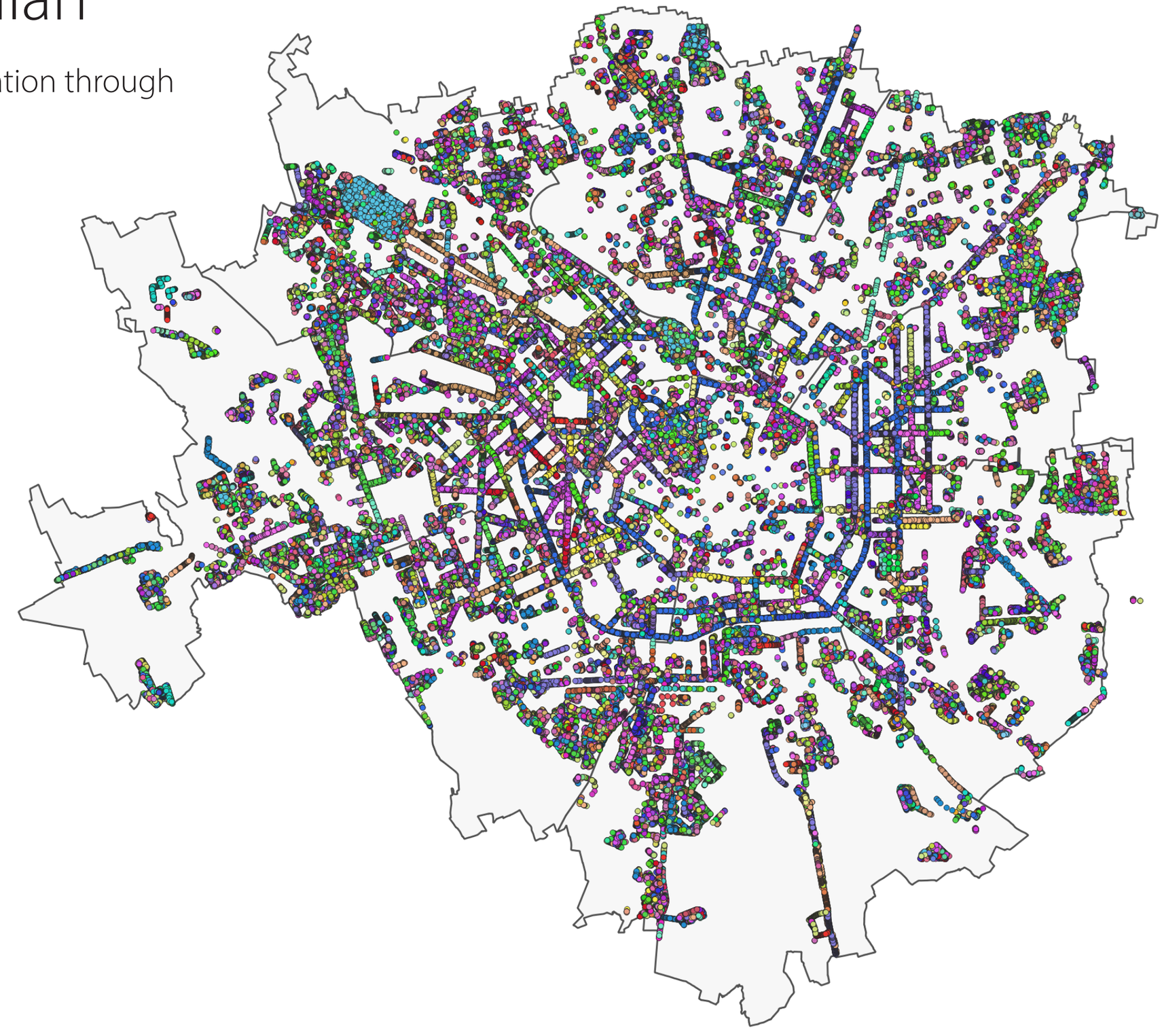
The Trees of Milan

An analysis of the tree population through species characteristics.



Tesi di laurea di:

Yazan Kondakji

Numero di matricola: 872380

Politecnico di Milano

Urbanistica: Città Ambiente Paesaggio

Anno Accademico: 2019/2020

Relatore: GUZZETTI FRANCO

The research subject

From a Hobby

Class Project - Mapping and identifying the tree of Piazza Leonardo Da Vinci

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Increased interest in GIS due to my internship.

Missing species descriptions in Milan's Inventory and so decided to merge it with species characteristic databases.

Goal of the thesis

A single database which allows for many different queries and studies to be made, including geo spatial analysis.

Using Milan as the subject of this database.

Why urban trees?

Economic benefits

- Save energy and cut costs for summer cooling (shade) and winter heating (windbreak).
- Increase property values, benefiting homeowners and increasing local tax revenues.
- Boost commercial district activity.
- Support green industry jobs.
- Reduce costs to taxpayers for traditional "grey" infrastructure.
- Supply wood products – ranging from recycled material such as mulch, to hardwood furniture, and fuel for energy production.

Environmental benefits

- Improve air quality by absorbing and filtering pollutants.
- Reduce greenhouse gases by direct carbon sequestration and through avoided carbon emissions from reduced energy use.
- Save energy by directly shading buildings and through the cooling effects of transpiration.
- Mitigate overall air temperature extremes and reduce urban "heat island" effect.
- Help manage stormwater, reduce flooding, and improve water quality.
- Support wildlife populations and overall biodiversity.

Social benefits

- Promote public health and well-being.
- Encourage physical activity by creating attractive, shaded outdoor spaces.
- Discourage crime and create safe places to gather.
- Strengthen community engagement and revitalize neighborhoods.
- Promote social equity and environmental justice for neglected communities.
- Supply healthy edibles – fruit and nuts.
- Provide solace, spiritual sustenance, and a sense of place.

_Disservices

Causes

Stresses - Abiotic / Biotic

- Specialized pest effecting commonly used species.
- Mechanical damage
- Soil compaction
- Decreased sunlight
- Urban heat islands

⋮

Miss-managment

- Wrong selection of species to plant
- Improper pruning methods
- Incorrect maintenance scheduling
- Wrong planting site selection

⋮

Disservices

-Increased costs of maintenance and removal.
-Displacement of natve species
-Physical damage due to breaking branches
-Blocking visibility
-Roots damaging infrastructure

⋮

_Maximizing benifits

Selecting fitting species

Criteria

Urban Site conditions

Biodiversity aspect and ecosystem services

Human requirements

→

Decreased maintenance costs
Longer tree live spans
Higher exosystemic services
Fitting Aesthetic

⋮

Management through Tree inventory

Components

Minimum components:

Location
Species
Size/age
Condition
Management responsibility

→

Better scheduled pruning operations.
Maintenance needs based on condition and age
Diversity studies based on species and location
Value of entire tree population
Yearly reports of the state of the population.

⋮

A combined database

Species characteristics databases

- I-Trees
- CiTree

Geospatial data pertaining to the urban environment

- DBT
- Dusaf
- Shadows shp
- Parks of Milan

⋮

Inventory of urban trees

- Green heritage databse Milan

Uses

Evaluating state of the current Urban tree population

Prediction of maintenance needs based on both the state of the trees and the urban environment.

Planning for the future in terms of plantings and removals.

Better estimating ecosystem services based on species specific characteristics.

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The Milano green heritage database

The Milan green heritage database contains Milans tree inventory. Managed using R3GIS GreenSpaces software.

Total amount of trees: 249120

Examples of the measured data:

- VTA visual tree assessment
- Coordinates
- Species
- DBH diameter at breast height
- Crown width
- Calculated age

The I-Trees and CiTree database

Online tools for species selection

I-Trees Database | By the United States Forest Service

A database in support of I-Trees other services, allowing for the download of database containing a total of 7144 different species of trees.
Fully downloadable.

Examples of some characteristics:

- -Family
- -Order
- -Percent Leaf Type
- -Growth Rate
- -Longevity
- -Height at Maturity

CiTree | By the Institute for Landscape Architecture TU Dresden

An online tool that supports in the selection processes of trees and shrubs for urban sites.

One by one.

Examples of some characteristics:

- -Light requirements
- -Drought tolerance
- -Blooming period
- -Maintenance needs
- -Leaf density
- -Honey Plant

The resulting database

GenXSpe: Normalized GENERA and SPECIES column used to merge the databases.

Resulting in 2 databases

I-Trees + Inventory

Quantity of trees - 249120 trees
Quantity of different species - 315

5 characteristics per species.

Citree + inventory

Quantity of trees - 188939 trees (75% of total)
Quantity of different species - 40

35 characteristics categorized into 7 types.

General statistics

Statistics through the inventory

Total quantity of trees	249120
Top 10 Species in % of total	35,21%
Top 10 Genera in % of total	64,00%
Top 10 Families in % of total	77,70%

Species richness	315
Dominant speces	Platanus x acerifolia 5,61%
Genera richness	108
Dominant genera	Acer 11,33%
Family richness	49
Dominant Family	Ulmaceae 11,35%

Statistics through the inventory combined with the I-Trees database

Leaf Type	Deciduous	201121	91,88%
Percent Leaf Type	Hardwood	204923	93,61%
Longevity	Moderate 35-55 years	85553	44,68%
Growth rate	Fast >60 cm/year	105747	52,38%

General statistics

Example of the most common characteristics in the city of Milan, through the inventory combined with the CiTree database.

Soil requirments

pH value max	8	94277	50,51%
pH value min	5,5	113813	60,98%
Soil compaction tolerance	low	78034	41,30%
Waterlogging tolerance	sensitive	91145	48,24%
Salt tolerance	medium	79157	42,41%
Soil moisture tolerance	medium	54478	28,83%
Substrate	pebbly, sandy, loamy	29481	15,80%
Soil depth	mean (<3 m), deep (>3 m)	82551	44,23%

Aethetics

Leaf shape	single leaf	149354	79,05%
Autumn Coloring	yellow	105096	55,62%
Fruit ornamental	no	97166	51,43%
Infructescence	nut	72741	38,97%
Fruit color	brown	88228	48,61%
Blossom period	May	125394	66,37%
Blossom odor	no	128375	67,95%
Blossom ornamental	no	114060	60,37%
Blossom color	unobstrusive	43443	22,99%
Inflorescence	capitulum	28819	15,25%

Diversity - Street trees vs Parks

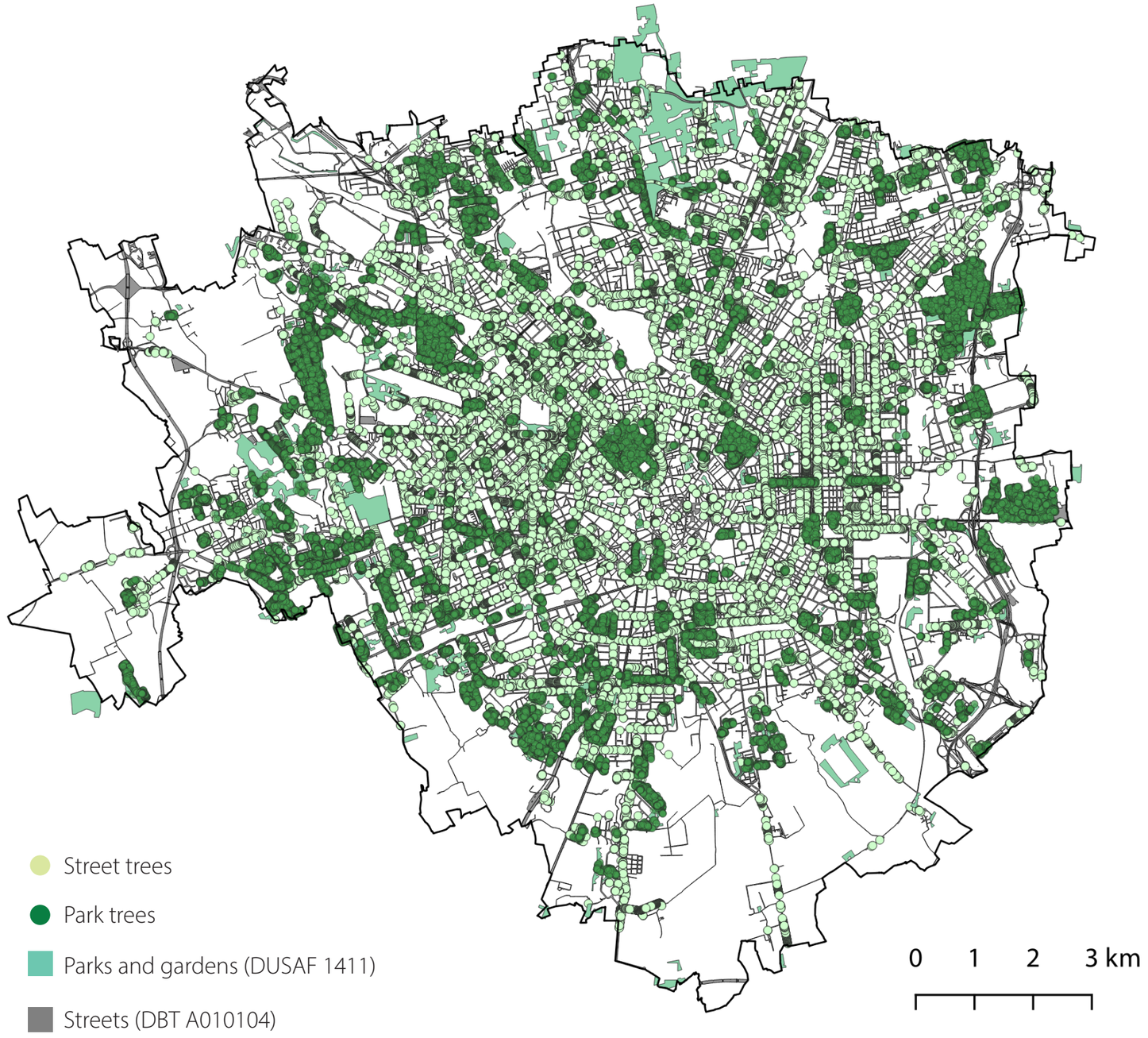
Using DUSAF 1411 and
DBT A010104
I Separate the street trees
from park trees.

The Shannon
Weiner diversity
index

$$H' = -\sum_{i=1}^{R} p_i \ln p_i$$

<1.5 for low diversity,
1.5<H<2.5 medium diversity
and >2.5 for high diversity

Other calculations



Diversity - Street trees vs Parks

Shows that Street trees:

- Depend more on a single species (Platanus X acerfolia)

- Have 41 less species (at 222 species)

- Lesser Shannon Weiner diversity index by 0,55 points.

- Compose 26% of all tree in Milan.

Park Trees (DUSAF 1411)

Species	Count	Percentage
Carpinus betulus	4125	4,06%
Celtis australis	4024	3,96%
Platanus x acerifolia	3797	3,74%
Quercus rubra	3724	3,67%
Populus nigra	3620	3,56%
Acer platanoides	3553	3,50%
Robinia pseudoacacia	3414	3,36%
Tilia cordata	3136	3,09%
Ulmus spp	3120	3,07%
Fraxinus excelsior	3053	3,01%
Remaing 253 speciecs	*65994*	*64,98%*

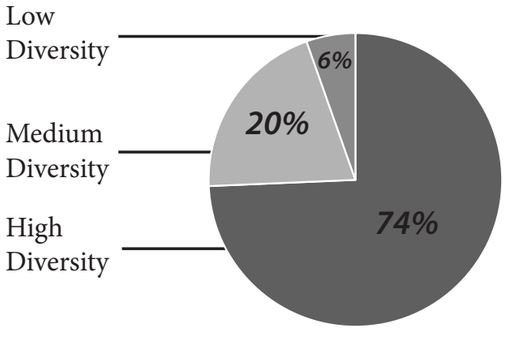
Street Trees (DBT A010104)

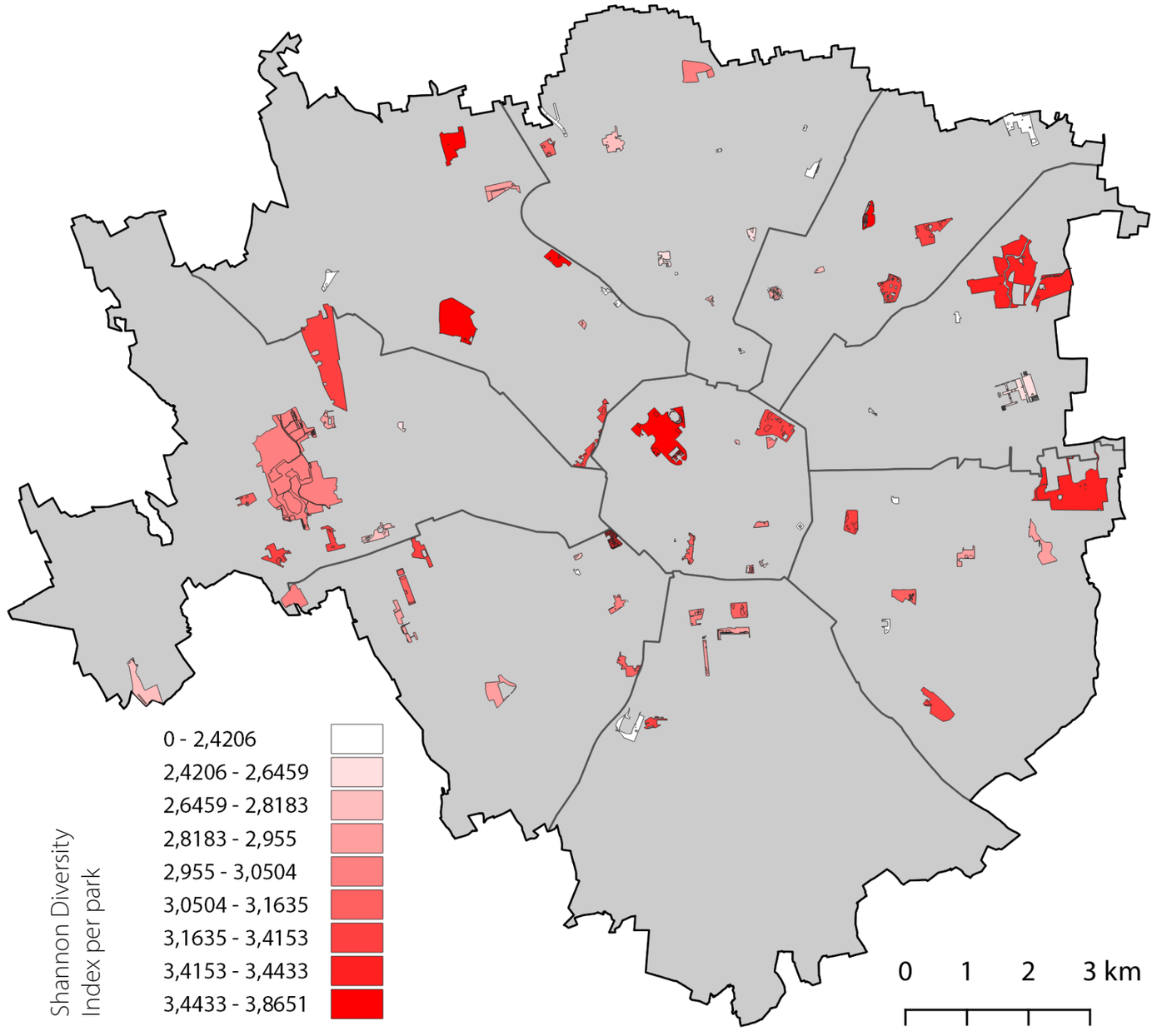
Species	Count	Percentage
Platanus x acerifolia	9125	14,06%
Celtis australis	6124	9,43%
Acer platanoides	3951	6,09%
Platanus spp	3526	5,43%
Sophora japonica	2025	3,12%
Ulmus pumila	1882	2,90%
Carpinus betulus	1786	2,75%
Liquidambar styraciflua	1742	2,68%
Fraxinus excelsior	1573	2,42%
Populus nigra	1464	2,26%
Remaining 212 species	*31715*	*48,86%*

	Park Trees (DUSAF 1411)	*Street Trees (DBT A010104)*
Species richness	263	222
Dominant species	Carpinus betulus 4,06%	Platanus x acerifolia 14,06%
Shannon Weiner diversity index	4,306277485	3,758543079
Simpson diversity index	0,979803327	0,954360947
Pielou's evenness index	0,77282097	0,695681569
Total quantity of trees	101560	64913
Top 10 species in % of total	35,02%	51,14%
Percentage from entire tree population	40,77%	26,06%

Diversity between parks

	Values	*Park and Garden names*
Lowest species richness	1	PARCO ARCHEOLOGICO DELL'ANFITEATRO ROMANO & GIARDINO VIA PORRO JENNER
Lowest diversity	0	PARCO ARCHEOLOGICO DELL'ANFITEATRO ROMANO & GIARDINO VIA PORRO JENNER
Lowest quantity of trees	1	PARCO ARCHEOLOGICO DELL'ANFITEATRO ROMANO
Lowest density trees/km2	506	PARCO ADRIANO
Lowest area m2	395	PARCO ARCHEOLOGICO DELL'ANFITEATRO ROMANO
Highest species richness	105	GIARDINI PUBBLICI INDRO MONTANELLI
Highest diversity	3,8651	PARCO DI VILLA SCHEIBLER
Highest quantity of trees	7283	PARCO LAMBRO
Highest density trees/km2	19415	PARCO DI VILLA SCHEIBLER
Highest area m2	1422539	PARCO DELLE CAVE





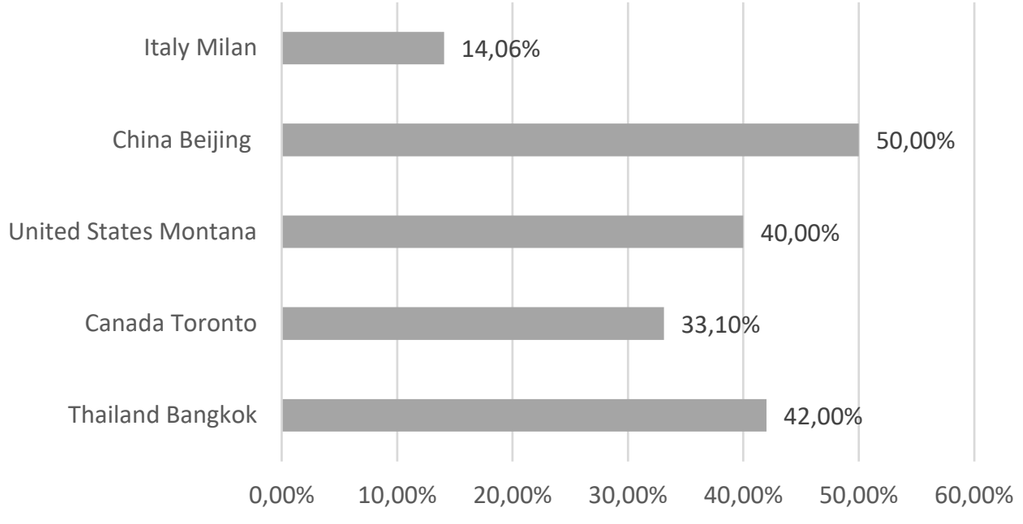
Diversification formula

Frank Santamour Standard 10-20-30 Standard for protection against pests:

- Species must remain less than 10% of population
- Genera must remain less than 20% of the population
- Family must remain less than 30% of the population

Comparision to other cities in terms of the most used species.

Country	Most common species	Percentage from entire population
Thailand Bangkok	Pterocarpus Indicus	42,00%
Canada Toronto	Acer spp.	33,10%
United States Montana	Fraxinus spp.	40,00%
China Beijing	Styphnolobium japonicum	50,00%
Italy Milan	Platanus x acerifolia	14,06%



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Remaining 212 species	*31715*	*48,86%*

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Genera	Count	Percentage
Platanus	14288	22,01%
Acer	7711	11,88%
Celtis	6588	10,15%
Ulmus	4094	6,31%
Prunus	3812	5,87%
Tilia	3001	4,62%
Fraxinus	2275	3,50%
Sophora	2025	3,12%
Carpinus	1786	2,75%
Liquidambar	1759	2,71%
Remaining 76 genera	*17574*	*27,07%*

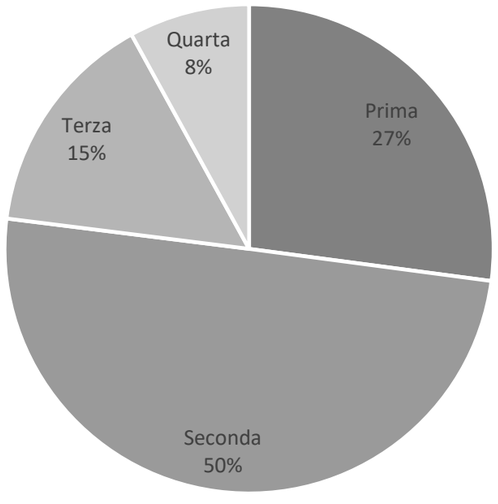
Families	Count	Percentage
Platanaceae	14288	22,01%
Ulmaceae	10707	16,49%
Aceraceae	7711	11,88%
Rosaceae	5742	8,85%
Fabaceae	5295	8,16%
Tiliaceae	3001	4,62%
Oleaceae	2711	4,18%
Betulaceae	2553	3,93%
Hamamelidaceae	1885	2,90%
Salicaceae	1683	2,59%
Remaining 35 families	*9337*	*14,38%*

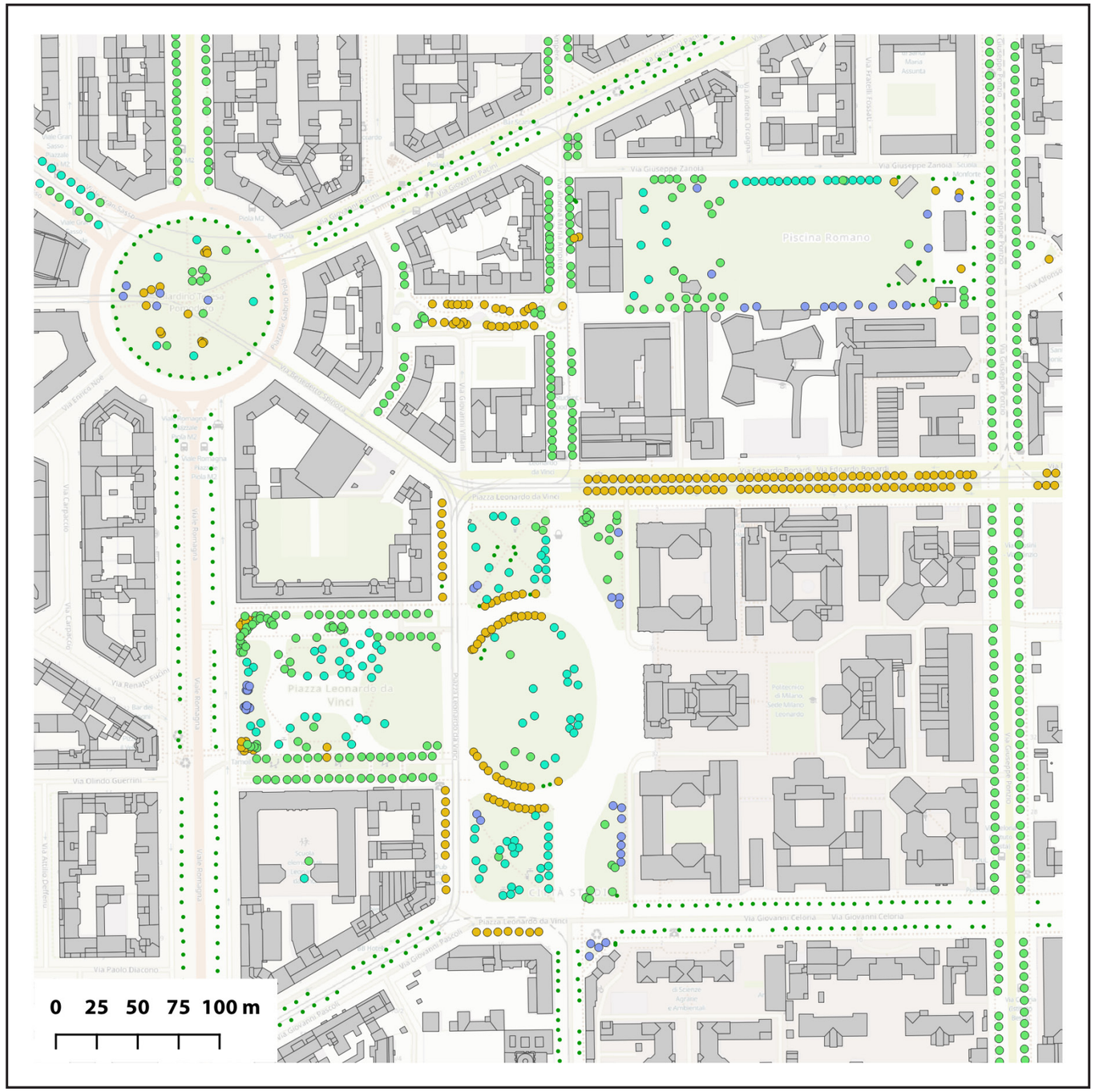
Height at maturity - Size class

Height at maturity - used to identify Size class as per the Regulation of use and protection of public and private greenery.

CLASSE DI GRANDEZZA	RAGGIO IN METRI
esemplari monumentali o di pregio	proiezione a terra dell'intera chioma
prima (altezza > 25 m)	5 m
seconda (altezza 15-25 m)	4 m
terza (altezza 8-15 m)	3 m
quarta (altezza < 8 m)	2 m

Classi di Grandezza	Count	Area
Prima	54949	2708875,802
Seconda	101142	3988878,653
Terza	30463	901058,9844
Quarta	16203	319510,1976
Grand Total	***202757***	***7918323,637***



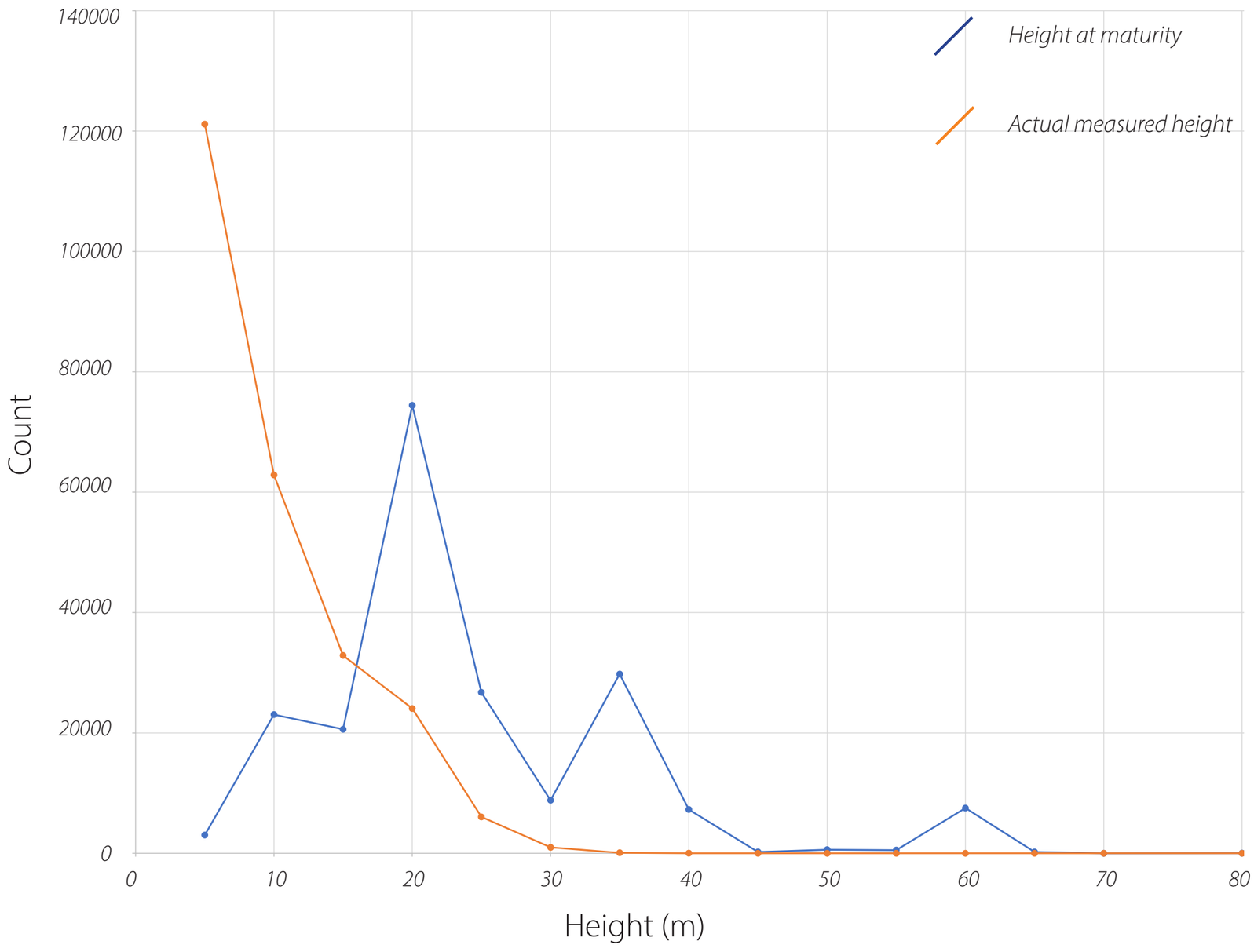


Height at maturity - Compared to measured height.

Height at maturity (m)	Count of height at maturity	Count of actual measured height
5	3029	121132
10	23040	62852
15	20597	32862
20	74415	24050
25	26727	6047
30	8807	982
35	29767	78
40	7270	11
45	221	2
50	599	0
55	523	2
60	7514	0
65	226	1
70	1	2
80	21	2
Grand Total	*202757*	*248023*

Height at maturity parameter obtained from the I-trees database.

While the measured height was obtrained on the Milan tree inventory

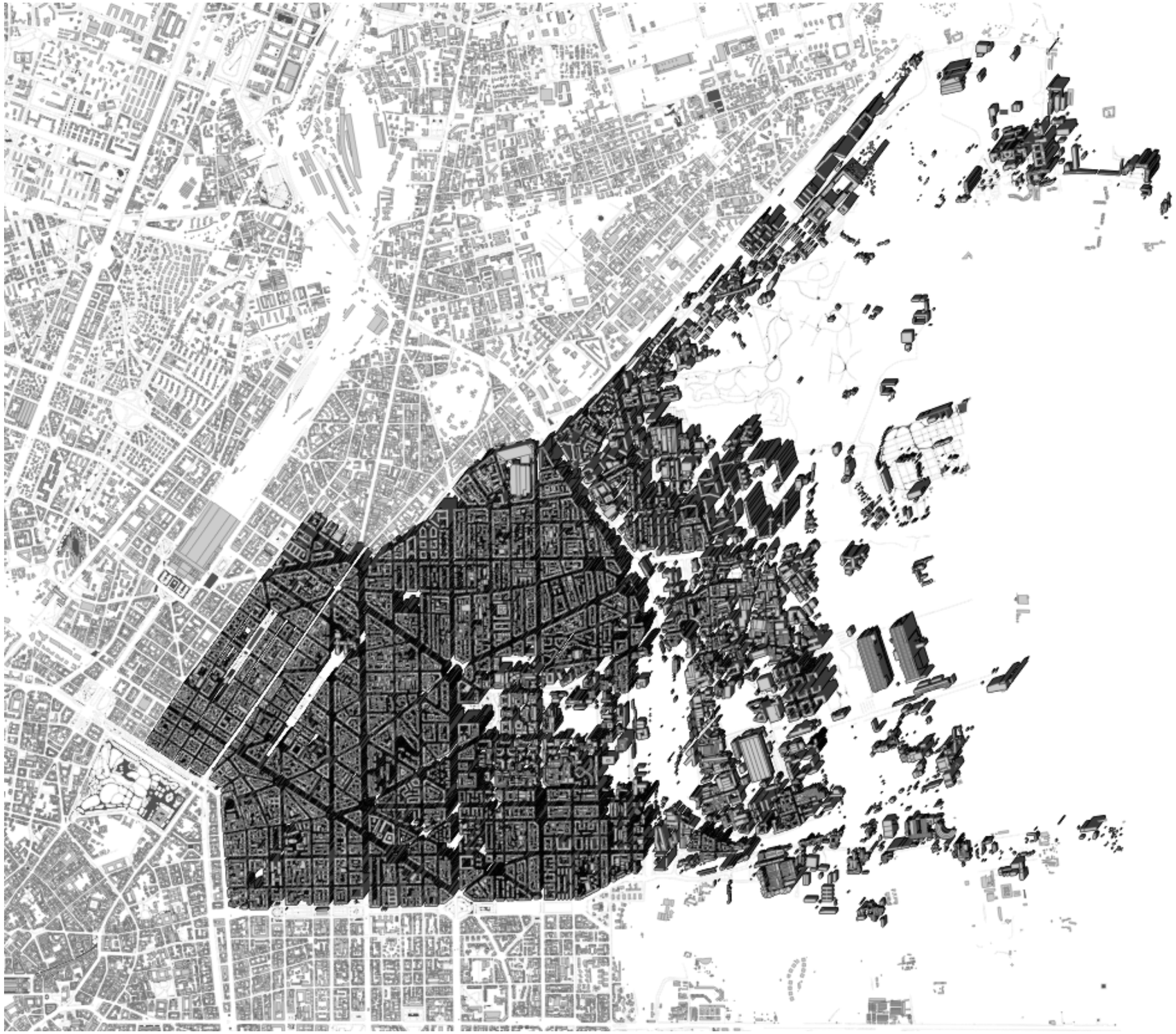


Sun requirments and shadows

An example of geospatial data about the urban environment to to use in tandem with Species specific needs.

Created Using R code SHADOWS package.

21 of december (Winter solstice) at 3 pm.



Sun requirments and shadows

Tree light requrments

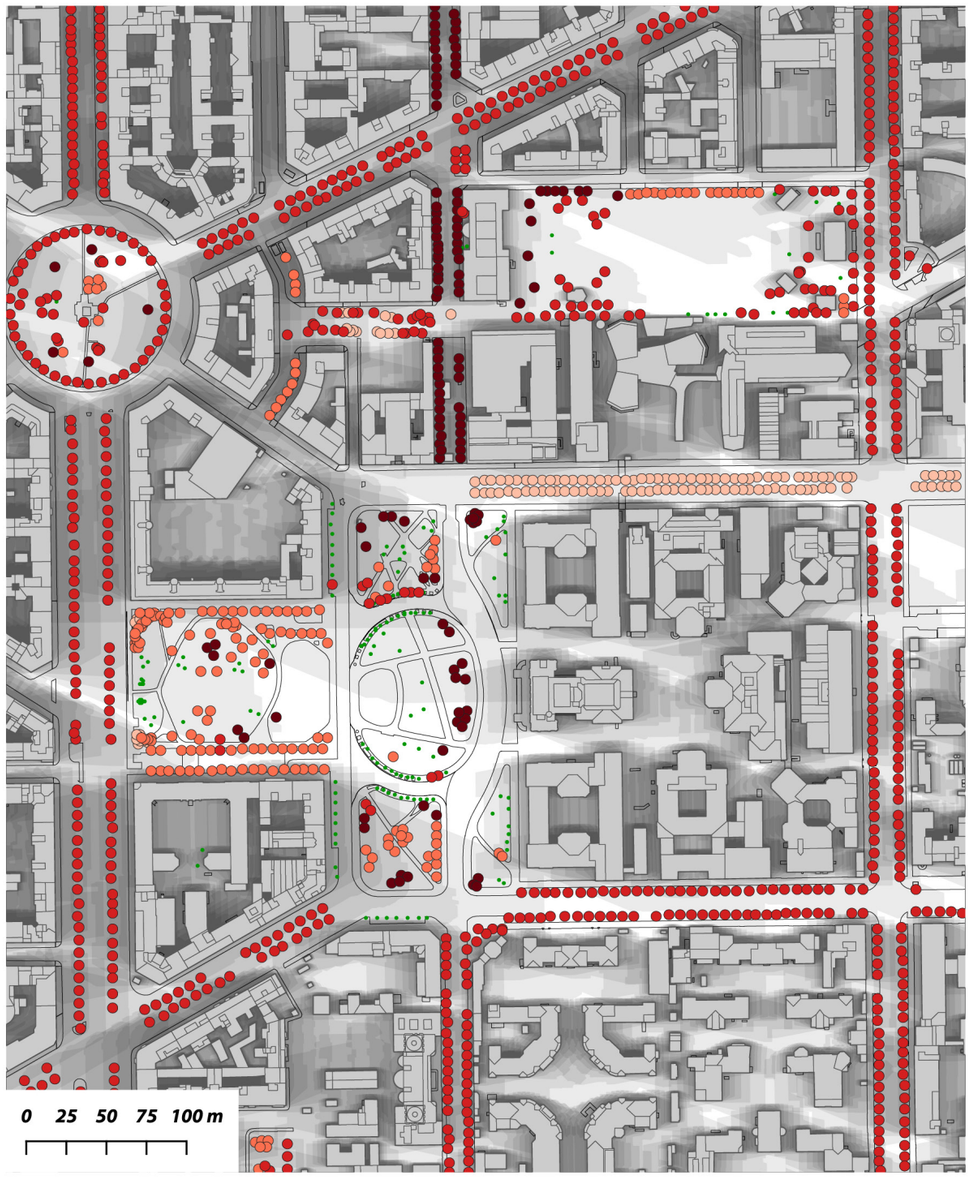
- sunny
- sunny, half sunny
- sunny, half sunny, half shady
- sunny, half sunny, half shady, shady

No direct sunlight

Direct sunlight all day

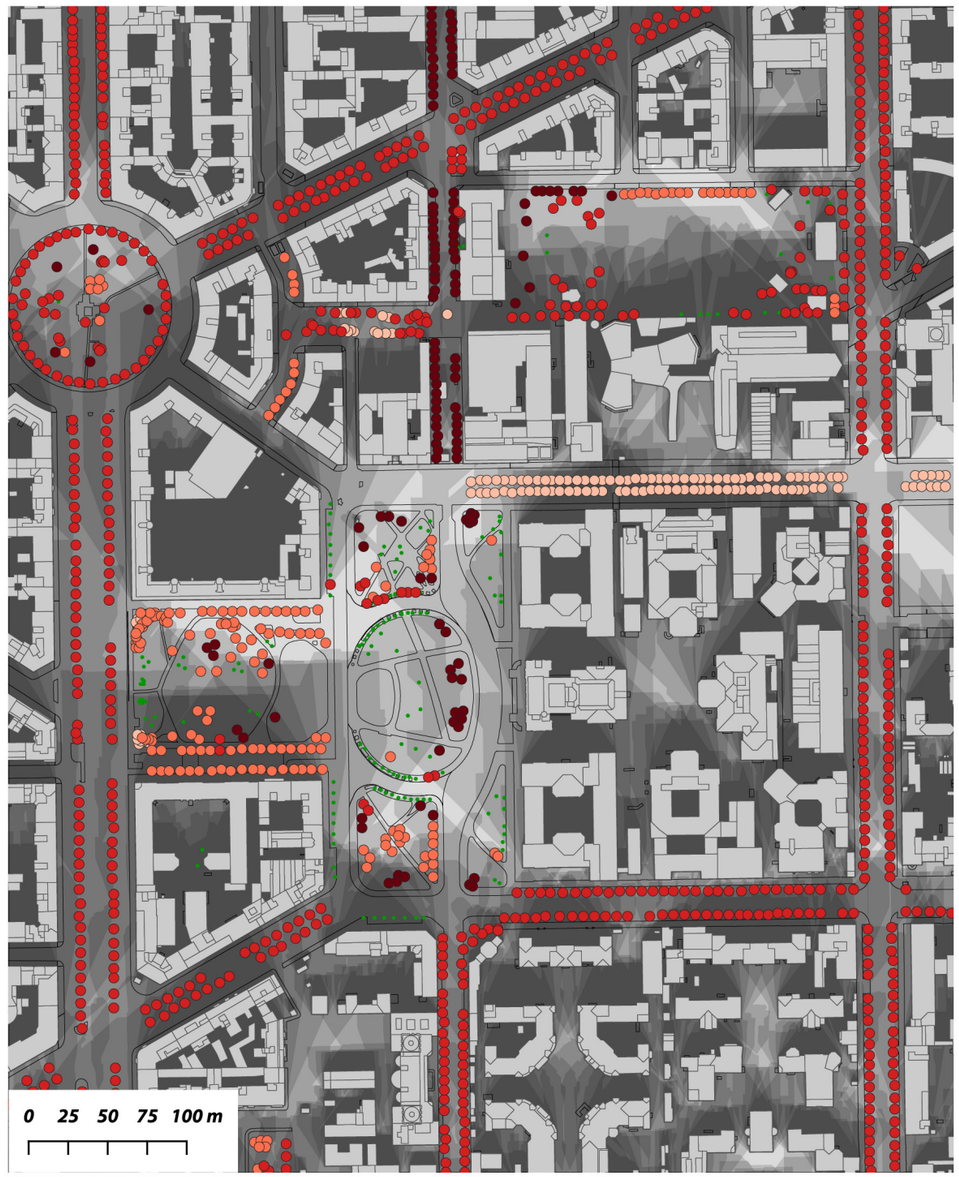
12 hour long days.

Summer solstice - June 21
from 8am to 8pm



6 hour long days.

Winter solstice - December 21
from 9am to 4pm

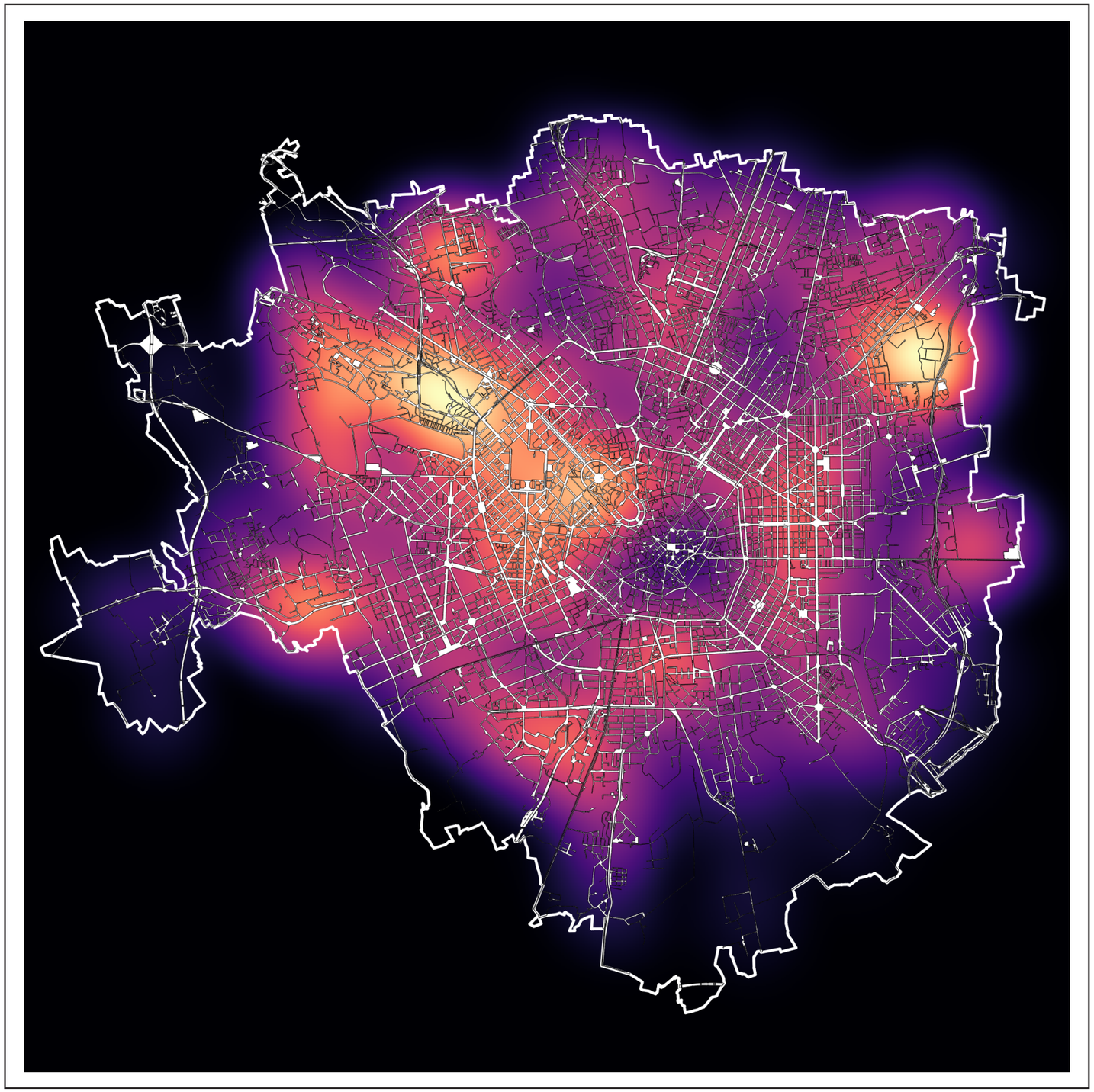


Heat map for area's of high allergins

Using the CiTree Allergenic field of the tree characteristic.,

I create a heat map that takes into consideration the concentration of these tree and how allergenic each tree is.

(Weighted heatmap)



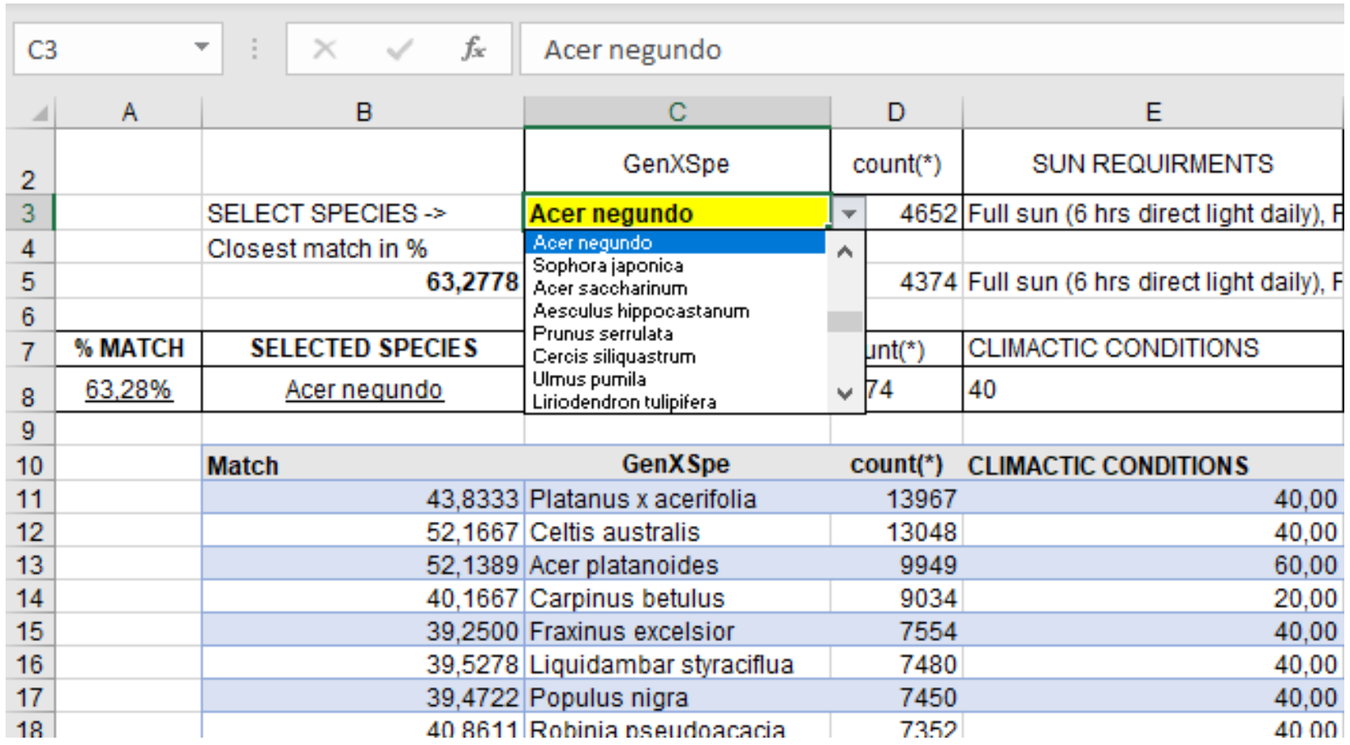
Program to compare species

Use of drop down menu to select a species to compare characteristics with other species on the list.

CiTree top 40 species created on excel.

Excel xlookup, IF, and Average Functions

Allows calculation of percentage per characteristic and then averaged into categories.



C3 | Acer negundo

	A	B	C	D	E
2			GenXSpe	count(*)	SUN REQUIRMENTS
3		SELECT SPECIES ->	Acer negundo	4652	Full sun (6 hrs direct light daily), F
4		Closest match in %			
5		63,2778		4374	Full sun (6 hrs direct light daily), F
6					
7	% MATCH	SELECTED SPECIES		unt(*)	CLIMACTIC CONDITIONS
8	63,28%	Acer negundo		74	40
9					
10		Match	GenXSpe	count(*)	CLIMACTIC CONDITIONS
11		43,8333	Platanus x acerifolia	13967	40,00
12		52,1667	Celtis australis	13048	40,00
13		52,1389	Acer platanoides	9949	60,00
14		40,1667	Carpinus betulus	9034	20,00
15		39,2500	Fraxinus excelsior	7554	40,00
16		39,5278	Liquidambar styraciflua	7480	40,00
17		39,4722	Populus nigra	7450	40,00
18		40,8611	Robinia pseudoacacia	7352	40,00

Acer negundo
Sophora japonica
Acer saccharinum
Aesculus hippocastanum
Prunus serrulata
Cercis siliquastrum
Ulmus pumila
Liriodendron tulipifera

% MATCH	*SELECTED SPECIES*	*CLOSEST MATCH*	count(*)	CLIMACTIC CONDITIONS	SOIL CONDITIONS	HABITUS
92,39%	Prunus serrulata	Prunus cerasifera	5424	80	100	88,88888889

LEAF	BLOSSOM	FRUIT	INTERFERENCES	RISKS	REQUIRED MANAGEMENT ACTIVITIES	ECOSYSTEM SERVICES
75	80	100	100	100	100	100

Program to compare species

Allows for comparison with all species.

With Conditional formatting it becomes easier to identify the categories of characteristics that match between the species.

Match	GenXSpe	count(*)	CLIMACTIC CONDITIONS	SOIL CONDITIONS	HABITUS	LEAF	BLOSSOM	FRUIT	
41,2778	Platanus x acerifolia	13967	40,00	50,00	44,44	75,00	20,00	33,33	
37,6667	Celtis australis	13048	40,00	25,00	33,33	75,00	20,00	33,33	
31,0833	Acer platanoides	9949	0,00	12,50	33,33	75,00	40,00	0,00	
25,1944	Carpinus betulus	9034	0,00	12,50	44,44	75,00	20,00	0,00	
30,0556	Fraxinus excelsior	7554	0,00	25,00	22,22	50,00	20,00	0,00	
20,1111	Liquidambar styraciflua	7480	20,00	25,00	11,11	75,00	20,00	33,33	
28,8889	Populus nigra	7450	0,00	75,00	22,22	75,00	0,00	0,00	
38,4167	Robinia pseudoacacia	7352	40,00	37,50	33,33	50,00	40,00	0,00	
39,4167	Ulmus spp	5947	40,00	62,50	33,33	75,00	0,00	0,00	
34,8889	Quercus rubra	5934	40,00	25,00	22,22	75,00	20,00	0,00	
30,6667	Tilia spp	5675	0,00	25,00	33,33	75,00	40,00	0,00	
30,6667	Tilia cordata	5671	0,00	25,00	33,33	75,00	40,00	0,00	
92,3889	Prunus cerasifera	5424	80,00	100,00	88,89	75,00	80,00	100,00	
33,2500	Acer pseudoplatanus	5399	0,00	37,50	33,33	75,00	20,00	33,33	
41,2778	Platanus spp	5394	40,00	50,00	44,44	75,00	20,00	33,33	
33,7778	Quercus robur	5189	40,00	25,00	11,11	75,00	20,00	0,00	
30,5833	Acer negundo	4652	20,00	12,50	33,33	50,00	40,00	33,33	
39,8056	Sophora japonica	4492	40,00	62,50	22,22	50,00	40,00	33,33	
33,1667	Acer saccharinum	4374	20,00	25,00	33,33	50,00	20,00	33,33	
44,5833	Aesculus hippocastanum	4326	40,00	12,50	33,33	50,00	60,00	33,33	
100,0000	Prunus serrulata	4011	100,00	100,00	100,00	100,00	100,00	100,00	
34,6667	Cercis siliquastrum	3982	40,00	25,00	33,33	75,00	40,00	33,33	
39,4167	Ulmus pumila	3521	40,00	62,50	33,33	75,00	0,00	0,00	
29,3889	Liriodendron tulipifera	3231	20,00	0,00	22,22	75,00	60,00	33,33	
41,2778	Platanus hybrida	2670	40,00	50,00	44,44	75,00	20,00	33,33	
56,3889	Pyrus calleryana	2588	40,00	50,00	22,22	75,00	60,00	33,33	
30,6389	Fraxinus ornus	2567	40,00	37,50	22,22	50,00	40,00	0,00	
46,6667	Prunus avium	2530	40,00	25,00	33,33	75,00	60,00	66,67	
38,0000	Tilia americana	2472	40,00	25,00	33,33	75,00	40,00	33,33	
38,2778	Ginkgo biloba	2440	60,00	25,00	11,11	50,00	20,00	33,33	
35,5000	Ailanthus altissima	2418	60,00	25,00	33,33	50,00	20,00	33,33	
39,4167	Acer campestre	2383	40,00	62,50	33,33	75,00	0,00	0,00	
35,9444	Hibiscus syriacus	2296	80,00	0,00	11,11	75,00	60,00	0,00	
24,3611	Cedrus atlantica	2184	20,00	37,50	11,11	25,00	0,00	33,33	
31,6389	Ulmus carpinifolia	2143	40,00	12,50	22,22	75,00	0,00	33,33	
46,9167	Morus alba	1978	20,00	37,50	33,33	75,00	20,00	33,33	
35,4444	Tilia platyphyllos	1893	20,00	25,00	44,44	75,00	40,00	0,00	
40,6667	Gleditsia triacanthos	1850	20,00	50,00	33,33	50,00	20,00	33,33	
100,0000	Prunus spp	1768	100,00	100,00	100,00	100,00	100,00	100,00	
37,6667	Celtis spp	1703	40,00	25,00	33,33	75,00	20,00	33,33	

Final Considerations

Due to the size of the database and the number of possible queries, I have yet to scratch the surface with how useful it could be.

This could be used as a basis for future research by all types of professionals and even enthusiasts.

The main short coming of the database:

- The lack of standardized tree descriptions.
- Inaccuracies in Milan's inventory.
- Lack of Geospatial data pretaining to the urban environment to compare with the species characterists.

Resolving these will get us closer to a wholistic green management system.

Thank you for your time !