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Selection of appropriate criteria in urban forestry (Case study: Isfahan city, Iran)

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ABSTRACT: The aim of this study is to select appropriate criteria such as ecology, economy, social and aesthetic for plantation in Isfahan city, Iran. In order to do this research, 19 questionnaires were distributed among the experts at the study area in 2013. Analytical Hierarchy Process (AHP) technique as a multi-criteria decision making was used for evaluation of urban forestry at this research. Expert Choice software was used for analysis. The results showed that the ecological criterion has the highest weight for urban forestry at Isfahan city and the aesthetic criterion has the lowest priority for urban forestry at the study area. According to the judgments of the decision makers, results also showed that the large parks have the highest priority for urban forestry and street margins have the lowest priority for urban forestry and green space.

Keywords: AHP; multi-criteria decision making

Urban forestry is the management of urban forests such as tree populations in urban settings for the purposes of improving the urban environment, health and socioeconomic aspect. Urban foresters typically focus on trees located along streets as well as in public parks and natural areas. However, since one of the main goals of urban forestry is to optimize forest benefits for society, urban foresters can also help guide the management of trees on private lands, which typically dominate the overall urban forest composition (Nowak et al. 2010).

One of the best definitions of urban forestry, based on Miller (1997) is the art, science and technology of managing trees and forest resources in and around urban community ecosystems for the physiological, sociological, economic and aesthetic benefits trees provide to society.

Liu et al. (2009) investigated an evaluation system of forest community structure in Shengyang, China. Analytical Hierarchy Process (AHP) was applied to find the weight value of each valuation, and then according to the probability and mathematical statistics theory, the community structure of each type of urban forest in Shenyang was evaluated. The AHP provides a convenient approach to solving complex multicriteria decision-making problems. Expert Choice software has significantly contributed to the wide acceptance of the AHP methodology (Anonymous 1990).

Jian (2009) applied the AHP technique for urban green space evaluation. He used 11 landscape indexes from ecology and aesthetics; the model could give a support to an urban green space construct. He concluded that the evaluation system of urban green space was a multifactor synthesis system with the character of subjectivity, complexity and uncertainty. The dynamic design of urban green space based on the sustainable development theory requests to establish an urban green space evaluation system with manoeuvrability and measurability.

Bunruamkaew and Murayama (2011) identified and prioritized the potential ecotourism sites using Geographic Information System (GIS) and AHP in Surat Thani province, Thailand. They identified the following factors as indicators of suitability within land ecosystems: landscape/naturalness, wildlife, topography, accessibility and community characteristics. The evaluating process for ecotourism sites was based on nine chosen criteria including visibility, land use/cover, reservation/protection, species diversity, elevation, slope, proximity to cultural sites, distance from roads and settlement

size. Those factors were selected according to the professional expert's opinions. AHP was effectively used in this study to calculate the details of the factors and class weights.

Wang et al. (2006) analysed the principal part and major points of an urban ecological environmental system in Nanjing. They established the evaluation indices related to the ecological environment. The indices system of urban ecological environmental quality was established, and the significance and function of this system were explained. AHP was applied to judge the weight of each evaluation index and to calculate the comprehensive assessment values of evaluation indices system.

Chen and Nie (2007) analysed the composition of urban forest in Nanjing, China. The economic analysis was used to estimate the urban forest ecological value.

The AHP technique as a multicriteria decision making was used at this research. AHP is a mathematical method used to analyse the complex decision problems with multiple criteria that were introduced by Saaty (1977, 1980).

AHP has been successfully applied to many kinds of decision situation (Zahedi 1986). In early forestry application, the AHP technique was used e.g. by Mendoza and Sprouse (1989), Kangas and Pukkala (1992) and Schmoldt et al. (1994).

AHP is also used in forestry and forest management planning. A list of applications from a variety of areas for decision making was reported by Zahedi (1986), and applications concerning natural resource management were recently reviewed by Mendoza (1997).

AHP has been used for urban forestry recently. The appropriate species selection in the urban forestry using AHP was investigated in Rasht, Iran (Rostami Shahraji et al. 2011). They determined appropriate species for plantation based on ecological capacity at the study area. They also determined the criteria priorities for plantation in Rasht.

The prioritization of urban forestry activities was investigated in some major European capital cities by Konijnendijk (1999). AHP is applicable to multi-objective urban forestry planning due to the simplicity, effectiveness, and ability to deal with qualitative as well as with quantitative criteria. Furthermore, the priorities estimated using the AHP are easy to interpret. Other reasons for applying the AHP to forest planning include e.g. that it forces decision-makers and participants to think about forestry values and objectives, and by using it the trade-offs between competing objectives and interests can easily be illustrated. AHP is a good tool in education and learning concerning multipurpose forestry as a whole as well as concerning trade-offs within a certain forest area. In addition, the AHP server as a good introduction to the world of multiple-criteria decision supports (Kurttila et al. 2000)

The aim of this study is to use the AHP technique to determine the appropriate criteria such as ecological, economic, social and aesthetic ones for plantation as a green space based on the interviewees' responses in Isfahan city, Iran.

MATERIAL AND METHODS

Study area. Isfahan city is the capital city of Isfahan province in Iran with an area of 250 km^2. Its altitude is 1,571 m, latitude is 32°39'25''N and longitude 51°40'39''E. Isfahan is located about 340 km south of Tehran. This city is located in a desert dry and semi-desert region and west of the Zagros mountain region (Fig. 1) (Varesi et al. 2010). The city is located in the lush plain of the Zayanderood River, at the foothills of the Zagros mountain range. The Zayanderood River divides Isfahan city into north and south parts. Isfahan is one of the most important cities of Iran because of its historical and economic values. Isfahan attracts a large number of tourists each year. The mean annual temperature of Isfahan is approximately 16°C. The Isfahan metropolitan area had a population of 1,791,069 in 2010, the second most populous metropolitan area in Iran after Tehran. Urban expansions, population growth and industrial development cause degradation of environmental quality in Isfahan city (Bihamta Toosi et al. 2012).

According to statistics, at present, the total area of the green space in Isfahan city is 400 ha and the green belt area is 1,700 ha. There are about 65 city parks and 975 local parks in Isfahan. Planted species in the green belt are cypress, mulberry, and acacia (ISFAHAN municipality 2014).

Method. In order to do this research, questionnaires were used. The questionnaire contained different criteria for plantation in an urban area (Table 1). The main purpose of this questionnaire is to have the expert's opinion to determine appropriate criteria of plantation and priority of city green space in Isfahan city. Therefore, in this study 19 questionnaires were distributed among the experts at Isfahan Municipality, Isfahan University, Natural Resources Office, and Park and Green Space Organization of Isfahan.

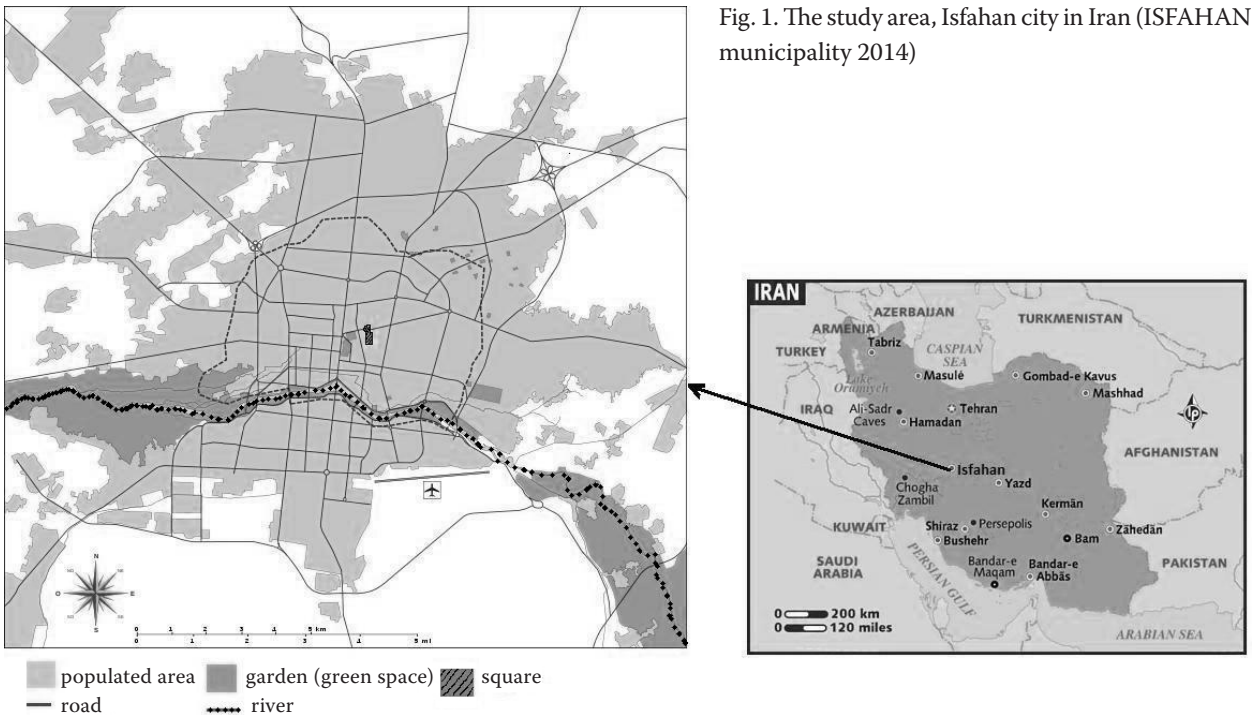

Fig. 1. The study area, Isfahan city in Iran (ISFAHAN municipality 2014)

AHP technique

AHP is a decision-making technique which can be used to analyse and support decisions which have multiple and even competing objectives. To do this, a complex problem is divided into a number of simpler problems in the form of a decision hierarchy (Erkut, Moran 1991).

Once the hierarchy has been established, a pairwise comparison matrix of each element within each level is constructed. Participants can weight each element against each other within each level, which is related to the levels above and below it, and mathematically tie the entire scheme together. AHP is often used to compare the relative suitability of a

Table 1. Definition and explanation of criteria, sub-criteria and alternatives

Abbreviation	Definition
Goal	selection of appropriate criteria for planting in Isfahan
Aesthet	aesthetic criterion
Landscape	landscape sub-criterion
Ecology	ecology criterion
Amenity	amenity sub-criterion
D. Noise	decreasing noise pollution
Wildlife	wildlife sub-criterion
Economic	economic criterion
Energy	saving energy sub-criterion
Saving	production of food and energy sub-criterion
Wood	production of wood sub-criterion
Social	social criterion
Recreat	recreation sub-criterion
Consolin	consoling sub-criterion
Rivers	river routes and frailer lands
Large park	city margin forests, large parks, road margins, green belt
City cen	city centre
City sub	city suburbs, small parks, reaction place
Streets	streets, building sides, boulevard, squares

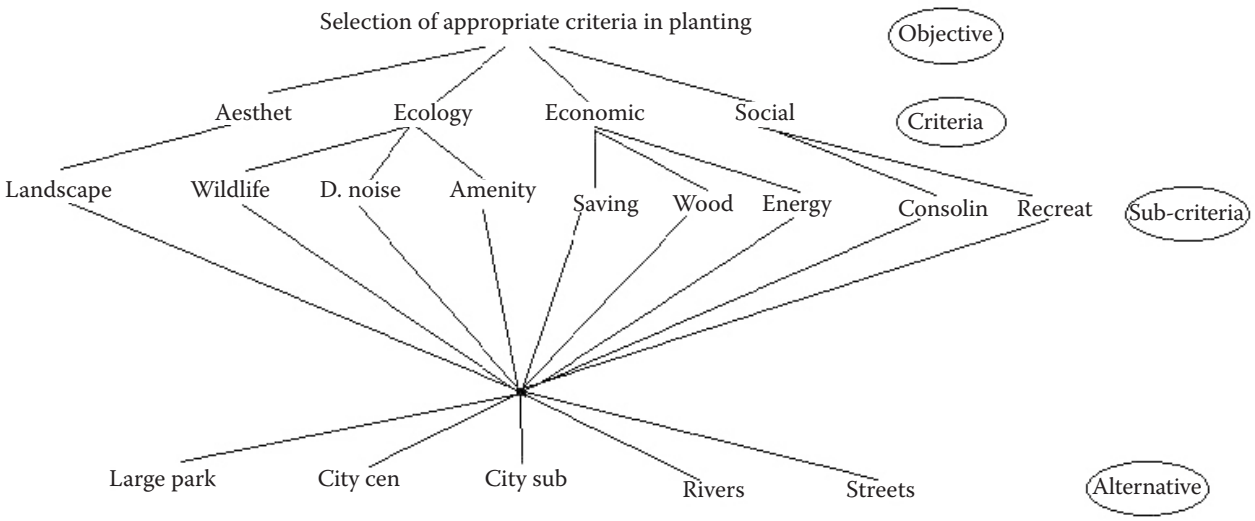

Fig. 2. The hierarchical structure status

small number of alternatives concerning the overall goal. AHP allows some small inconsistency in judgment. The reason is that human is not always consistent. The ratio scales in AHP are derived from the principal Eigen vectors and the consistency index is derived from the principal Eigen value.

To start with AHP, first a hierarchy structure is required. While building the hierarchy tree, including more than nine elements in any objective group is not considered since it is cognitively challenging for humans to evaluate more than nine factors at a time. When the model is built, the next step is to evaluate the elements by making pairwise comparisons (Alanbay 2005). The hierarchical structure evaluation at this research is shown in Fig. 2. It uses a multi-level hierarchical structure of objectives, criteria, sub-criteria, and alternatives. The pertinent data are derived using a set of pairwise comparisons. These comparisons are used to obtain the weights of importance of the decision criteria, and the relative performance measures of the alternatives in terms of each individual decision criterion. If the comparisons are not perfectly consistent, then it provides a mechanism for improving consistency (Putrus 1990).

The consistency ratio values of all comparisons were lower than 0.10, which indicated that the use of the weights was suitable (Eastman 2003).

AHP in group decision making

When using AHP with its questionnaire, each member of the group has to make judgment by doing a pairwise comparison of criteria in the categories and subcategories of the hierarchical structured decision problem. The advantages are as below:

– It is a structured approach to find weights for criteria and sub-criteria in a hierarchically structured decision problem.
– All participants' inputs count; no opinion or judgment is ignored and all group members have to fill out the questionnaire.
– Participants' evaluation can be weighted by predefined (and agreed) criteria, like expertise, responsibility, or others, to reflect the actual involvement of decision makers.
– The consolidated group result is calculated using a mathematical method; it is objective, transparent and reflects the inputs of all decision makers (Klaus 2013).

From practical experience, especially the last point results in a usually high acceptance of the group result. Aggregation of individual judgments in AHP can be done using the geometric mean: each matrix element of the consolidated decision matrix is the geometric mean of the corresponding elements of the decision makers' individual decision matrices. The outcome – consolidated weights or priorities for criteria in a category – can be used as group result for the calculation of global priorities in the decision problem (Klaus 2013).

At this study after filling out the questionnaires by experts at the Isfahan city, Expert Choice software version 9 (Expert Choice Inc., Pittsburgh, USA) was used for analysis.

RESULTS

Results of data analysis show that the criteria such as ecology, aesthetics, economy and social are respec-

Fig. 3. Weight of criteria (inconsistency ratio = 0.07)

tively important in determining the appropriate type of urban forestry and green spaces.

The weights and inconsistency are shown in Fig. 3. As shown in Fig. 3, the ecology criterion is more important and its weight is 0.623. The second important criterion is social and its weight is 0.216. The third important criterion is economic and its weight is 0.087. Finally, the less important criterion is aesthetic value and its weight is 0.079. The inconsistency rate is 0.07. If the value of inconsistency ratio is smaller or equal to 0.1, the inconsistency is acceptable. If the consistency ratio is greater than 0.1, we need to revise the subjective judgment. Hence, according to the value of inconsistency ratio (0.07), it is not required to revise the subjective judgment at this study for criteria.

Different criteria have some sub-criteria as shown in Fig. 5. Results indicated that amenity sub-criterion is more important and has priority for urban plantation. It has the highest weight and its weight is 0.403. The second important sub-criterion is noise decrease and its weight is 0.182. Consoling view is at the third place based on the questionnaires and its weight is 0.140. The weights of sub-criteria such as recreational value, energy production and landscape are 0.66, 0.53 and 0.51, respectively, and they have middle weights. Finally the sub-criteria such as wildlife, energy saving and wood production have the lowest weights and their weights are 0.50, 0.31 and 0.24, respectively. The inconsistency rate also is 0.08. Therefore, it is not required to revise the subjective judgment at this study for sub-criteria.

The final weight of each alternative in a hierarchical process is the sum of multiplication of the criteria importance and sub-criteria evaluation that is associated to the aim of investigation and the coefficients of criteria and sub-criteria. The final score of each alternative is determined based on the integrating of coefficient importance.

The results of final weights are shown in Fig. 4. Results show that the large parks have the highest priority for urban forestry and its weight is 0.302. The second important location for urban forestry is river margins and its weight is 0.276. City centre is at the third place for green space and its weight is 0.144. Finally, the last two areas for urban forestry are city suburb and streets margins. The weights for city suburb and streets margins are 0.140 and 0.139, respectively. The inconsistency ratio is 0.08. Therefore, it is not required to revise the subjective judgment.

DISCUSSION

Urban development with industrialization restricts the use of natural environment for the people (Rostami Shahraji 2003). Trees and forests

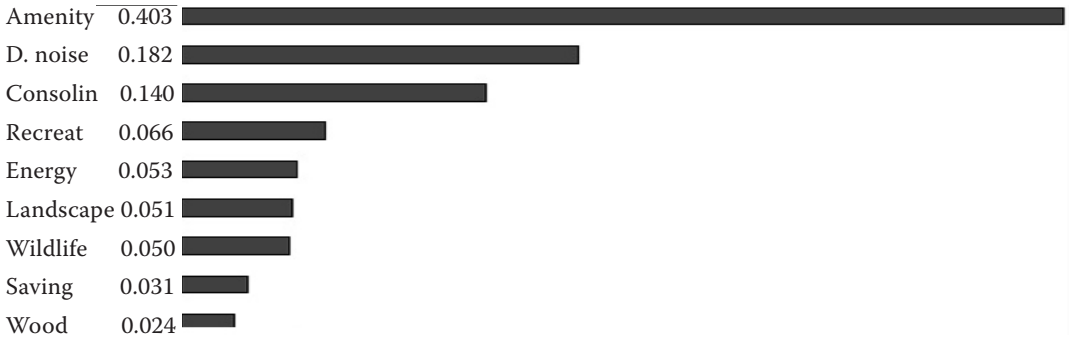

Fig. 4. Weight of sub-criteria (inconsistency ratio = 0.08)

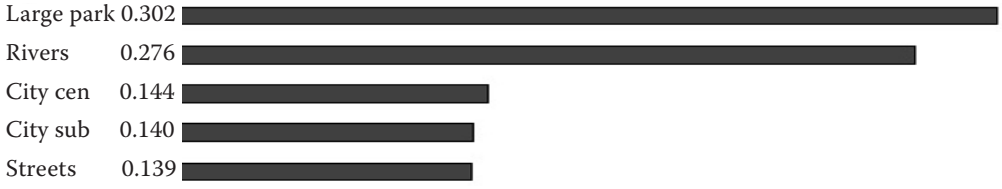

Fig. 5. Weight of different places for urban forestry (inconsistency ratio = 0.08)

are the most prominent elements of urban nature, because of seasonal changes and their size, shape, and colour. Their benefits and uses range from intangible psychological and aesthetic benefits to amelioration of urban climate and mitigation of air pollution. Historically the main benefits of urban trees and forests relate to health, aesthetic and recreational benefits in industrialized cities. In addition, green spaces have provided people with subsistence for providing food, fodder, fuel, wood and timber for construction (Tyrvainen et al. 2005).

Selection criteria listed in this paper should be a basis for the selection criteria used in urban green space programs. Properties related to the urban situation are related to stresses caused by social values, recreation and consoling. The economy values are related to production of food and energy and production of wood. In addition, aesthetic values are important selection criteria. The priority ranking of the selection criteria depends on the environment (ecology criterion) wherein the plants are to be used. The contribution that urban forestry makes to the social environment and the role trees play in land values. Safety includes the selection of trees that have the life forms that will not cause hazards to traffic, pedestrians and infrastructure. Economic values of green space are not so important at this study. The aesthetic value of urban forestry is less important at this research.

Activities related to trees in the urban environment are: (1) policy making, planning and designing etc., (2) technical focus, such as selection programs and establishment techniques and (3) management aspects (Konijnendijk, Randrup 2002).

The urban forest can play a major role to improve the urban environmental conditions and safeguarding biodiversity. Environmental benefits do not relate solely to areas of woodland, however; smaller groups, avenues and isolated trees can equally improve environmental conditions in urban areas (Tyrvainen et al. 2005). Konijnendijk (1999) investigated the urban forestry activities in some European capitals and declared that the social function is a priority at all cities. The second priority is the protection that is an ecological criterion and the third priority is wood production that is an economic sub-criterion.

Rostami Shahraji et al. (2011) used the AHP method to determine the appropriate species for Rasht city in the north of Iran. Their results showed that the first priority for species selection is social criterion as in our study the first priority was ecological criterion.

Karami (1999) studied the green space of the railway margin in Tehran using AHP. His results showed that the first priority for green space is ecological criterion as it was similar to the results of our study. Therefore, the first criterion priority for plantation could vary at different study areas due to city location and environmental conditions.

Chen and Nie (2007) analysed the composition of urban forest in Nanjing. The economic and economical values of urban forests are calculated. From the economics point of view, it was a good suggestion to accelerate the development of urban forestry and ecological urban construction.

Green spaces are a vital part of any urban conglomeration, providing a range of environmental, social, cultural and economic benefits. Trees in woodlands, parks and gardens, and aligning streets and squares are the most frequent elements of such green areas, yet their benefits are often overlooked and their proper care is neglected (Konijnendijk et al. 2005).

Results of our study show that the large parks have the highest weight for urban forestry and the river routes and frail lands are the next priority. Duhme and Pauleit (1992) investigated the nature protection program for Munich, Germany. They concluded that single old trees in parks can be an important habitat for birds, bats and invertebrates. Habitat surveys and floristic and faunistic studies have shown the importance of tree cover in urban land uses such as residential areas for biodiversity. They mentioned that density of tree cover, overall extent of stands of trees and age of trees are especially important factors influencing biodiversity. Their results also show that an overall tree cover of at least 20% is a target for urban forestry planning for residential areas in Munich City.

The natural element and nature around it and branched streams (muddies) have played a significant role, so four elements of water, soil, plant and wind have come together and merged. Flowing water in muddies, branched gutters and density of trees have a significant impact on air purification and blowing cold made by water and trees presents very fine and enjoyable weather. The development of green areas along the river has been done to prevent construction in the proximity of the river (Amjad et al. 2012). This topic implies the importance of creating green space and urban forestry in the margin of the Zayandehrood River in Isfahan, Iran.

Wolf (1988) mentioned that trees had reduced the heat effect of buildings and paving materials and

had been reducing house cooling costs in residential areas about 8 to 12 percent each year. Miller (1997) investigated the role of trees and green space in saving energy in California and he mentioned that energy consumption was about 50–60% lower in houses where trees existed around them. All of the above-mentioned researches emphasize the multifunctional roles of green space in urban areas.

CONCLUSIONS

This is the first research that was conducted in Isfahan city using the AHP method for determining the optimal criteria in urban forestry. The results of this study can help the managers of urban green space to improve the urban forestry management. In this research, the criteria such as ecology, social, economic and aesthetic are respectively important in determining the appropriate urban forestry and green spaces in Isfahan city. It is recommended that managers pay more attention to the ecological conditions of the region to improve their green spaces. Amenity, noise decrease, consoling view, recreational value, energy production and landscape, wildlife, energy saving and wood production are respectively important sub-criteria in urban green space at the study area. Therefore, these sub-criteria should be considered according to their priorities for creating and improving green space in Isfahan city. Finally, according to the expert view large parks and riverside should be considered more for urban green space.

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