A THESIS FOR THE MASTER DEGREE OF FOREST SCIENCE

A choice-based conjoint analysis of public preferences on urban tree attributes in Shanghai, China

선택형 컨조인트분석을 통한 도시림 속성에 대한 도시민의 선호체계연구: 중국 상하이를 대상으로

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by

Piao Meiyan

Department of Forest Science

Seoul National University

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지도 교수 윤 여 창

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박미연 (PIAO MEIYAN)

박미연 의 농학석사학위 논문으로 인준함

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위 원 장	김 홍 석	(인)
부위원장	윤 여 창	(인)
위 원	김 현 석	(인)

Abstract

Urban parks play a vital role in urban ecosystems by providing a wide range of ecosystem services and amenities. Trees, as a critical element of park design, contribute to the function of urban parks, especially in the aesthetic and ecological functions. With the acceleration progress of urbanization and urban environmental problems, selection of trees is important for making the urban ecosystem healthy and for residents' needs to be met. Urban greening is one of policies which has been emphasized for realization of ecological civilization in China.

This research applied choice-based conjoint analysis to investigate public preferences on different attributes of urban tree species in Shanghai. In addition, the study tries to find out if there is any preference heterogeneity in tree attributes by the social-economic characteristics of Shanghai citizens. A pretest was conducted to select important attributes of trees in advance. The six attributes, namely shape of canopy, seasonal change of leaf, carbon sequestration, cooling and humidity, reducing dust and capacity to enhance biodiversity were selected.

A survey was conducted in Shanghai city in China with a total valid sample size of 421. The result shows that, among the 6 attributes selected, shape of canopy, seasonal dynamics of leaf, carbon sequestration and dust absorption capacity are found to be more influential in the public's welfare. Canopy round shape rather than oval or weeping canopy is more preferred by the Shanghai public. Meanwhile, residents in Shanghai are more concerned about carbon fixation and dust absorption function of trees in urban parks. This is probably because the global warming issue becomes more awared and air pollution becomes more serious in recent years in China. This result is considered to reflect the fact that air quality problem has become a great concern to the public in urban areas in China. Therefore, the author suggests that in designing of urban parks, trees should be selected so as to enhance the public environment for the health and global environment. This study also revealed the differences in preference of the citizens' social-economic characteristics. Old people more favor the cooling and humidification function of urban trees, while less favor carbon sequestration function.

Keywords: choice-based conjoint analysis, urban parks, landscape design, Shanghai, citizen preference, tree attributes

Student Number: 2012-23993

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Chapter 1

Introduction

There is 50% of the world population inhabit in urban cities in 21th century, and the world urban population is expected to increase by 72% by 2050 (United Nations, 2012). While in case of main land China, according to the National Bureau of Statistics, the number of urban residents exceeds the rural population for the first time by the end of 2011, and this trend is expected to extend in the following decades. Despite of so many conveniences that urbanization brings to us, a series of social and environmental problems were exposed increasingly, for instance, air pollution, waste, noise, heat island effect, losing biodiversity, too much mental stress, so on and so forth. Urban green space, as the green infrastructure of city and the critical part of city ecosystem, plays a vital role in mitigating the environmental problems as well as maintaining residents' physical and mental health. As the concern of climate change becomes global, the urban greening is considered to play an important role in mitigating global warming recent years (Gill, 2007).

Urban green space is one type of land use in cities, which is used for improving urban health, protecting environment, and providing recreational services. Under the policy program of the government of urban greening, Chinese cities showed steady increase of urban green coverage from 17.0% in 1989 to 37.3% in 2009 (Zhao et al, 2013).

Urban green space in China is categorized into 5 parts according to Standard for classification of urban green space (2002) ---- urban park green space, production green space, protection green space, attached green space and other green space.

Table 1 Categories of urban green space

Category	Content
Urban park green space	The urban green space which is open to public, and take recreation as the main function, as the meanwhile provide with various functions, such as ecological, landscaping, disaster prevention
Production green space	Nursery space, which provide with seedlings, flowers and grass, seeds, for instance, nursery and parterres.
Protection green space	The space in cities that has hygiene, isolation, and security functions. Including health quarantine zone , road protection green space, urban high-voltage corridor green belt, windbreak belt, buffer zone, etc.
Attached green space	The attached green space of various urban construction land outside the green space land, including residential land, public facility land, industrial sites, warehouse space, transportation land, roads and squares land, municipal facility land and green space of special sites.
Other green space	The green space that have a direct impact on the environmental quality of urban ecology, residents leisure life, urban landscape and biodiversity conservation, including scenic spots, water source protection areas, country parks, forest parks, nature reserves, scenic woodland, urban greenbelt, wildlife zoo, wetlands and recovery green land from landfill, etc.

Source: Ministry of Construction of the People’s Republic of China, 2002

Urban parks, as an important component of urban green space, act as a crucial bond between human and nature and play an essential role in maintaining ecological balance. Vegetation is an important element in urban green space in China (Ministry of Construction of the People's Republic of China, 2007). Trees, as the main body of vegetation, epitomize the aesthetic and ecological benefits of urban parks. Nevertheless, there are some problems in application of landscape tree selections in parks. Bo (2006) criticized that landscape tree species are randomly selected resulting in poor overall functions. Also, recent selection of landscape tree species seldom takes ecological and healthcare functions into consideration, which leads to landscape functions not fully exhibited. He suggested other than ornamental and tolerant function, ecological health should be considered during green infrastructure design. Also, Wang (2006)' s research indicated that in practical application of plant planting for landscape architecture in China, the urban renewal and aesthetic functions is commonly more valued rather than ecological functions, like micro climate mitigation, soil retention and absorption of noise and air pollutants (Fu, 2000). Some scholars advocate that plant configuration should be from human-oriented principle, and suggest vegetation design of specific urban green space (according to different categories of urban green space) should be based on people's requirements (Che, 2004; Wang, 2006).

On the other hand, as regarding to enhancing public welfare on parks, many of the previous researches focus on public preferences on certain recreational attributes -

infrastructures, accessibility, trails and so on. Alves et al (2008) applied choice-based conjoint analysis to examine the environmental attributes relevant to older people's preferences for neighborhood open spaces in UK, in which desity of tree/plants was one of the attributes. A discrete choice experiment was conducted to investigate the preferences of urban dwellers for various attributes of urban forests in South Korea by Koo et al (2013). The main focus of their research was the biodiversity represented by tree species. Similarly, Ponje (2005) studied 22 infrastructure relevant attributes of parks. Nordh et al (2011) assessed the relative importance of specific components in Scandinavian pocket parks using conjoint methodology. In their study trees, bushes, grass cover and flowers were selected as the attributes of park.

In spite of the essential roles that plants play, there are not enough research performed to detect public preferences on the attributes of tree from citizen's perspective. Therefore, this study aims to investigate public preferences of urban trees in terms of diverse attributes, as well as to find out if there is difference in public preference on tree features within demographic characteristics. Based on the results of public preference on tree attributes, suggestions on vegetation selection are expected to give for designers of park green space.

Chapter 2

Methodology

Conjoint analysis (CA) is a technique to elicit consumers' preferences in an indirect way (Louviere, 1988; Ebling et al, 2010). The word "Conjoint" has a meaning of "joint together" in English language, which represents to "consider jointly". CA is based on two assumptions: (1) Consumer choice behavior is governed by maximization of utility; (2) A product or service can be viewed as a bundle of attributes from which consumers gain utility (Carson et al, 1994).

The key feature of CA is that respondents evaluate product profiles composed of multiple conjoint elements or attributes (or features) (Orme, 2010). In other words, a product or service can be described according to several attributes with different levels. By rearranging levels of different attributes, a product or service profile forms. Respondents evaluate or compare products or services with respects to the profiles. Then a quantitative statistical technics helps to elicit respondents' preferences over diverse attributes and to estimate the degree of preference the respondent has on each attribute assigned to the product or situation (Alriksson and Öberg, 2008). The key advantage of conjoint analysis is that it allows respondents to evaluate a product or service conjointly, which is more close to the actual decision-making situation.

CA was initially applied in commercial psychology and marketing field in 1960s and developed rapidly in the following decades. To date, CA has been widely applied in marketing, health care, environmental evaluation, and transportation fields among others.

CA is categorized into at least three different groups: choice modeling, hierarchical conjoint analysis and hybrid conjoint analysis. Alriksson and Öberg (2008) grouped choice-based methods such as ‘choice experiments’, ‘contingent rating’, ‘contingent ranking’ and ‘paired comparison’ as choice modeling. They positioned CA as a research method for revealing preference by statement of respondents.

Choice-based conjoint analysis (or experimental choice analysis, choice modeling) is an application of discrete choice modeling to understand consumer decision-making (Bakken and Frazier, 2006). Instead of ranking or scoring the profiles, choice-based conjoint analysis (CBC) is relatively easy to be implemented because respondents only have to choose one profile within alternatives that attracts them most.

In the following equation (Louviere et al, 2010), U_{in} stands for the utility for individual n choosing i attribute. V_{in} refers to the behavior observed representing the level of utility indirectly, while ε_{in} is the random error, which is unexplainable (unobservable or unobserved attributes):

$$\mathbf{U_{in} = V_{in} + \varepsilon_{in}} \qquad \text{(Eq.1)}$$

V_{in} is a function of attributes of the good/service and characteristics of an individual, often modeled as shown in Eq.2:

$$\mathbf{V_{in} = \sum X_{in}\beta + Z_n\gamma} \qquad \text{(Eq.2)}$$

X_{in} representatives the attributes vector, and Z_n stands for a vector of characteristics of individual n. β and γ are the coefficients to be estimated. If and only if attribute i can improve the utility of individual n, the attribute i would be preferred, which is shown in the following equation:

$$\mathbf{(V_{in} + \varepsilon_{in}) > (V_{jn} + \varepsilon_{jn})\ \forall j \neq i} \qquad \text{(Eq.3)}$$

Rearranging Eq. 3:

$$\mathbf{(V_{in} - V_{jn}) > (\varepsilon_{jn} - \varepsilon_{in})\ \forall j \neq i} \qquad \text{(Eq.4)}$$

Since we do not know if $(V_{in} - V_{jn}) > (\varepsilon_{jn} - \varepsilon_{in})$, choice outcomes can only be determined up to the analysis of the probability of choosing one alternative over another. $(\varepsilon_{jn} - \varepsilon_{in})$ is assumed to follow a certain distribution, and the distribution of $(V_{in} - V_{jn})$ depends on different design of choice set. The probability to choose the set of attributes is defined as:

$$\mathbf{Prob\ (\ i \mid C) = Prob\ \{\ V_{in} + \varepsilon_{in} > V_{jn} + \varepsilon_{jn}\ ,\ all\ j\ \in\ C\ \}} \qquad \text{(Eq.5)}$$

Where C is the complete choice set. Three models estimation methods are applied to analyze CBC data, namely, linear probability model (LPM), logistic model as well as probit model. Which model to use depends on the data structure.

Implementing CBC has four key procedures, including selecting of attributes and their levels, forming choice sets, data collection and model estimation, which are explained in the next section.

Chapter 3

Experiment design

3.1 Selection of attributes and their levels

3.1.1 Selection of attributes

The issue of attributes identification is relatively controversial, and there is no widely accepted standard way to select attributes. Basically, attributes that are demand-relevant, policy-relevant and measurable should be used (Blamey et al, 2002). Generally, four attribute selection methods are commonly used: residents-based/focus-group-based, experts-based, literature-based and hybrid method.

Louviere (1988) suggested direct questions could be used by asking people which attributes drive their preferences, which is similar with residents-based method. Mackenzie (1990), Molin et al (2001) and Tano et al (2003) used this approach or focus group based approach in their researches. In this study resident-based approach was applied. A pretest was conducted to find the most considerable attributes by dwellers in Shanghai city, China.

By reviewing literatures, 15 attributes (Table 2) that are considered to related to tree functions in urban parks were selected.

Table 2 The functions of urban trees

Category	Specific function
Aesthetic function	Shape of canopy
	Seasonal dynamics of leaf (ex: maple's leaf turns red in autumn)
	The color of flower
	The color of fruit
Ecological function	Carbon sequestration (mitigating global warming)
	Reduction of dust
	Cooling and humidity control (adjust micro climate)
	Absorbing noxious emission, such as SO_2, NO_2
	Wind block
	Water and soil conservation
	Reduction of noise
	Increasing urban biodiversity by providing habitats to insects and animals
Economic function	Edibility
	Medicinal use
	Industrial use

The number of attributes matter a lot in implementing CBC. According to Cattin and Wittink (1982) and Green and Srinivasan (1990), the number of attributes in surveys usually varies from 3 to 15, but in most surveys 6 to 7 attributes were used.

An on-line pretest with a total sample of 38 was conducted in order to decide the most influential attributes to the public. Respondents were asked to select 6 out of

15 attributes of trees, which are considered to be most important in urban parks. Six attributes selected are ‘shape of canopy’, ‘seasonal dynamics of leaf’, ‘carbon sequestration’, ‘reduction of dust’, ‘cooling and humidification’ and ‘increasing biodiversity’.

3.1.2 Setting the level of attributes

The level of attributes of urban trees was set based on the literature.

1) Canopy shape: There are 75 species frequently used as landscaping trees in Shanghai (Huang, 2006). The most common shapes of trees are selected ‘round’, ‘oval’, ‘pyramidal’ and ‘weeping’.

2) Seasonal dynamics of leaf: We followed the classification of Zhu (2002) and Shou (1997) who used the change of plants’ color as the criteria . We classified trees into 2 groups according to whether there is seasonal change of leaf in color.

3) Carbon sequestration: We applied the carbon sequestration study result of Wang et al (2007). The level of carbon sequestration of trees is grouped into two, divided by the threshold of 8 g per m^2 of leaf area per day.

4) Cooling and humidity: We applied the result of Mo et al. (2007), in which 138 ornamental plants in Shanghai were measured and calculated with regarding to the temperature decreasing and the humidification. High and low levels of cooling and humidification were set by the standard of Mo

Jianbin et al.'s. The thresholds of cooling effect is 0.15 ℃ decrease of temperature. In case of humidification, the threshold is 810 g per m^2 per day of released water in a leaf unit.

5) Reducing dust: We applied the result of research project named "Scientific grade of dust-retaining ability within 84 plants in Shanghai" conducted by Shanghai Botanical Garden in 2013 which are available from their website. The high and low groups were divided at the level of 0.25 g of dust obsorbed by 1 m^2 of leaf.

6) Increasing biodiversity: Attracting birds by providing food is an important and common way of enhancing urban biodiversity. We grouped the trees into two groups – one providing food for birds and the other not providing food for birds.

Therefore, the final attributes and levels selected are listed in Table 3.

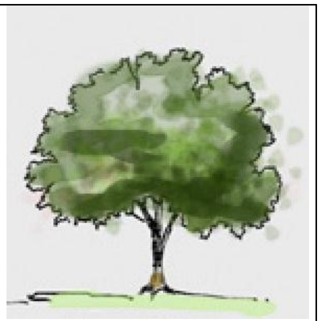
Table 3 Attribute table

Attributes	Attributes Description	Levels				Level Description
Shape of canopy	Shape of canopy	Round	Oval	Pyramidal	Weeping	
Seasonal dynamic of leaf	If their leaves have seasonal color change for a constant period, such as fall color trees	No		Yes		
Carbon sequestration	Carbon sequestration amount of a leaf area unit in a day	Low		High		Low: < 8 g/m^2 High > 8 g/m^2
Cooling & humidification	Amount of released water in a leaf unit & decreased temperature	Low		High		Low: < 810$g/(m^2d)$ & < 0.15℃, High: > 810$g/(m^2d)$ & > 0.15℃
Reducing dust	Amount of reducing dust a leaf area unit in a day	Low		High		Low: < 0.25 g/m^2, High: > 0.25 g/m^2
Biodiversity	If can attract birds, or if can provide food to birds	No		Yes		

3.2 Forming choice sets

The choice sets formation is the combination of the attributes levels used to construct the alternatives included in the choice sets (Mengoni, 2010-2011). In general, there are two types of experiment design ---- full factorial design and fractional factorial design. The former refers to including all possible combinations of all levels of the attributes. On the other hand, fractional factorial design is more like a sample from full factorial design. If a full factorial experiment was adopted, then 4^1*2^5=128 conjoint tasks would be required. To reduce the number of tasks that respondents have to answer, a fractional factorial design was created by the 'Support. CEs' package in R[1] project. The experiment design has 4 blocks and each block has 4 questions with 2 alternatives. Table 4 shows the example of the CBC questions. (See Appendix 1 for Specific design.)

Table 4 Example of CBC question

Shape of canopy	 Pyramidal	 Round
Seasonal color change of leaf	No	Yes
Carbon sequestration	Low	Low
Cooling & humidification	High	High
Reducing dust	High	Low
If can attract birds	Yes	Yes
Options	1	2

[1] R is a program for statistical computing and graphics, which can be download for free on its website. (www.r-project.org)

3.3 Data collection

3.3.1 Research site

Shanghai sits on eastern coast of China (E121° 26’, N31° 12’), is one of the four direct-controlled municipalities. With an approximate population of 23 million, Shanghai covers a total area of approximately 6340.5 km^2. Shanghai has 18 districts and 1 county. This research covered all of the districts and counties of Shanghai.

Shanghai belongs to north subtropical monsoon climate, with moderate and moist sufficient sunshine and abundant rainfall. Shanghai has four seasons, and the annual average temperature is 16.5 ℃. Since 1950s, the annual mean air temperature has been ascending slowly (Cao, 2008). Figure 2 shows the ascending trend of average annual temperature of Shanghai in recent years. Sunshine time is approximately 1800 hours every year and relative humidity is 77% - 83% (Ge, 1999). Shanghai has plentiful rainfall with an annual average rainfall of 1000 mm.

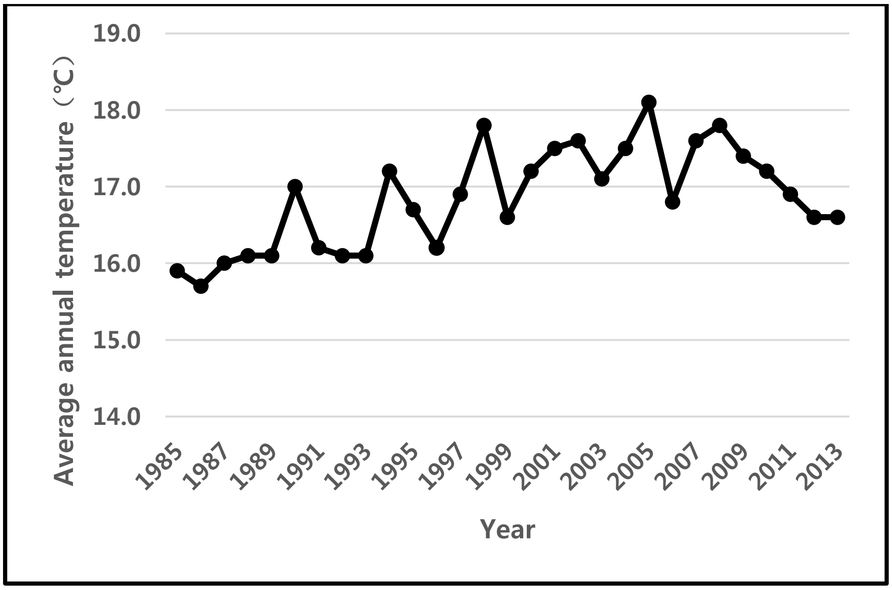


Figure 1 Trend of annual temperature in Shanghai

Source of data: Shanghai Bureau of Statistics

Compared to municipalities in other countries, the development of urban green space in Shanghai is late. Before 1949, there was only some small private garden and foreign concession with green space, and urban green land area was only 0.13 m^2 per capita. After the establishment of the state in 1949, urban green space was rapidly developed. Data from Shanghai Bureau of Statistics (2013) shows that there was dramatic increase of urban green space area from 1990 to 2010 (Figure 2). Despite the great progress has been made during the past decades, the green construction in Shanghai was criticized that tree species have been used are monotonous (Shi, 2010), the seasonal change of plants' color is not obvious, and configuration of plant diversity was not enough (Yang, 2000). This is one reason why we selected Shanghai as the research site. Also, most of Shanghai citizens have relatively high education level so that it is easy for them to understand the research questions.

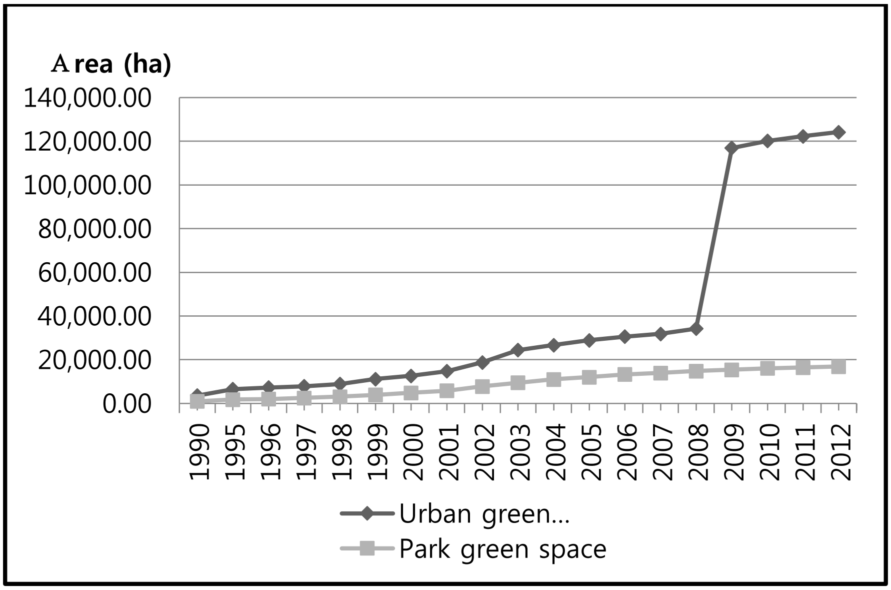


Figure 2 Trend of urban green space in Shanghai

3.3.2 Data collection

Well-designed questionnaire tends to reveal target populations' preference without significant biases. A pilot survey was carried out in order to improve the questionnaire. Once questionnaire is developed, the sampling issues should be considered. Sampling issues contain sampling strategy and sample size determination.

Difference types of collection approaches can be used:

- Face-to-face interview (Molin et al, 2001)
- Mail survey (Mackenzie, 1990)
- Telephone survey (Hurlimann and McKay, 2007)
- Web-based survey (Cheung and Chung, 2008)

Sample size often constrained by research budget, however, it should be sufficient for reliable estimation of model. At least 300 respondents are recommended for robust quantitative research where one does not intend to compare subgroups (Orme, 2010).

A questionnaire was developed in order to collect the data required to estimated the preference over the attributes of urban trees withheld by citizens of Shanghai. The questions contained in the questionnaire include:

1) The frequency of visiting urban parks in a month.

2) The main objective of visitng urban parks.

3) The knowledge of urban trees in mitigating urban environmental problems.

4) The importance degree of tree species selection in urban parks.

5) The satisfaction of curcent tree species in urban parks.

5) Personal demographic characteristics questions

An online survey was administrated in March and April of 2014, and the time span was 2 weeks. The data collection was implemented by a Chinese investigation agency. A total of 1225 individuals were invited to the survey, and 421 of respondents participated and fulfilled the whole task. Each on-line survey took around 8 minutes to complete. The sample was selected by stratified sampling method so as to represent the Shanghai population, in terms of income, gender, location and age.

Chapter 4

Results and Discussion

4.1 Sample characteristics

A total sample of 1225 respondents was investigated. By excluding those who did not finish the survey or who dwell in Shanghai less than a year, a total of 421 samples were qualified for the research (response rate=34.37%). In addition to answers to the CBC questions and personal data on demographics, their attitudes to word tree species were collected. Each respondent was asked to answer 4 CBC questions with 2 alternatives for each question. Table 5 listed the profile of the participants with a reference of census data. By comparing the census data in 2010, the sample represents the population very well. 50.36% of the respondents have visited urban parks for recreation (Figure 3). A total of 84.56% respondents visited urban parks not very frequently, less than 11 times in a month (Figure 4). Table 5 listed the profile of the participants with a reference of census data.

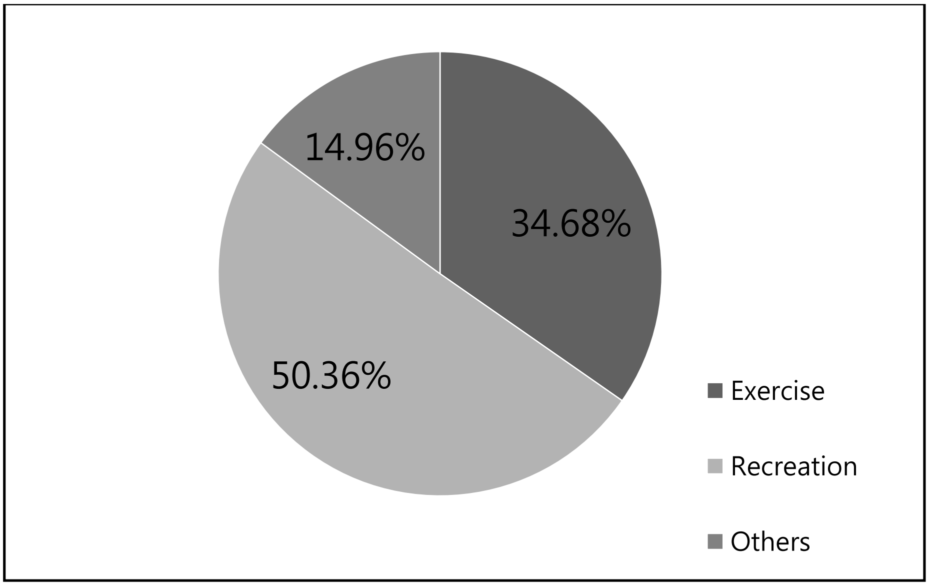


Figure 3 Objectives of visiting parks

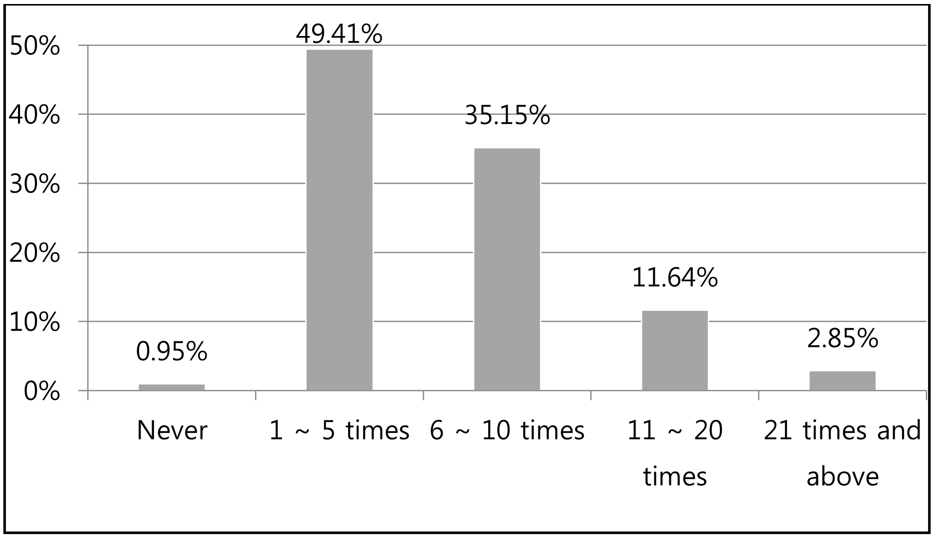


Figure 4 Frequency of visiting parks per month

Table 5 Sample characteristics

Socio-economic variables	Census[1] (%)	Sample (%)
Age		
19 ~ 29	29.52	29.93
30 ~ 39	23.03	23.28
40 ~ 49	20.92	21.85
50 ~ 59	20.05	18.76
60 ~ 65	6.47	6.18
Gender		
Male	52.03	52.02
Female	47.97	47.98
Marriage		
Single		29.45
Married		70.55
Education		
University degree or higher		68.65
Otherwise		31.35
Income		
Up to 9999		26.12
10000 ~ 19999		21.38
20000 ~ 29999		19.24
30000 and above		33.26
Objectives for visiting		
Exercise		34.68
Recreation		50.36
Others		14.96
Frequency of visiting in a month		
Never		0.95
1 ~ 5 times		49.41
6 ~ 10 times		35.15
11 ~ 20 times		11.64
21 times and above		2.85

1. National Bureau of Statistics of China [2010]

However, more than 3 out of 4 respondents (77.43%) thought tree selection in urban parks was extremely (very) important or relatively important in mitigating urban environmental problems (Figure 5).

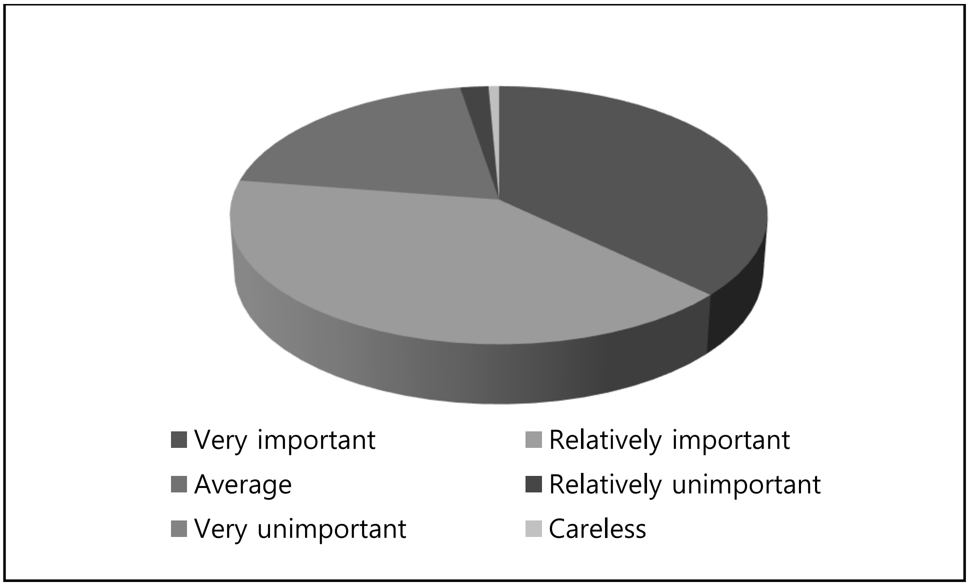


Figure 5 Importance of tree species selection

4.2 Model estimation

In order to elicit public preference on urban tree attributes, linear probability model was used to analyze the data. V_{in} is the observable factors that influence the decision-maker's choice.

$$\mathbf{Y = \beta_0 + \sum \beta_i X_{ij} + u_i} \qquad \text{(Eq. 6)}$$

where,

Y=response (1=being selected, 0= not being selected)

i= attribute i

j=level j

X= the value of attributes

u_i = error term

There are 6 attributes that might be influential in people's decision making process in this study. Those are Shape (round, oval, pyramidal, weeping), Seasonal dynamics of leaf (leaf), Carbon sequestration (carbon), Cooling and Humidification (CH), Dust reduction (dust), and enhancing biodiversity (biodiversity).

Therefore, the basic model is as followings:

$$\mathbf{Y_i=\beta_0+\beta_{oval}X_{oval}+\beta_{pyramidal}X_{pyramidal}+\beta_{weeping}X_{weeping}+\beta_{leaf}X_{leaf}+\beta_{carbon}X_{carbon}+\beta_{CH}X_{CH}+\beta_{dust}X_{dust}+\beta_{biodiversity}X_{biodiversity}+u_i} \quad \text{(Eq. 7)}$$

Ordinary least squares (OLS) method was used to estimate the model. To make sure the validity of OLS, variance inflation factors (VIF) test and autocorrelation test were made.

VIF test can quantify the severity of multicollinearity in OLS analysis. The mean value of VIF is 1.21 so that there is no severe multicollinearity exists. As regarding to heteroskedasticity, LPM has a pitfall that heteroskedasticity always exists. Weighted least squares (WLS) was conducted to release this problem, but R-squared value had little improvement compared to the OLS results. In terms of autocorrelation, the Durbin-Watson statistic (DW= 3.0874) shows relative high first order autocorrelation exists so that lag term of residual (AR(1)) was introduced to the model on the intention of releasing autocorrelation problem.

Table 6 Results of OLS with heteroskedasticity-consistent standard error

Variable	Coefficient	Std. Error		t-Statistic		Prob.	
		OLS	HC	OLS	HC	OLS	HC
C	0.4712	0.0487	0.0461	9.6686	10.2278	0.0000***	0.0000***
Oval	-0.0678	0.0191	0.0193	-3.5477	-3.5036	0.0004***	0.0005***
Pyramidal	-0.0119	0.0190	0.0183	-0.6281	-0.6513	0.5300	0.5149
Weeping	-0.0397	0.0186	0.0163	-2.1316	-2.4286	0.0331*	0.0152*
Sdl	-0.1087	0.0431	0.0408	-2.5220	-2.6608	0.0117*	0.0078**
Carbon	0.1769	0.0388	0.0395	4.5643	4.4779	0.0000***	0.0000***
C&H	-0.0099	0.0120	0.0119	-0.8286	-0.8356	0.4074	0.4034
Dust	0.0316	0.0130	0.0141	2.4381	2.2470	0.0148*	0.0247*
Biodiversity	-0.0130	0.0121	0.0109	-1.0750	-1.1895	0.2824	0.2343
Age	0.0006	0.0009	0.0009	0.6421	0.6709	0.5208	0.5023
Gender	0.0029	0.0097	0.0096	0.2947	0.2998	0.7682	0.7643
Income	-0.0007	0.0023	0.0023	-0.3144	-0.3166	0.7532	0.7516
Edu	0.0022	0.0078	0.0076	0.2793	0.2864	0.7800	0.7746
Age*C&H	0.0029	0.0011	0.0010	2.6531	2.8964	0.0080**	0.0038**
Age*Carbo	-0.0034	0.0010	0.0010	-3.4892	-3.3956	0.0005***	0.0007***
AR(1)	-0.5484	0.0145	0.0145	-37.8518	-37.8811	0.0000***	0.0000***
R-squared		0.3104		Mean dependent var		0.4999	
Adjusted R-squared		0.3073		S.D. dependent var		0.5001	
S.E. of regression		0.4162		Akaike info criterion		1.0894	
Sum squared resid		580.4415		Schwarz criterion		1.1185	
Log likelihood		-1817.9930		Hannan-Quinn criter.		1.0998	
F-statistic		100.5723		Durbin-Watson stat		2.3296	
Prob(F-statistic)		0.0000***					
Inverted AR Roots		0.5500					

Signif. Codes: ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05

To further test the influence of heteroskedasticity, heteroskedasticity-consistent standard error (HC) was estimated. By comparing the results from OLS and HC, it can be found that there is no big differences so that it did not influence the significance of variables. Therefore, heteroskedasticity issue has been ignored in the model.

Table 6 shows the result of final model. The overall model is significant at 1% level. In discrete choice data, r squared value is relative low due to the data itself, and in empirical studies, r squares lies in 0.2 to 0.6. Therefore, in this research, the explanatory power is relatively good. DW test was down to 2.33 which shows no sever residual autocorrelation exists.

4.3 Results of linear probability model

4.3.1 Public preferences on diverse attributes of tree species

The results for this model are shown in the final column of Table 5. Intercept and five attributes are significant at 5% level or better. This implies some differences exist in preference for these attributes. Intercept value ($c=0.4712$, $p<0.001$) stands for the probability of reference profile (round canopy with no seasonal dynamics of leaf, low carbon fixation function, low cooling & humidification effect, low dust control capability and provision of food for birds) to be selected. The negative sign of coefficient of oval ($coef.=-0.0678$, $p<0.001$) represents that round canopy is obviously more preferable compared to oval canopy. The coefficient of oval means that when fixing other variables, oval canopy can decrease 6.78% of probability to be selected. Similarly, comparing to weeping canopy (coef.=-0.0397, $p<0.05$), citizens in Shanghai tends to be more in favor of round canopy. There is no evidence show any difference between round canopy and pyramidal canopy.

Interestingly, no seasonal dynamics of leaf is more favorable at .05 significant level. Shanghai is subtropical climate, at the meanwhile many of the frequently used species are evergreen tree. In the past, the application of trees with seasonal dynamics of leaf was relatively rare. These reasons may give the citizens the impression that green is more close to the nature than other colors. High degree of urbanization make people more willing to get close to the nature than before. However, in recent years, Shanghai introduced more than 100 tree species with colorful leaves, which is contradicted with public preferences. Decision-makings on introducing new tree species probably should reconsidered by balancing city renewal and public welfare.

Citizens in Shanghai are strongly in favor of high carbon sequestration function (coef.=0.1769, $p<0.001$), which indicates people concern about global warming issue. This is related to the high education level of the residents and the publicity of low carbon concept by the government recent years. Similarly, the coefficient of reducing dust is positive (coef.=0.0316, $p<0.05$) so that Shanghai citizens are in favor of dust removal function of trees. This is mainly due to the sharp decline of air quality recent years in Chinese urban cities, especially municipalities like Shanghai. Cooling & humidification and enhancing biodiversity are not statistically significant, which indicates no preference differences on those attributes are detected.

4.3.2 Preference heterogeneity by social-economic characteristics

The model excluded all insignificant interactions except kinds of interactions between tree attributes, which are statistically significant interactions were found.

Age and cooling & humidification function of tree have a positive interaction effect (coef.=0.0029, $p<0.01$), which means that old people tends to more prefer cooling & humidification function than younger people. Oppositely, age and carbon sequestration have a negative interaction effect (coef.=-0.0034, $p<0.001$), meaning that old people have less probability to choose high carbon sequestration function. That is, old people tend to have more concerns on micro climate rather than global climate. This is because old people have less awareness of global environmental problems than young people, while they are better in the practice of saving energy. Furthermore, they are more vulnerable to high temperature. On the other hand, young people have better tolerance on hot weather so that they show careless on cooling and humidification function. However, they tend to be easily educated or influenced by the publicity of low carbon concept.

4.4 Limitations

We only selected 6 attributes to avoid exposing overwhelming information to the respondents, which becomes a potential pitfall of this study. So we could not find more attributes that may influence people's decision-making on tree selection.

Although we well defined the levels between attributes, it is possible that respondents did not fully understand the difference between levels, which leads to insignificant results of attributes (such as seasonal dynamics of leaf, carbon sequestration, cooling and humidification, biodiversity). By online survey we could not explain the research questions in details to respondents.

Chapter 5

Conclusion

This study tried to answer what attributes of trees are important for urban park design, by conducting a choice modeling study in Shanghai. People's preference regarding to different tree functional attributes was revealed by this research. There are two main findings of this work. That is:

Within the 6 attributes we selected, people attach more attentions to canopy shape, seasonal dynamics of leaf, carbon sequestration and dust removal ability. Round canopy rather than oval and weeping canopy is more preferable by the Shanghai public. Meanwhile, residents in Shanghai concerns about carbon sequestration and dust control function of trees in urban parks, which is probably because the abnormal weather and the air pollution becomes more and more serious recent years in China. In addition, people in Shanghai do not appreciate trees with seasonal dynamics of leaf.

Two preferences heterogeneity with different demographic characteristics have been discovered. That is, age has a positive correlation with cooling and humidification function and negative correlation with carbon sequestration of trees.

Suggestions can be made based on the results. In order to maximize public welfare, during the decision making of tree selection in Shanghai, trees with high dust control and high carbon fixation capacity should be given a high priority consideration. In case of the aesthetic aspect, round canopy can be more desirable than other shape. Additionally, tree selection should take the preference heterogeneity into the consideration. These findings can help those who are involved in the design and management of urban parks to carry out interventions in order to maximize public welfare. Even though, there are already many researches in other countries which applied choice-based conjoint analysis to detect public preference on park design and management, there are not many studies which addressed the aspects of landscape design. More in-depth studies on attributes of urban tree species are needed for decision-making on tree selection.

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Appendix 1 Experiment design

Block	QES	Alternative 1						Alternative 2					
Attribute		shape	leaf	carbon	cooling	dust	biodiversity	shape	leaf	carbon	cooling	dust	biodiversity
1	1	pyramidal	no	low	high	high	yes	round	yes	low	high	low	yes
1	2	weeping	no	low	high	low	no	weeping	no	low	low	low	yes
1	3	weeping	yes	high	high	low	yes	weeping	no	high	high	high	yes
1	4	pyramidal	no	high	low	low	yes	pyramidal	no	high	high	low	yes
2	1	round	no	low	high	high	no	round	no	high	high	low	no
2	2	oval	yes	high	high	low	no	weeping	yes	high	low	low	no
2	3	round	no	high	low	low	no	oval	no	low	low	low	no
2	4	round	yes	high	high	high	yes	oval	yes	low	high	high	yes
3	1	weeping	yes	low	low	high	yes	weeping	yes	low	high	high	no
3	2	oval	yes	low	low	high	no	round	no	low	low	high	no
3	3	weeping	no	high	low	high	no	round	yes	high	low	high	yes
3	4	pyramidal	yes	high	high	high	no	pyramidal	yes	low	high	low	no
4	1	oval	no	low	high	low	yes	pyramidal	yes	high	low	high	no
4	2	round	yes	low	low	low	yes	pyramidal	no	low	low	high	yes
4	3	pyramidal	yes	low	low	low	no	oval	no	high	high	high	no
4	4	oval	no	high	low	high	yes	oval	yes	high	low	low	yes

Appendix 2: Questionnaire

上海市民对园林树种的偏好调查

您好!

我是韩国首尔大学山林科学系的研究生。这是一份毕业论文的调查问卷，目的在于研究上海市民对园林树种的偏好，旨在为园林树种的选择提供理论依据，从而提高上海市民对园林树种的满意度。由于调查的结果将直接影响到本次论文的结论和质量，因此，恳请您认真填写。谢谢您的支持与协助。本次调查不会泄露您的任何个人信息，所得数据，只做数据研究分析。

多谢您的配合，祝愿您身体健康，一切顺利！

▣ 地 区: 1. 宝山区 2. 长宁区 3. 奉贤区 4. 虹口区 5. 黄浦区 6. 嘉定区 7. 金山区 8. 静安区 9. 卢湾区 10. 闵行区 11. 南汇区 12. 浦东新区 13. 普陀区 14. 青浦区 15. 松江区 16. 徐汇区 17. 杨浦区 18. 闸北区 19. 崇明县

1. 您的年龄是：

   满 __________ 岁 —→ 小于19岁调查终止

2. 您的性别：

   1） 男

   2） 女

3. 在上海的居住时间有多久？

满 ________ 年 → 少于1年调查终止

在调查开始之前，请阅读下面有关城市园林的说明。

公园绿地是供公众游览，观赏，休憩，开展科学文化及锻炼身体等活动，有较完善的设施和良好的绿化环境的公园绿地。公园类型包括：综合性公园，居住区公园，居住小区游园，带状公园，街旁游园和各种专类公园等。（中华人民共和国行业标准公园设计规范）
公园绿地不但为市民提供休憩、体验自然的场所，同时还有净化大气污染，阻滞灰尘，减少噪音，保持水土，为野生动物提供栖息地，吸入二氧化碳缓解气候变化等生态功能。

▶ 首先将对城市园林的认识和使用情况进行提问。

4. 在过去一年间，您平均每个月去多少次城市公园绿地？

1）0 次

2）1 ~ 5次

3）6 ~ 10次

4）11 ~ 20次

5）21 ~ 30次（每天）

5. 您去公园的主要原因是什么？请在下列选项中选出一项。

1）锻炼身体（散步等）

2）休憩（休息，体验自然）

3）教育

4）途经公园

5）其它（请填写：______________________________）

6. 一周中，您运动10分钟以上有多少天？

1）从来不运动

2）1天

3）2天

4）3天

5）4天

6）5天

7）6天

8）7天（每天）

7. 请列举几个您经常去的公园的名字：

____

8. 在此之前，除了公园的休憩功能外，您还知道多少公园对城市环境的其它益处？

1）非常了解

2）比较了解

3）一般了解

4）不太了解

5）完全不了解

9. 您认为公园绿地在缓解城市环境问题上有多重要？

1）非常重要

2）比较重要

3）一般重要

4）不太重要

5）完全不重要

10. 请选出园林树木在城市中您认为最重要的功能，请选5个选项：

1）美观功能：欣赏树的整体形状

2）美观功能：欣赏树叶随季节的色彩变化，例如有的树叶秋天变成红色

3） 美观功能：欣赏花的颜色

4）美观功能：欣赏果实的颜色

5）生态功能：树叶可吸收二氧化碳，缓解全球气候变暖

6）生态功能：树叶可阻滞灰尘

7）生态功能：降低局部温度，增加空气湿度

8）生态功能：吸收有毒气体，净化空气

9）生态功能：降低风速

10） 生态功能：保持水土，防止水土流失

11） 生态功能：减少噪音污染

12） 生态功能：为昆虫，动物，鸟类提供栖息地，增加城市的生物多样性

13） 经济功能：可食用性（树木果实可食用，如枇杷）

14） 经济功能：药用价值（树木可入药，如花，果，根可入药等）

15） 经济功能：工业价值（树木可作木材，可提取橡胶，可提取润滑油等等）

11. 您觉得公园绿地中树种的选择重要吗？

1）非常重要

2）比较重要

3）一般重要

4）不太重要

5）完全不重要

12. 您是否喜欢周边公园里的树种?

1）非常喜欢

2）比较喜欢

3）一般喜欢

4）不太喜欢

5）非常不喜欢

6）无所谓（不关心）

▶接下来您将被展示几组树木的资料，每组两张，请比较两个树木的属性与层级，选出您相对更喜欢的树木。

[问题 1~4] 卡片组合 ________展示] □ 调查人员记录部分

问题 1) 比较这两个树木, 您更喜欢哪一个?

1. 第一个 2. 第二个

问题 2) 比较这两个树木, 您更喜欢哪一个?

1. 第一个 2. 第二个

问题 3) 比较这两个树木, 您更喜欢哪一个?

1. 第一个 2. 第二个

问题 4) 比较这两个树木, 您更喜欢哪一个?

1. 第一个 2. 第二个

▶以下为有关应答者社会经济特性问题

13. 您目前的婚姻状态是：

1） 未婚

2） 已婚 （包括离婚，分居，丧偶）

14. 您有多少名未满19岁的孩子？

______________________名

15. 您目前所从事的职业是：

1）国家机关/政党机关和社会团体

2）科研及综合技术服务业

3）电力/煤气及水的生产和供应业

4）卫生/药品/保健业

5）教育/文化和广播电影电视业

6）交通运输仓储业

7）金融保险业

8）计算机IT业

9）房地产业

10） 汽车业

11） 通讯业

12） 制造业

13） 批发零售贸易业

14） 商务/咨询服务业

15） 旅游/餐饮/娱乐业

16） 学生

17） 家庭主妇

18） 其它

16. 您的学历是：

1）小学及以下

2）初中

3）高中

4）本科及以上

17. 您的家庭平均月收入是多少？包括年终奖和其它收入，请选择总的家庭月平均收入。

1）5000元以下

2）5000 – 9999元

3）10000 – 14999元

4）15000 – 19999元

5）20000 – 24999元

6）25000 – 29999元

7）30000 – 34999元

8）35000元及以上

국 문 초 록

선택형 컨조인트분석을 통한 도시림 속성에 대한 도시민의 선호체계연구: 중국 상하이를 대상으로

박미연 (PIAO MEIYAN)

산림과학부 산림환경학 (Forest Environment Major)

College of Agriculture and Life Science

Seoul National University

도시공원은 도시 생태계에서 다양한 생태계 서비스와 어메니티를 제공하는 등의 중요한 역할을 한다. 공원 설계에 중요한 요소인 수목은 도시공원의 심미적, 생태적 기능을 제공한다. 도시화의 가속화와 환경문제 측면에서 건강한 도시 생태계 형성과 도시민의 수요 충족을 위해서는 적절한 수종 선택이 중요하다. 중국에서는 생태문명 실현을 위한 정책의 일환으로 도시녹화를 강조해왔다.

이 연구는 선택형 컨조인트 분석법을 적용하여 상하이 지역의 도시림 속성에 대한 시민의 선호체계를 살펴보기 위해 수행되었다. 또한, 상하이 시민이 선호하는 도시림 특

성이 이들의 사회경제적 특성에 따라 상이한지를 밝히고자 한다. 사전조사를 통해 도시림의 주요 속성을 선정하였다. 본조사에는 수관 형태와 수엽의 계절적 변화, 탄소 흡수량, 냉각/가습 조절 효과, 먼지 흡수 능력, 생물다양성 증진 등 여섯 가지 속경이 적용되었다.

중국 상하이시에서 421개 표본을 대상으로 설문조사를 실시하였다. 조사 결과, 여섯 가지 속성 가운데 수관 형태와 수엽의 계절적 변화, 탄소 흡수량, 먼지 농도 감축 능력 등이 후생에 더 영향을 미치는 것으로 나타났다. 타원형이나 늘어진 형태의 수관보다 원형 수관이 선호 되었다. 또한 상하이 시민들은 도시 공원에서 수목의 기능 가운데 탄소 고정 기능과 먼지 흡수 기능을 더 중요하게 여기는 것으로 나타났다. 이는 최근 중국의 지구온난화에 대한 인식 증대와 대기오염 증가에서 기인하는 것으로 보인다. 이러한 결과는 대기질이 중국 내 도시민들 사이에서 중요한 문제가 되었음을 반영하는 것이다. 따라서, 도시 공원 설계 시 건강한 공공 환경과 지구 환경 개선을 위한 기준으로 선택되어야한다. 또한 이 연구는 사회경제적 특성에 따라 선호체계가 다름을 밝혀내었다. 나이가 많을 수록 도시림의 냉각/가습 조절 기능을 더 선호하는 반면, 이들의 탄소상쇄 기능 선호도는 비교적 낮은 것으로 나타났다.

주요어 : 선택형 컨조인트분석, 도시공원, 조경설계, 상하이, 시민의 선호, 수목 속성

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