts of five forest management alternatives and several forest characteristics on the preservation of biodiversity and habitats in the boreal zone of the Nordic countries. Ocampo et al. (2018) studied the sustainable ecotourism indicators with the Fuzzy Delphi method in Philippine. Toumbourou (2018) used the Delphi approach to identify the most efficacious interventions to improve Indonesia's forest and land governance. Barron et al. (2016) use a Delphi approach to develop a set of key indicators for healthy urban forest planning and designing future forests. Barzekar et al. (2011) studied criteria and indicators in monitoring ecotourism sustainability in the Northern forests of Iran by the Delphi technique.

Considering the strong concerns of increasing the urbanization and reducing green space in industrial big cities in the last decade, this study was conducted to explore the most important criteria to achieve the better scientific understanding of ecological, social and economic benefits of urban forests from the perspective of forestry experts by Fuzzy Delphi method and to provide the clear and scientific express to urban forest planners and urban green space decision-makers to use the most effective criteria to expand green spaces and forest parks.

Materials and Methods

Study area

The study was performed in Tabriz city as the fifth largest and one of the important industrial cities located in the capital of Azarbaijan province, northwest of Iran (Fig. 2) with population of 1,558,693 (Based on the results of the 2016 census), at an altitude of 1361 m a.s.l and in 38°5′ N and 46°16′ E geographical coordinates. The mean annual precipitation is approx-

Fig 2. Location of the study area.

imately 290 mm, the mean temperature is 12.5 °C and classified in the Semi-Arid region according to the De Martonne aridity index. (Zarghami and Akbariyeh 2012, Hami and Tarashkar 2018, Sharafkhani et al. 2018).

Data analysis

Design questionnaire: This study used a Fuzzy Delphi method to identify criteria and highlight the importance of understandings in the field of urban forestry, and therefore, first to establish a set of criteria and sub-criteria. A questionnaire was developed based on the main criteria introduced in works of literature (Tyrvainen 2001, McPherson and Simpson 2003, Nowak et al. 2013, Barron et al. 2016, McPherson et al. 2017) (Table 1).

Table 1. Set of key urban forest indicators used in this study.

Criteria	Sub-criteria	Descriptions
Ecological	Urban trees biodiversity	An urban forest with a variety of species is more adaptable and resistant to the factors of change, such as climate change, pests and diseases. This diversity includes age, species, genus and family. Diversity guarantees the long-term sustainability of the forest.
	Trees canopy coverage	Crown coverage is the most common criterion used to estimate the characteristics of an urban forest in cities because it is both easy to measure and publicly available.
	Flood control	Trees help the water penetration into the soil and purify the water and reduce the amount of surface runoff volume in an appropriate system.
	Species habitat provision	Urban forests can help protect biodiversity by creating a high-quality habitat for Fauna and Flora. A forest park can well provide the needs for the nature of a city.
	Carbon storage and Greenhouse gases sequestration	Carbon sequestration refers to the amount of carbon dioxide absorbed by leaves of trees and stored in the wood and soil texture. Carbon dioxide is the most abundant greenhouse gas that is achieved by using fossil fuels. Calculating the amount of carbon storage indicates the contributing of urban forests to reduce the impacts of global warming and climate change.
Social	Physical Assess to nature	Access to the natural area leads to an increase in physical activities in nature, such as hiking and outdoor recreation, therefore there are the important aspects of physical, mental and psychological well-being for citizens.
	Visual Assess to nature	There is scientific evidence that access to nature will reduce stress and increase physical and mental health, even with watching a beautiful view from the window.
	Increasing growing space in the city	The amount of natural space in the urban forest is an indicator of the potential of the community to increase the protection of urban forests. Without suitable space and soil, the urban forests will face to the problem in developing and managing.
	Air quality improvement	Trees are very useful to improve air quality and human health. Trees promote health and social well-being by removing air pollution, reducing stress, encouraging physical activity, and promoting social ties and community.

Criteria	Sub-criteria	Descriptions
	Danger probability of urban trees	The fall of the trees' trunks and branches due to storm or uproot the trees and vulnerability to pests, pathogens of diseases are potentially concerned for urban forest dangers that may result in irreparable damages. But, these risks will be reduced easily by taking measures to protect the health of the trees, the age, and the proper species at the right places in urban forests.
Economical	Energy conservation	This criterion is used to calculate the contribution of urban forests to reducing energy consumption in the community, which can be achieved by reducing the energy consumption of buildings by trees shade on buildings over warm summers or using cool and fresh air during warm hours.
	Increase property value	Estate close to urban forests is more expensive and thus affects people's economies. There are economic indicators that can easily calculate this value.

Then, three ecological, social and economic criteria and sub-criteria were determined by interval weights among 1 to 9 (Table 2). At the second step, a total of 13 experts and academic lecturers in the field of forest sciences were chosen (Linstone 1978, Tsaur et al. 2006, Skulmoski et al. 2007) to sit on the panel of experts based on more than 6 to 10 years' experience (Hasan et al. 2017).

Table 2. Importance of the sub-criteria weights.

Weights of sub-criteria	Code	Descriptions (with triangular fuzzy numbers)
Quite unimportant	1	The sub-criteria has no significant effects in the urban forest (1,1,3)
Partly important	3	The sub-criteria has a partly significant effect in the urban forest (1,3,5)
Moderate important	5	The sub-criteria has a moderately significant effect in the urban forest (3,5,7)
Important	7	The sub-criteria has a significant effect in the urban forest (5,7,9)
Very important	9	The sub-criteria has a very significant effect in the urban forest (7,9,9)

Note: the numbers in brackets mean triangular fuzzy numbers.

Steps of data analysis: in the end, data analysis of the Fuzzy Delphi technique was performed by paired comparison matrix for sub-criteria according to participant opinions. The analysis steps included Fuzzy numbers definition based on the membership function of the triangle, paired fuzzy comparing between sub-criteria, the fuzzy relative weight of criteria calculating and finally the most effective factors determination to evaluate key urban forest indicators (Hasan et al. 2017, Toumbourou 2018), as follows:

The basic steps of the Fuzzy Delphi process:

- Surveying experts: At first, it is surveying experts about effective factors.

- Calculation of fuzzy numbers: To calculate fuzzy numbers $\left(\tilde{a}_i\right)$ the opinion of experts was used directly. Fuzzy numbers calculated based on the membership function of the triangle. The fuzzy numbers defined as the following functions (1–4):

Function (1): $a_{ij} = (\alpha_{ij}, \delta_{ij}, \gamma_{ij})$, where a_{ij} are triangular fuzzy numbers.

Function (2): $\alpha_{ij} = min\ (\beta_{ijk})$, $k = 1, \ldots, n$, where α_{ij} is the lower limit of expert's opinion; β_{ijk} is relative importance of *i* to *j* from *k*th expert.

Function (3): $\delta_{ij} = (\prod_{k=1}^{n} \beta_{ijk})^{1/n}$, $k = 1, \ldots, n$, where δ_{ij} is the geometric mean of experts' opinion.

Function (4): $\gamma_{ij} = max\ (\beta_{ijk})$, $k = 1, \ldots, n$, where γ_{ij} is the higher limit of expert's opinion.

The fuzzy opinion for the survey can be denoted as $\alpha_{ij} \le \delta_{ij} \le \gamma_{ij}$. In addition, the components change from intervals of $\left[\frac{1}{9}, 9\right]$.

- Fuzzy inverse matrix $(\tilde{A})$: Paired fuzzy comparing between sub-criteria was done based on the following function (5):

Function (5): $\tilde{A} = \left[\tilde{a}_{ij}\right]_{n \times n}$ $\tilde{a}_{ij} \times \tilde{a}_{ij} \approx 1$ $I, j = 1, 2, \ldots, n$

$$\tilde{A} = \begin{bmatrix} (1,1,1) & (\alpha_{1j}, \delta_{1j}, \gamma_{1j}) & (\alpha_{1n}, \delta_{1n}, \gamma_{1n}) \\ \left(\frac{1}{\gamma_{1j}}, \frac{1}{\delta_{1j}}, \frac{1}{\alpha_{1j}}\right) & (1,1,1) & (\alpha_{2n}, \delta_{2n}, \gamma_{2n}) \\ \left(\frac{1}{\gamma_{1j}}, \frac{1}{\delta_{1n}}, \frac{1}{\alpha_{1n}}\right) & \left(\frac{1}{\gamma_{2n}}, \frac{1}{\delta_{2n}}, \frac{1}{\alpha_{2n}}\right) & (1,1,1) \end{bmatrix}$$

- Calculation of fuzzy relative weight of criteria – functions (6) and (7):

Function (6): $\tilde{Z}_i = \left[\tilde{a}_{ij} \ldots \tilde{a}_{in}\right]^{1/n}$.

Function (7): $\tilde{W}_i = \tilde{Z}_i / (\tilde{Z}_i \oplus \ldots \oplus \tilde{Z}_n)$, where: $\tilde{a}_1 \otimes \tilde{a}_1 = (a_1 \times a_2, \delta_1 \times \delta_2, \gamma_1 \times \gamma_2)$ and sign $\otimes$ show multiple of fuzzy numbers and $\oplus$ show the addition of fuzzy numbers. $\tilde{Z}_i$ is the total relative fuzzy weights of the criteria $\tilde{w}_i$ is a row vector and shows fuzzy weighting of criteria *i*.

- None fuzzy weighting of criteria: The geometric mean of the fuzzy number of the weight of criteria and sub-criteria calculated according to Function (8). Thus, the weight of criteria and sub-criteria explain as a certain number:

Function (8): $W_i = \left(\prod_{j=1}^{3} w_{ij}\right)^{1/3}$.

Finally, the effective factors were determined (Abedi and Ganji 2015, Kazemi et al. 2015, Ocampo et al. 2018). Sometimes, this method requires multiple replications for asking experts' opinions that must continue until they get a consensus. In this study, the data from the first round survey reached an appropriate consensus, and there was no need to require multiple rounds.

Results

Eventually, final weighs of criteria ($\tilde{w}_i$) were calculated to evaluating and rat a set of important indicators in creating a framework for designing and planning sustainable urban forests in the future. According to the results, five ecological sub-criteria were classified into three categories. The carbon storage and greenhouse gases sequestration (0.25) sub-criteria were the most important ecological criteria, followed by trees canopy coverage (0.21), floodwater control, species habitat provision and urban trees biodiversity (0.18), respectively (Fig. 3).

The final weights of social criterion showed that air quality improvement (0.24) sub-criteria were the most important criterion, followed by physical access to nature (0.21), visual access to nature (0.21), increasing growing space in the city (0.19) and danger probability of urban trees (0.12), respectively, therefore five sub-criteria were classified into five categories (Fig. 4).

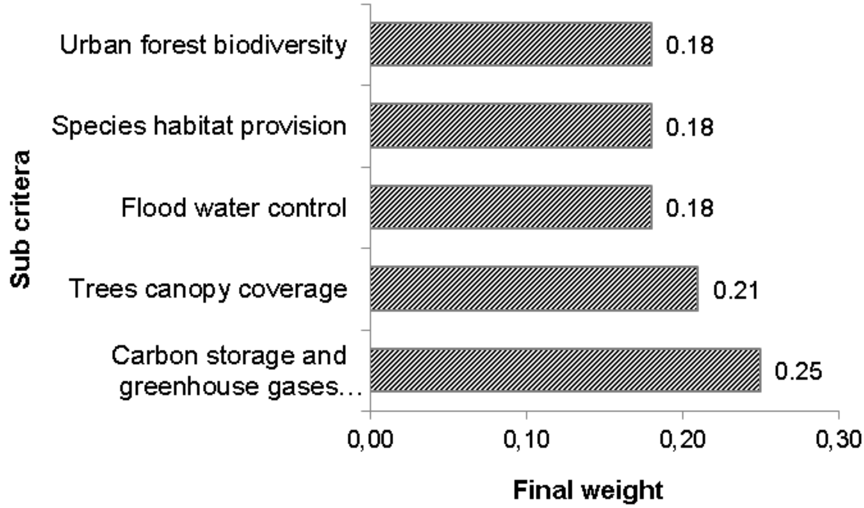

Fig 3. Final weights of Fuzzy Delphi sub-criteria for ecological criterion.

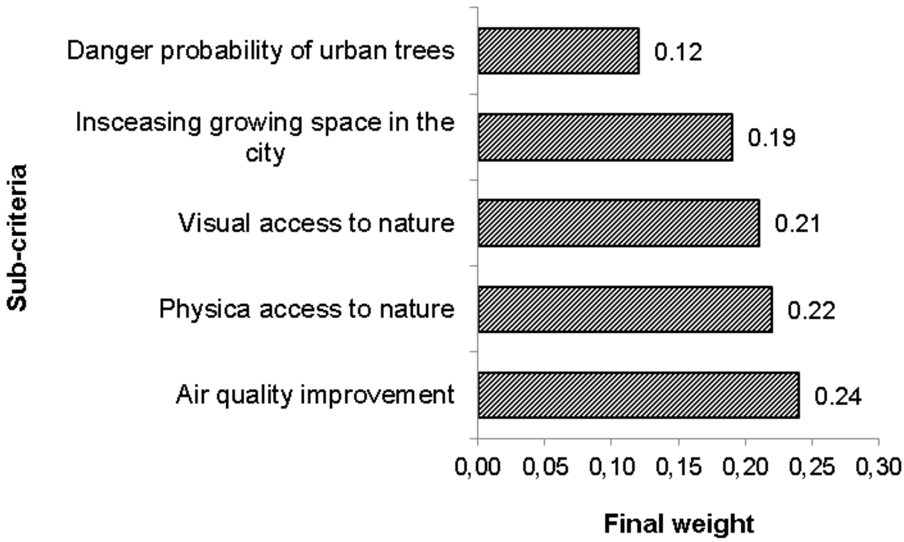

Fig 4. Final weights of Fuzzy Delphi sub-criteria for social criterion.

The sub-criteria of economic criterion were classified into two categories to evaluate indicators for the sustainable urban forest. Energy conservation has the first level of importance (0.66) and increase property value was the second (0.33) (Fig. 5).

Results of Fuzzy Delphi mean rating matrixes of all participants' consensus $(\tilde{z}_i)$ were formed for ecological, social and economic criterion (Table 3).

In addition, the average fuzzy vs. non-fuzzy weights of all criteria resulted from all participants were calculated and shown in Table 4.

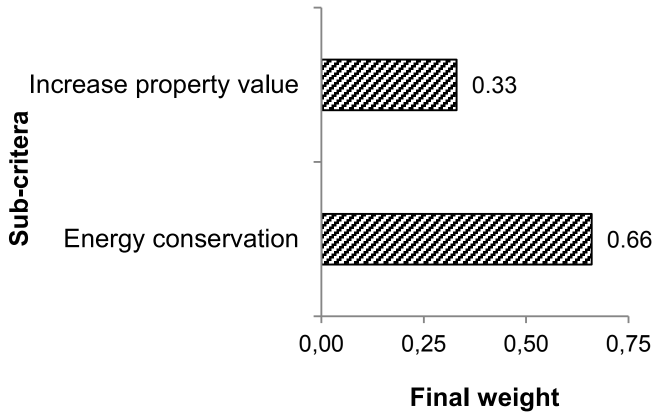

Fig 5. Final weights of Fuzzy Delphi sub-criteria for economic criterion.

Table 3. Total relative fuzzy weights of the criteria.

Criteria	Subcriteria	$\widetilde{Z}_i$		
		z_1	z_2	z_3
Ecological	1	0.51	0.87	1.58
	2	0.62	1.02	1.87
	3	0.48	1.00	1.58
	4	0.53	0.95	1.50
	5	0.89	1.19	1.97
	Total	3.04	5.03	8.49
Social	1	0.83	1.15	1.58
	2	0.78	1.14	1.50
	3	0.70	1.00	1.40
	4	0.95	1.23	1.69
	5	0.42	0.61	1.00
	Total	3.68	5.14	7.16
Economical	1	0.75	1.26	3.00
	2	0.33	0.79	1.34
	Total	1.08	2.05	4.34

Table 4. Average fuzzy and non-fuzzy weights of first, second and third criteria.

No	Criteria	Subcriteria	Fuzzy weights			Non-fuzzy weights
			w_3	w_2	w_1	
1	Ecological	1	0.06	0.17	0.52	0.18
		2	0.07	0.20	0.61	0.21
		3	0.06	0.20	0.52	0.18
		4	0.06	0.19	0.49	0.18
		5	0.10	0.24	0.65	0.25
		Mean	0.07	0.20	0.56	0.20

No	Criteria	Subcriteria	Fuzzy weights			Non-fuzzy weights
			w_3	w_2	w_1	
2	Social	1	0.43	0.22	0.12	0.22
		2	0.41	0.22	0.11	0.21
		3	0.38	0.20	0.10	0.19
		4	0.46	0.24	0.13	0.24
		5	0.27	0.12	0.06	0.12
		Mean	0.39	0.20	0.10	0.20
3	Economical	1	2.78	0.61	0.17	0.66
		2	1.24	0.39	0.08	0.33
		Mean	2.01	0.50	0.12	0.50

Discussion

One important aspect of a city environmental function is the urban forests affects included social, ecological and economic benefits, which is measurable by implementing questionnaires programs to design the best fit to achieve values and increasing awareness of the role of the urban forest in enriching human health and well-being (Barron et al. 2016).

The carbon storage and sequestration is the concept of carbon dioxide absorption by trees in wood and soil texture during photosynthesis and carbon as biomass. Carbon dioxide is the most abundant greenhouse gas resulting from the use of fossil fuels. Calculating the amount of carbon storage reflects on the high contribution of urban forests to reducing climate change. Nowak et al. (2013) showed that an average of 7.69 kg·cm^{-1} of tree cover density and average 0.28 kg·cm^{-1} carbon sequestrations of tree cover per year were store by urban trees in the USA. In addition, they emphasise that analysis of urban forest carbon sequestration capacity can improve people's knowledge level for forest ecological benefits and values, it can also provide a scientific basis for tacking regional climate change and develop planning and development of forest carbon sink market to build a healthy ecological urban environment. Yu et al. (2017) founded that forest area and tree cover percentage are the major factors influencing regional carbon sequestration capacity in cities. Although, tree average carbon storage ability per square meter varies in different cities and states (Nowak et al. 2013). An analysis of forest ecosystem carbon sequestration capacity can provide scientific references for urban forest management strategies. Before the 1990s, people paid little attention to urban forest carbon storage (Yu et al. 2017). Nevertheless, the results of our study showed that this awareness has increased significantly.

The importance of trees to improve air quality in urban environments is a very clear issue. Trees are able to absorb a variety of air pollution with different amounts, depending on the species, age, location and health of the trees (Beljan et al. 2015). The reviewing of the literatures identified that mitigation pollution and carbon dioxide sequestration are the main urban forest services (Nowak et al. 2013, Yu et al. 2017). Environmental quality strategies make it possible to maximize people's overall life quality in a city. Urban forests are the sum of all urban trees, shrubs and lawns located in highly altered and extremely complex urban areas characterized by a high amount of population densities and pollution (Escobedo et al. 2011).

Escobedo et al. (2011) introduce fuel conservation as an energy-saving service of urban trees shading. Energy conservation measures the amount of urban forest use to reduce energy consumption in the community and achieved by reducing energy consumption by shad on buildings over warm summers or using cool and fresh air in hot weather. McPherson et al. (2017) stated that the extent of urban residents benefit from these goods and services depends on their location relative to the urban tree canopy and canopy health. McPherson and Simpson (2003) estimate that existing trees in California reduce annual air conditioning energy use by 2.5 % with a wholesale value of $ 485.8 million. The location of trees near the buildings to shade and the regional climate influence on the difference in potential energy saving.

McPherson et al. (2017) introduce the term ‘Eco services' (ecosystem services) for urban forest services including energy conservation, air quality improvement, carbon storage, stormwater runoff reduction, wildlife habitat and raise property values and produce goods such as food and wood products and provide social, economic, aesthetic and health benefits. Song et al. (2018) reported that the most frequently studies to quantify the benefits of urban forests are related to environmental regulation, property values, carbon reduction and air quality.

Conclusions

This study attempted to understand main criteria and sub-criteria required to plan urban forests – Iran perspective and focused on an academic expert's opinion by the Fuzzy Delphi method. The results demonstrate that urban forests not only beautify the landscape, they even play a major role in ecological, social and economic values. In this case, the main sub-criteria were evaluated: carbon storage and sequestration greenhouse gasses emission, air quality improvement and energy conservation, respectively. The results of this study will be implemented in urban forests developing projects by helping in suggesting proper tree species to maximize carbon sequestration and qualify air condition and other main factors investigated in this study.

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