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TREE SPECIES SELECTION GUIDELINES FROM THE PERSPECTIVE OF BIOCLIMATIC LANDSCAPE DESIGN

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Abstract

In landscape architecture, numerous researches carried out in different climatic regions around the world show that arborescent vegetation has the most significant role in the improvement of microclimate. The study is focused on the adaptation and integration of human bioclimatology and bioclimatic design principles in planting and landscape design in order to develop tree species selection methods. Thus, in order to identify the most valuable tree species, a number of criteria have been identified considering the impact of trees on the main factors influencing microclimate, such as heat, wind speed, air humidity, light, air ionization and air quality. The results consist of a comparative analysis of tree species from the temperate continental plain area. A ranking of the species was generated considering their potential favourable impact on the microclimate as well as the eco-climatic resilience of the trees. The bioclimatic values of the analysed species were attributed according to biological and ecological characteristics such as tree habitus, canopy density, longevity, carbon storage capacity, air ionization level, resistance to wind, drought and air pollution, etc. The tree species were assessed by researching specialized dendrological studies and through field observations. The conclusions reveal the most valuable bioclimatic trees species, which are classified according to the way they can be used in different types of green areas.

Key words*: tree species selection, bioclimatic landscape design, urban microclimate improvement.*

INTRODUCTION

A comparative analysis of arborescent vegetation was initiated in order to identify which tree species presents the highest potential for urban microclimate improvement in the case of four different types of green areas: A - shelterbelts, B - mobility areas, C - green areas adjacent to buildings and D - green cores (green areas over 1 ha). Classification of green areas was carried out in previous studies (Boc, 2017) depending on the differential impact of the vegetation on urban microclimatic variables.

In the present study, the analysed species are ranked according to the microclimatic impact and to the ecological and climatic resilience in the context of local conditions in Bucharest. The hierarchy of the species has been established taking into account specific criteria that vary in each type of green area such as habitus, sunlight requirements, compatibility with built environment or paved areas, emissions of volatile organic substances; but also by general criteria, valid for all types of urban green areas, such as leaf area index (LAI), carbon storage capacity, crown (canopy) density, pollutants bioaccumulation capacity, air ionization, wind resistance, resistance to urban air pollution and tolerance to drought conditions.

MATERIALS AND METHODS

The assessed vegetation consist of frequently encountered tree species in urban areas in the Bucharest-Ilfov metropolitan area were selected and a number of rarely encountered species, which are well adapted to the local climatic conditions. The evaluated tree species were divided into three major categories:

- Conifers trees (persistent foliage);
- Deciduous trees I-II height level;
- Deciduous trees III height level.

For each green area typology, the evaluation criteria were selected according to the indicators mentioned in the introduction. For each criterion, a score was attributed to the degree of bioclimatic value of the species. Thus, in the case of a low value, 1 point was

assigned, for an average value - 2 points, and for a high value - 3 points. Also, for each criterion, the limits of each score have been set. The values have been attributed by integrating research results of specialized studies, data provided by large tree nurseries in Europe and visual observations in the north of Bucharest (such as Chitila, Bucureştii Noi, Domenii, Băneasa, Herăstrău). The assessment methods and the source of the documentation are presented in the list of analysis criteria. Also, for each criterion, the classification and ranking of the assigned values are presented.

The general criteria for analysis are divided into criteria for the bioclimatic impact of tree species (Boc, 2017) and criteria for climatic and ecological resilience in the case of the temperate-continental urban microclimate, which is specific to Bucharest.

The criteria for bioclimatic impact assessment include:

1. The relative Leaf Area Index (LAI) - the species were ranked according to Asner et al. (2003) and to visual observations[1]:

- Low LAI (1 point) = LAI between 1 and 2;
- Average LAI (2 points) = LAI from 3 to 4;
- High LAI (3 points) = LAI between 5 and 6;

2. Canopy density (species ranked following visual observations and according to Iliescu, 2005, Van den Berk, 2017):

- Rare canopy (1 point) = Density below 40%;
- Average canopy (2 points) = Canopy density between 40 and 75%;
- Dense canopy (3 points) = Canopy density over 75%;

3. Longevity of the species (species ranked according to Iliescu, 2005; Iliescu, 2006; Chira and Bolea, 2008; Van den Berk, 2017):

- Low longevity (1 point) = under 50 years;
- Average longevity (2 points) = between 50 and 100 years;
- High longevity (3 points) = over 100 years;

4. Security against allergens (species ranked following visual observations and according to Iliescu, 2005; Carinanons and Casares-Porcel, 2011; Van den Berk, 2017):

- High risk (1 point) = strong allergic species;
- Moderate risk (2 points) = strong allergenic dioecious species (only masculine specimens are allergenic) or moderate allergenic species;
- Low risk (3 points) = species without significant allergenic risk or moderately allergenic dioecious species;

5. Carbon storage capacity - directly proportional to the growth rate and LAI, except for VOC (Volatile organic compound) emissions in air polluted areas (species ranked according to Nowak, 2002; Nowak et al., 2007; Iliescu, 2005; Costăschescu et al., 2010; Van den Berk, 2017):

- Low capacity (1 point) = slow growth rate and low LAI;
- Average capacity (2 points) = average growth rate and average LAI or fast growth rate and high LAI or slow growth rate and high LAI;
- High capacity (3 points) = fast growth rate and high LAI;

6. Air ionization (species ranked according to Iliescu, 2005; Costăchescu et al., 2010; Teodoreanu, 2011)

- Reduced ionization (1 point) = deciduous species emitting positive ions;
- Average ionization (2 points) = other deciduous species;
- High ionization (3 points) = coniferous trees and species with lanceolate leaves;

7. Bioaccumulation of chemical pollutants (according to Nowak, 2002; Iliescu, 2005; Chira, Bolea, 2008; Costăchescu et al., 2010):

- Low capacity (1 point) = reduced bioaccumulation compared to analysed species;
- Medium capacity (2 points) = moderate bioaccumulation, close to the average of the studied species;
- High capacity (3 points) = high bioaccumulation compared to other species;

8. Dust and particle retention capacity (species ranked according to Iliescu, 2005; Chira, Bolea, 2008; Costăchescu et al., 2010; Van den Berk, 2017 and following field observations):

- Reduced capacity (1 point) = species with rare canopy and small leaves;
- Medium capacity (2 points) = species with rare canopy and large leaves or dense canopy and small leaves;
- High capacity (3 points) = species with large canopy and large leaves.

The general criteria for the assessment of climatic and ecological resilience include (Ranking according to visual observations, Iliescu, 2005; Iliescu, 2006; Chira, Bolea, 2008; Costăchescu et al., 2010; Van den Berk, 2017):

[1]It was estimated for trees aged 20-40 years

9. Resistance to wind;
10. Resistance to drought;
11. Resistance to air pollution.
The following hierarchy applies to all criteria concerning environmental and climatic resilience: low resistance (1 point), medium resistance (2 points), high resistance (3 points).
The specific criteria are listed below, separately for each green zone typology. Following the evaluation of the species, the arithmetic mean of the values for each of the two categories of criteria was established. Thus, the final score resulted by achieving the arithmetic mean of the microclimatic impact general score and the climatic and ecological resilience score. Species were ranked according to the final score (global average) according to which they were grouped into three major categories within each green zone typology:
Species recommended as dominants - high bioclimatic impacts and high climatic and ecological resilience (impact and resilience scores ≥ 2.25, species which obtained over all the criteria above 1 point) - total score represented in green in Tables 1, 2, 3, 4 and 5;
Complementary species - average bioclimatic impact values and climate and ecological resilience (impact and resilience scores ≥ 1.75, species which have received no more than two marks of 1 point for the general criteria or a maximum of 1 point for the specific criteria) - represented in yellow in the tables;
Not recommended species (average impact and resilience scores ≤ 1.75, species which obtained more than two marks of 1 point on the analysed criteria) - represented in orange.

RESULTS AND DISCUSSIONS

Bioclimatic value of tree species according to general criteria

The species identified with the highest bioclimatic potential following assessment based only on the general criteria are:
- Coniferous tree species recommended as dominants (Table 1): *Pseudotsuga menziesii* ssp. *glauca, Juniperus virginiana, Pseudotsuga menziesii* ssp. *menziesii, Picea pungens, Abies concolor;*
- Deciduous tree species (height level I-II) recommended as dominants (Table 2): *Carpinus orientalis, Fraxinus angustifolia, Fraxinus excelsior, Fraxinus americana, Celtis australis, Acer platanoides, Quercus rubra, Carpinus betulus, Quercus robur, Ulmus carpinifolia, Ulmus glabra;*
- Deciduous tree species (height level III) recommended as dominants (Table 3): *Elaeagnus angustifolia, Corylus avellana, Quercus pubescens, Morus alba, Pyrus communis, Pyrus nivalis, Fraxinus ornus, Prunus cerasifera Pissardii, Salix babylonica, Salix matsudana, Acer tataricum, Cercis canadensis, Sorbus aria, Ginkgo biloba, Quercus cerris.*

Zone A - Protection green areas. Shelterbelts
In the case of relatively narrow urban shelterbelts, the use of dense canopy species and a predominantly vertical habitus is recommended, allowing the formation of compact planting compositions. Considering the high density of plantations, the adaptation of the species for partly shaded areas is also an important condition for climate and ecological resilience. Following the analysis, in the group of coniferous trees, three species obtained scores from 2 up to all criteria and, implicitly, the highest score. Thus, after the evaluation, the species were divided into the following three categories:
Coniferous trees (Table 5):
-Recommended species: *Pseudotsuga menziesii* ssp. *glauca, Juniperus virginiana, Pseudotsuga menziesii* ssp. *menziesii;*
- Not recommended species: *Pinus silvestris, Pinus strobus.*
Deciduous tree species (height level I-II) (Table4):
- Recommended species: *Carpinus orientalis, Fraxinus angustifolia, Ulmus glabra, Celtis australis, Fraxinus excelsior, Fraxinus americana, Carpinus betulus, Ulmus carpinifolia, Maclura pomifera, Acer platanoides, Ginkgo biloba*[2]*, Quercus rubra;*
- Not recommended species: *Populus tremula, Populus x canadensis, Platanus x hybrida, Populus alba, Betula pendula, Robinia pseudacacia, Paulownia tomentosa, Ailanthus altissima.*
Deciduous tree species (height level III) (Table 5):

[2]Ginkgo biloba was placed in the deciduous trees category considering it is not an evergreen coniferous.

- Recommended species: *Corylus avellana, Elaeagnus angustifolia, Crataegus monogyna, Fraxinus ornus, Prunus cerasifera 'Pissardii', Sorbus aria;*
- Not recommended species: *Salix babylonica, Acer negundo, Prunus avium, Prunus cerasus, Malus baccata, Malus domestica, Prunus 'Accolade', Koelreuteria paniculata, Malus silvestris, Prunus domestica, Albizzia julibrissin, Prunus serrulata 'Kanzan';*

Zone B - Mobility green areas. Greenways, trees alignments and planted platforms

In the case of the green areas designed for mobility, the density of planted areas is relatively low and the main bioclimatic role of vegetation is to provide shade and retain the heat reflected by the paved surfaces. In this regard, species with a dense and wide canopy will be chosen to cover larger areas. Regarding the ecological resilience of species, it is essential to choose species compatible with road and pedestrian infrastructure from the point of view of the root system and fruit that can affect the paved areas.

In zone B, the coniferous tree species were not taken into account as the ability to provide shade and resistance to air pollution are generally low. Considering the results, the following species for mobility areas were identified:

Deciduous tree species (height level I-II) (Table 4):

- Recommended species: *Carpinus orientalis, Fraxinus angustifolia, Fraxinus excelsior, Acer platanoides, Carpinus betulus, Fraxinus americana, Celtis australis, Quercus rubra, Ginkgo biloba, Quercus robur, Quercus cerris, Ulmus carpinifolia;*
- Not recommended species: *Ulmus glabra, Salix alba, Populus tremula, Paulownia tomentosa, Populus nigra, Aesculus hippocastanum, Sophora japonica, Populus alba, Populus x canadensis, Betula pendula, Ailanthus altissima, Robinia pseudacacia;*

Deciduous tree species (height level III) (Table 5):

- Recommended species: *Quercus pubescens, Elaeagnus angustifolia, Corylus colurna, Prunus cerasifera 'Pissardii', Fraxinus ornus, Sorbus aria, Acer tataricum;*
- Not recommended species: *Salix babylonica, Ulmus pumila, Prunus 'Accolade', Acer negundo, Malus baccata 'Street Parade', Albizzia julibrissin, Prunus serrulata 'Kanzan', Malus silvestris.*

Zone C - Buffer green areas.

Plantations adjacent to the buildings

In the green areas planted adjacent to the buildings, the density of the vegetation should be high and the planted areas consist of relatively narrow strips (Boc, 2017). In this case, we will choose species with vertical habitus compatible with the built environment from the point of view of tree crowns, root systems and fruits that may affect paved surfaces. Subzone C1 is a type of buffer green infrastructures located near the southern facades. Subzone C2, situated near the northern facades and subzone C3, located between buildings, it was taken into account the complementary criterion of resistance to semi-shade conditions. The following species have been hierarchized for subzone C1:

Deciduous tree species (height level I-II) (Table 4):

- Recommended species: *Fraxinus angustifolia, Carpinus orientalis, Carpinus betulus, Fraxinus excelsior, Fraxinus americana, Acer platanoides, Celtis australis, Quercus rubra, Ulmus carpinifolia, Ginkgo biloba, Quercus cerris, Quercus robur;*
- Not recommended species: *Ulmus glabra, Acer pseudoplatanus, Salix alba, Populus tremula, Populus nigra, Platanus x hybrida, Aesculus hippocastanum, Acer campestre, Populus x canadensis, Paulownia tomentosa, Populus alba, Betula pendula, Acer negundo, Robinia pseudacacia, Ailanthus altissima;*

Deciduous tree species (height level III) (Table 5):

- Recommended species: *Elaeagnus angustifolia, Corylus avellana, Pyrus communis, Pyrus nivalis, Fraxinus ornus, Prunus cerasifera 'Pissardii', Sorbus aria;*
- Not recommended species: *Salix babylonica, Acer tataricum, Acer negundo, Malus baccata, Malus domestica, Prunus 'Accolade', Prunus domestica, Ulmus pumila, Malus silvestris, Albizzia julibrissin, Prunus serrulata 'Kanzan'.*

The following semi-shade species, identified for subzones C2 and C3, have been identified:

Coniferous trees (Table 5)

Since coniferous trees are compatible with the built environment and the rest of the analysis criteria are similar to those in the case of the shelterbelts, then the results from zone A are valid also for subzones C2 and C3.

Deciduous tree species (height level I-II) (Table 4):

- Recommended species: *Carpinus orientalis, Fraxinus angustifolia, Carpinus betulus, Fraxinus excelsior, Fraxinus americana, Celtis australis, Acer platanoides, Ginkgo biloba, Ulmus carpinifolia, Quercus rubra;*
- Not recommended species: *Tilia tomentosa, Acer pseudoplatanus, Ulmus glabra, Salix alba, Quercus cerris, Quercus robur, Gleditsia triacanthos, Aesculus hippocastanum, Sophora japonica, Populus tremula, Populus nigra, Platanus x hybrida, Populus x canadensis, Paulownia tomentosa, Liriodendron tulipifera, Populus alba, Acer negundo, Robinia pseudacacia, Ailanthus altissima;*

Deciduous tree species (height level III) (Table 5):

- Recommended species: *Elaeagnus angustifolia, Corylus avellana, Fraxinus ornus, Populus simonii, Prunus cerasifera Pisardii, Sorbus aria, Prunus padus;*
- Not recommended species: *Pyrus communis, Pyrus nivalis, Salix matsudana, Salix babylonica, Prunus avium, Ulmus pumila, Prunus Accolade, Acer negundo, Koelreuteria paniculata, Prunus domestica, Malus silvestris, Prunus serrulata Kanzan, Albizzia julibrissin.*

Zone D - Green cores

Green cores include consistent planted areas and do not impose specific restrictions regarding road infrastructure and buildings. Thus, in this case it is recommended to choose the dominant species from among the trees with the most bioclimatic impact resulting from the assessment based on general criteria. In this case, other species except those mentioned in the selection analysis may be inserted separately, provided that the recommended dominant species are used in the planting composition.

CONCLUSIONS

Following the ranking of the species, it was found that trees with the highest bioclimatic potential belong to the deciduous tree group (height level I-II) (Table 1). The genera characterized by the highest values are *Fraxinus, Carpinus, Celtis* and *Acer*, which are compatible with all four types of green areas (Table 4).

Among the deciduous tree of height level III, there is a high degree of compatibility with all types of green areas in the case of the species *Eleagnus angustifolia, Fraxinus ornus, Prunus cerasifera* and *Sorbus aria* (Table 5).

From the coniferous category, the species with the highest score are *Juniperus virginiana* and *Pseudotsuga* sp. (Table 5). It should be noted that although they have a high degree of adaptability to environmental conditions, the two coniferous species are rarely used in Bucharest.

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Table 1. Assessment and ranking of coniferous tree species according to the relative bioclimatic value

	FACTORS INFLUENCING THE BIOCLIMATIC IMPACT OF DENDROLOGIC VEGETATION													
GENERAL CRITERIA	**IMPACT ON EOLIEN FACTORS**			**IMPACT ON AEROCHEMICAL AND AEROELECTRIC FACTORS**					**CLIMATE AND ECOLOGICAL RESILIENCE**					
Coniferous tree species	Estimated LAI	Canopy density	Longevity	Allergens security	Carbon storage	Air ionization	Accumulat-ion of chemical pollutants	Dust particles retention	Wind resistance	Drought resistance	Resistance to air pollution	Total 1 - Impact	Total 2 - Resilience	TOTAL
Pseudotsuga menziesii ssp. glauca	3	2	3	3	2	3	2	3	3	3	3	2,63	3,00	2,81
Juniperus virginiana	2	3	3	3	2	3	2	2	3	3	2	2,50	2,67	2,58
Pseudotsuga menziesii ssp. menziesii	3	2	3	3	2	3	2	3	3	2	2	2,63	2,33	2,48
Picea pungens	2	3	2	2	2	3	3	2	3	2	2	2,38	2,33	2,35
Abies concolor	2	3	3	2	2	3	2	2	3	2	1	2,38	2,00	2,19
Abies nordmanniana	3	2	3	2	2	3	3	3	3	1	1	2,63	1,67	2,15
Abies alba	3	2	3	3	2	3	2	3	3	1	1	2,63	1,67	2,15
Cupressocyparis leylandii	2	3	2	2	2	3	3	3	1	2	2	2,50	1,67	2,08
Thuja plicata	3	3	2	2	3	3	2	3	1	1	2	2,63	1,33	1,98
Picea abies	3	2	3	3	2	3	3	2	2	1	1	2,63	1,33	1,98
Chamaecyparis lawsonianna	2	3	2	2	2	3	3	3	1	1	2	2,50	1,33	1,92
Pinus nigra	2	2	3	2	2	3	1	2	2	2	1	2,13	1,67	1,90
Pinus strobus	2	2	3	2	2	3	2	2	2	1	1	2,25	1,33	1,79
Pinus silvestris	2	1	3	2	2	3	1	1	2	2	1	1,88	1,67	1,77

Relative bioclimatic value

1 - low | 2 - medium | 3 - high | no data

Table 2. Assessment and ranking of deciduous tree species (height level I-II) according to the relative bioclimatic value

Deciduous tree species (Height level I-II)	Estimated LAI	Canopy density	Longevity	Allergens security	Carbon storage	Air ionization	Accumulat-ion of chemical pollutants	Dust particles retention	Wind resistance	Drought resistance	Resistance to air pollution	Total 1 - Impact	Total 2 - Resilience	TOTAL
Tilia tomentosa	3	3	3	1	2	2	3	3	3	3	3	2,50	3,00	2,75
Carpinus orientalis	3	3	3	2	2	2	3	3	3	3	2	2,63	2,67	2,65
Fraxinus angustifolia	3	2	3	2	3	2	3	3	3	2	3	2,63	2,67	2,65
Fraxinus excelsior	3	2	3	2	3	2	3	3	3	2	3	2,63	2,67	2,65
Fraxinus americana	2	2	3	2	3	2	3	3	3	2	3	2,50	2,67	2,58
Celtis australis	2	2	3	2	2	2	2	2	3	3	3	2,13	3,00	2,56
Acer platanoides	3	3	2	2	3	2	3	3	2	3	2	2,63	2,33	2,48
Carpinus betulus	3	3	3	2	2	2	3	3	3	2	2	2,63	2,33	2,48
Quercus rubra	2	2	3	2	2	3	2	2	3	2	3	2,25	2,67	2,46
Acer pseudoplatanus	3	3	2	2	3	2	3	2	3	1	3	2,50	2,33	2,42
Salix alba	2	2	3	2	3	3	3	2	3	1	3	2,50	2,33	2,42
Ulmus carpinifolia	2	2	3	2	2		2	2	3	2	3	2,14	2,67	2,40
Ulmus glabra	2	2	3	2	2		2	2	3	2	3	2,14	2,67	2,40
Maclura pomifera	2	2	2	2	3	2		2	2	3	3	2,14	2,67	2,40
*Ginkgo biloba**	2	2	3	3	2		3	2	2	2	3	2,43	2,33	2,38
Quercus robur	2	2	3	2	2	3	3	2	3	2	2	2,38	2,33	2,35
Populus nigra	3	2	2	1	3	3	3	2	3	2	2	2,38	2,33	2,35
Populus tremula	2	2	2	1	3	3	3	3	3	1	3	2,38	2,33	2,35
Quercus cerris	2	2	3	2	2		3	2	3	2	2	2,29	2,33	2,31
Platanus hybrida	3	2	3	1	3		2	2	2	2	3	2,29	2,33	2,31
Sophora japonica	2	2	1	3	3		3	2	2	2	3	2,29	2,33	2,31
Populus canadensis	2	1	2	1	3	3	3	2	3	1	3	2,13	2,33	2,23
Populus alba	2	1	2	1	3	3	3	2	2	2	3	2,13	2,33	2,23
Aesculus hippocastanum	3	3	3	1	2		2	3	2	2	2	2,43	2,00	2,21
Gleditsia triacanthos	1	1	3	3	2	1	2	1	2	3	3	1,75	2,67	2,21
Quercus palustris	2	2	3	2	2	1		2	3	1	3	2,00	2,33	2,17
Juglans regia	2	2	3	2	2	3	2	2	3	1	2	2,20	2,00	2,10
Robinia pseudacacia	1	1	2	1	1		3	1	2	3	3	1,43	2,67	2,05
Paulownia tomentosa	2	1	2	3	3		3	3	1	1	3	2,43	1,67	2,05
Liriodendron tulipifera	2	2	3	3	3	2	2	2	2	1	2	2,38	1,67	2,02
Acer campestre	2	2	2	2	2	2	2	2	2	2	2	2,00	2,00	2,00
Tilia platyphyllos	2	2	3	1	2	1	3	2	2	2	2	2,00	2,00	2,00
Betula pendula	1	1	2	1	1	3	3	1	2	2	3	1,63	2,33	1,98
Ailanthus altissima	2	1	1	2	2	1	2	2	2	2	3	1,63	2,33	1,98

Relative bioclimatic value

1 - low | 2 - medium | 3 - high | no data

Table 3. Assessment and ranking of deciduous tree species (height level III) according to the relative bioclimatic value

GENERAL CRITERIA	IMPACT ON EOLIEN FACTORS			IMPACT ON AEROCHEMICAL AND AEROELECTRIC FACTORS					CLIMATE AND ECOLOGICAL RESILIENCE					
Deciduous tree species (Height level III)	Estimated LAI	Canopy density	Longevity	Allergens security	Carbon storage	Air ionization	Accumulat-ion of chemical pollutants	Dust particles retention	Wind resistance	Drought resistance	Resistance to air pollution	Total 1 - Impact	Total 2 - Resilience	TOTAL
Elaeagnus angustifolia	2	2	3	2	2	3	3	2	3	3	3	2,38	3,00	2,69
Corylus avellana	2	3	3	2	2		3	3	3	2	3	2,57	2,67	2,62
Quercus pubescens	2	2	3	2	2			2	3	3	3	2,17	3,00	2,58
Crataegus monogyna	2	2	3	2	1		2	2	3	3	3	2,00	3,00	2,50
Populus simonii	3	3	2	2	3	3	3	2	3	1	3	2,63	2,33	2,48
Morus alba	2	2	3	2	2		3	2	2	3	3	2,29	2,67	2,48
Pyrus communis	2	2	3	3	2		2	2	3	3	2	2,29	2,67	2,48
Pyrus nivalis	2	2	3	3	2		2	2	3	3	2	2,29	2,67	2,48
Fraxinus ornus	2	2	3	2	3	2	3	3	2	3	2	2,50	2,33	2,42
Prunus cerasifera Pisardii	2	3	2	3	2		2	3	2	2	3	2,43	2,33	2,38
Salix babylonica	2	2	2	2	3	3	3	2	3	2	2	2,38	2,33	2,35
Salix matsudana	2	2	1	2	3	3	3	2	3	2	2	2,25	2,33	2,29
Acer tataricum	2	2	2	3	2	2	2	2	2	2	3	2,13	2,33	2,23
Cercis canadensis	2	2	1	3	2		2	3	2	3	2	2,14	2,33	2,24
Sorbus aria	2	2	3	3	2		2	2	2	2	2	2,29	2,00	2,14
Prunus padus	2	3	2	2	2			3	1	2	2	2,33	1,67	2,00
Ulmus pumila	2	1	2	2	2			1	2	2	3	1,67	2,33	2,00
Acer negundo	2	2	1	2	2	2	3	2	1	2	3	2,00	2,00	2,00
Prunus Accolade	1	1	2	2	2		2	1	2	2	3	1,57	2,33	1,95
Catalpa bignonioides	2	2	2	3	2		2	2	2	1	2	2,14	1,67	1,90
Prunus avium	1	2	2	2	2		1	2	2	2	2	1,71	2,00	1,86
Albizzia julibrissin	1	1	1	3	1		2	2	2	2	2	1,57	2,00	1,79
Koelreuteria paniculata	2	2	1	2	2	2	2	2	1	2	2	1,88	1,67	1,77
Prunus cerasus	1	2	2	2	2		2	2	2	1	2	1,86	1,67	1,76
Malus baccata	1	2	2	2	1		2	2	2	1	2	1,71	1,67	1,69
Malus domestica	1	2	2	2	1		2	2	2	1	2	1,71	1,67	1,69
Prunus domestica	1	2	2	3	2		2	2	1	2	1	2,00	1,33	1,67
Prunus serrulata Kanzan	1	2	2	1	2			2	1	2	1	1,67	1,50	1,58
Malus silvestris	1	2	2	2	1		1	1	2	1	2	1,43	1,67	1,55

Relative bioclimatic value

1 - low **2 - medium** **3 - high** **no data**

Table 4. Compatibility level between deciduous tree species (height level I-II) and green areas typologies

Deciduous trees height I-II	Zone A	Zone B	Subzone C1	Subzone C2, C3	Zone D
Acer campestre					
Acer negundo					
Acer platanoides					
Acer pseudoplatanus					
Aesculus hippocastanum					
Ailanthus altissima					
Betula pendula					
Carpinus betulus					
Carpinus orientalis					
Celtis australis					
Fraxinus americana					
Fraxinus angustifolia					
Fraxinus excelsior					
*Ginkgo biloba**					
Gleditsia triacanthos					
Juglans regia					
Liriodendron tuilipifera					
Maclura pomifera					
Paulownia tomentosa					
Platanus hybrida					
Populus alba					
Populus canadensis					
Populus nigra					
Populus tremula					
Quercus cerris					
Quercus palustris					
Quercus robur					
Quercus rubra					
Robinia pseudacacia					
Salix alba					
Sophora japonica					
Tilia platyphyllos					
Tilia tomentosa					
Ulmus carpinifolia					
Ulmus glabra					
Compatibility level	**Low**	**Medium**	**High**		

Table 5. Compatibility level between coniferous tree species and green areas typologies (up and down)

Coniferous trees	Zone A	Zone B	Subzone C1	Subzone C2, C3	Zone D
Abies alba					
Abies concolor					
Abies nordmanniana					
Chamaecyparis lawsonianna					
Cupressocyparis leylandii					
Juniperus virginiana					
Picea abies					
Picea pungens					
Pinus nigra					
Pinus silvestris					
Pinus strobus					
Pseudotsuga menziesii ssp. glauca					
Pseudotsuga menziesii ssp. menziesii					
Thuja plicata					

Deciduous trees height III	Zone A	Zone B	Subzone C1	Subzone C2, C3	Zone D
Acer negundo					
Acer tataricum					
Albizzia julibrissin					
Catalpa bignonioides					
Cercis canadensis					
Corylus avellana					
Corylus colurna					
Crataegus monogyna					
Elaeagnus angustifolia					
Fraxinus ornus					
Koelreuteria paniculata					
Malus baccata					
Malus domestica					
Malus silvestris					
Morus alba					
Populus simonii					
Prunus Accolade					
Prunus avium					
Prunus cerasifera Pisardii					
Prunus cerasus					
Prunus domestica					
Prunus padus					
Prunus serrulata Kanzan					
Pyrus communis					
Pyrus nivalis					
Quercus pubescens					
Salix babylonica					
Salix matsudana					
Sorbus aria					
Ulmus pumila					

Compatibility level	Low	Medium	High