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Plant selection method for urban landscapes of semi-arid cities (a case study of Tehran)

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ABSTRACT

Choosing appropriate plants for urban landscapes is vital to avoid potential financial and environmental losses that may occur if all selection parameters are not taken into account. A methodology has been developed to assist landscape architects, planting designers, and urban horticulturists in the plant selection process. Tehran has been picked as a case study due to its arid and semi-arid climate which poses more challenges in front of an expert. After grouping plants, selection parameters have been defined for each plant group. Plant species were comparatively graded for each parameter by a group of eight specialists. Analytical hierarchy process (AHP) technique and hierarchical cluster analysis have been utilized to find the most adaptable plant species for the area according to the main selection parameters of zone tolerance, urban conditions, esthetics, maintenance, growth characteristics, and specific features. Several new plants were ranked high in the final tables suggesting that the urban landscape of Tehran has a great potential to become more attractive, less allergic, and less costly, as well as consuming less water. Before introducing new plants to the urban environment, they should be experimented on in small numbers for several years to confirm that they will not change the ecology of the whole region through invasion or posing a threat to any local plant species.

Introduction

The planting and maintenance of plants in urban landscapes is very expensive. Therefore, having a policy to use appropriate plants that are cheaper to grow and more adaptable to local conditions is vital to significantly decrease the expenses of large-scale practices. Plants can be a source of human disturbance in urban areas if they are not well selected. For example, more than 1.8 million cedar trees were planted on the periphery of Tokyo, Japan, decades ago and today, during their pollination in spring, they have turned this mega-city into the allergy capital of the world with three million allergic residents in Tokyo (Corkill, 2009). The massive amounts of anti-allergic medicine consumed annually by Tokyo residents are evidence of its impact on health and the resources of a nation. In another example, planting female ginkgo trees on streets of several U.S. cities, such as Iowa City, has prompted complaints about their bad odor. A few cities (e.g. Easton, Pennsylvania) have moved to remove them.

For site location, finding appropriate plant matches for a site has always been a challenge for planting designers because each plant has several characteristics, and the designers could easily miss one important point in their decision-making that could lead to catastrophic results in the long term. Even though scientific studies provide details and very useful information about reactions of plants to each urban stress parameter, these studies are limited in their practical everyday use for practitioners (Roloff et al., 2009). Practitioners usually develop their own independent procedures for selecting plants relying on real urban conditions, sometimes regardless of scientific findings (Sjöman and Nielsen, 2010). This issue presents the need for easier and more practical methods of plant selection that make scientific findings applicable

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in practitioners' everyday plant selection procedures. In addition, examining the existing plant species of an urban environment and introducing better options should be core in developing any sustainable urban landscape (Konijnendijk et al., 2005), especially when the global and local climates are rapidly changing, massive buildings are being constructed influencing micro climate, and biological and environmental stresses on plants fluctuate in urban areas. In this dynamic, there is a need for a method to evaluate the compatibility of existing plants, and a plan for a sustainable future.

In most city municipality offices, there are lists of suitable plants for the local environment; these lists are based mostly on local planting experience. A clear scientific methodology has not been proposed for this selection process. Each city has its own plant selection parameters and they would not be the same for another city due to environmental differences. For example, in Seattle, emphasis on selecting plants has been for erosion control capacities (Day, 2004), whereas in Utah, trees are mainly selected based on drought tolerance (Kuhns and Rupp, 1995) as well as tolerance to freezing, soil alkalinity, and local diseases (Larry and Libbey, 1996). Most of the existing plant databases and planting guidelines are for woodlands (Sjöman and Nielsen, 2010). Choosing plants for arid and semi-arid regions appears to be more challenging because of the higher environmental limitations. In xeriscaping, planting in arid and semi-arid regions, local plants can significantly contribute to the success of a project (Franco et al., 2006).

Sæbø et al. (2005) proposed climate adaptation, growth and exterior characteristics, and resistance against pests and diseases as the main plant selection criteria for street and park trees (Sæbø et al., 2005). Roloff et al. (2009) considered drought tolerance and winter robustness as decisive criteria for selecting tree species for urban habitats considering climate change. Although Roloff et al. did not take other parameters into account due to their study limitations, they suggested that additional criteria such as soil parameters, shade resistance and esthetics be included in the future planning process (Roloff et al., 2009). In a systematic review of ecological literature, Sjöman and Nielsen, 2010 concluded that to meet requirements of urban tree planners, the available information for plant selection was either too general or too focused or contradictory. Also, books directed at plant use in cities and nursery catalogs did not explicitly refer to the location of the planting from which the authors' personal experiences were gained, so the books did not sufficiently integrate the local perspective (Sjöman and Nielsen, 2010). Hibberd analyzed ornamental plants for the United Kingdom based on their adaptability to various soils and suitability in different environmental contexts (Hibberd, 1989). The Tehran greenbelt project suggested that the water needs of plants, cold resistance, and locality of plants should be the selection criteria for Tehran (Company, 2001; Yarai, 1995), while another researcher (Khorasani, 1992) noted that ecological factors including climate, soil condition, and plant coverage status were the basis of tree selection. In other studies, accurate selections of plant species would contribute to a more attractive environment with better wildlife, cause less allergic reactions, and preserve energy (Fitzgerald et al., 1991; Cutler and Richardson, 1989). In the above research studies, plant adaptability to urban environments has specifically emphasized the prevention of root damage to sewage systems, building foundations/basements, and power supply lines. A limitation in most of the above studies is that a clear research method has not been presented and the suggestions are mostly based on the authors' personal experiences with plants.

Various books and reports include lists of qualitative selection factors which are usually comparable (Mitchell, 1974; Finnerty et al., 2005; Humphries et al., 1992). Tree selection factors are occasionally divided into primary and secondary parameters. The primary parameters include life expectancy, dimensions, strong rooting system, and cleanliness. The secondary parameters include resistance to drought, heat and cold, wind, storms, plant pests and diseases, an improper soil situation and bad drainage, compact soil, branch resistance to weight of snow, and competition (Javanshir, 1992). Several user-friendly plant selection databases and software programs are available, such as: http://www.sustland.umn.edu/plant; http://plantselect.org/plant-search/; http://anpsa.org.au/download.html; and http://www.kew.org/ceb/sepasal/. Furthermore, an accurate and recognized plant selection method that takes the weight difference of each parameter does not exist for urban landscapes based on multi-criteria recommendations of plants. We aim to develop a method by emphasizing the most influential parameters through quantifying the available qualitative information. We target developing a flexible method using the Analytic Hierarchy Process (AHP) in order to work with different local climates and soil conditions. Finally, our aim is to provide planting design experts with means to evaluate the adaptability of plants to each environment by taking several parameters into account simultaneously.

Methodology

A method of converting qualitative to quantitative parameters was adapted for this research in order to comparatively analyze plants species. Since plants grow differently in different environments, a reliable method enabled us to numerically add up the advantages and identify those plants with the most strength and ignore those with the most weaknesses. In addition, each plant had several qualities, making a clear and definite decision difficult for selection. The challenge was when certain parameters had more priority over others. For example, for a city in the middle of a desert with water shortages, drought tolerance carried more weight in plant selection than color variety, even though they were both important. Therefore, two essential elements were considered when outlining the selection criteria. The first was to identify the appropriate selection parameters for a specific region, and the second was to find the value or the importance coefficient factor of each parameter compared to other parameters. In our study, the methodology, structured a hierarchy consisting of a goal and subordinate attributes of the problem. Other important components of this methodology were a pairwise comparison used between various parameters to quantify value judgments (selection criteria would be ranked with respect to their importance in the hierarchy), and matrix multiplication used to convert level specific criteria into a larger decision priority.

Site selection and characteristics

To specify the selection criteria based on a real existing urban environment, the city of Tehran, with foothills in the north and desert in the south, was chosen for this research. The moist west wind alleviates the drought of the southern desert weather in the northern areas of the city. However, this wind loses its momentum when reaching the desert in the south and east. A temperate breeze from the mountains cools the northern parts of the city during the night while the southern desert suffers from dusty wind. Also, the center of the city is influenced by the desert climate more than the mountains. Apart from the significant climatic and altitudinal differences between the south and the north of the city, Tehran's location also impacts on social segregation as the wealthy traditionally tend to live in the north (Table 1). Previous research on plant ecology in Tehran revealed that plant distribution patterns were highly influenced by the climate of Tehran. Consequently,

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