Woody species and supporting ecosystem services: the case study of the city of Turin (Italy)

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Abstract

The growth of the world's urban population enhances the interest for urban forests and their ecosystem services (ES). Trees and shrubs in urban environments provide habitats for many living organisms and several supporting services for human well-being, such as biodiversity increasing. The aim of the research was to assess supporting ES in terms of biodiversity provided by woody species of the Turin city, one of the most polluted Italian cities. After a deep bibliographic research, data of the *census* provided in March 2019 by the Turin Municipality (AlberaTo system) were analysed using a GIS platform. The main ecological indicators have been analysed to evaluate the level of woody species biodiversity of the city (Simpson' diversity index and Shannon evenness index) and their ecosystem services. The levels of biodiversity are different among neighborhoods, the mean diversity values were generally medium-high, and the evenness values were high. Furthermore, the degree of similarity among neighborhoods was calculated with Jaccard index and Bray-Curtis index. The study suggested planning guidelines for selecting in which Turin neigborhoods the improvement of biodiversity is a priority. The future green areas planning activities must consider these results, aiming at increasing the number of woody species and the related level of biodiversity in the neighborhoods of Turin.

Keywords: urban horticulture, green areas, ecological index, nature-based solutions, biodiversity

INTRODUCTION

Urban green areas are important for sustainable and healthy cities' development, supplying several ecosystem services. In dense urbanised cities, biodiversity, that belongs to the supporting ecosystem services, can be improved with correct urban green infrastructure planning (Capotorti et al., 2019). Trees have an important role in increasing biodiversity and ecosystem provision in cities (Morgenroth et al., 2016), but also shrubs, that not always are considered, can give a contribute in this sense. According with Carrus et al. (2015) the level of biodiversity in urban or peri-urban green spaces influences positively the human wellbeing.

Battisti et al. (2019a) reported that Turin neighborhoods are different themselves for the ecosystem services provision and socio-demographic conditions. Particularly, they observed that the biggest need of ecosystem services improvement is in neighborhoods located in the central and southern part of the city.

In this context, the present research proposed a methodology for identify the level of biodiversity in the different Turin neighborhoods. Like proposed by Hurley and Emery (2018) the study was focused not only on trees but also on shrubs.

Research aim

The aim of the research was to assess supporting ecosystem services (ES) in Turin city provided by woody species at neighborhood's scale. For this reason, the level of biodiversity related to the woody species was analysed with some ecological indices.

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MATERIALS AND METHODS

Study area

Turin is an Italian city located in the West Po Valley in Piedmont close to the Alps and is characterized by a low air circulation and high air pollution (European Environmental Agency, 2018). It is the Turin's Metropolitan City's capital, characterised by 312 municipalities, covering 6,827 km^2 with about 2,270,000 inhabitants. Turin extents over 130 km^2 where nearly 883,000 people are living in.

Turin public geoportal contains the main cartographic information about the city. Relatively to the woody species, they were censed into a web application used for trees management called Albera.TO. Like shown in Figure 1, in Albera.TO 63 701 trees and shrubs are mapped. Cartographic analysis was carried out with QGIS 2.18.1 software (Open Source Geospatial Foundation, Beaverton, OR, USA). Data was provided by Albera.TO in March 2019 (Albera.TO, 2019).

Figure 1. Woody species censed on Turin's Albera.TO system. Data for neighborhoods 21 and 22 are not available. Turin neighborhoods: Centro (1), San Salvario (2), Crocetta (3), San Paolo (4), Cenisia (5), San Donato (6), Aurora (7), Vanchiglia (8), Nizza Millefonti (9), Mercati Generali (10), Santa Rita (11), Mirafiori Nord (12), Pozzo Strada (13), Parella (14), Le Vallette (15), Madonna di Campagna (16), Borgata Vittoria (17), Barriera di Milano (18), Falchera (19), Regio Parco (20), Madonna del Pilone (21), Borgo Po e Cavoretto (22), Mirafiori Sud (23).

Assessment method

In order to assess supporting ecosystem services provided by Turin's woody species' biodiversity, ecological analyses were performed. Statistical data were processed using Past 3.14 (Hammer et al., 2001). Ecological analysis considered the species diversity among neighborhoods, based on Simpson diversity index and the Buzas and Gibson's evenness (Simpson, 1949; Buzas and Gibson, 1969) and the degree of similarity among the woody species in the neighborhoods, performing the Jaccard and the Bray-Curtis indexes (Chao et al., 2006).

Species diversity

At neighborhoods scale, all the individual trees and shrubs were summed, and the number of species was calculated. Cartographical analyses were made with QGIS software.

Simpson diversity index represents the probability that two trees randomly selected from a sample will belong to different species. The value ranges between 0 and 1. The greater the value, the greater the sample diversity. The index was obtained with the following formula:

$$\text{Simpson index} = 1\text{-}D$$

where D is the Dominance (Hammer et al., 2001).

Buzas and Gibson's evenness index assumes a value between 0 (communities with only a single taxon) and 1 (communities with many taxa), with 1 being complete evenness. It was obtained with the following formula:

$$\text{Buzas and Gibson's evenness} = e^{H/S}$$

where H is the Shannon index and S the number of taxa (Hammer et al., 2001).

Degree of similarity among neighborhoods

The degree of woody species abundance between neighborhoods was performed using Jaccard and Bray-Curtis similarity indices.

Jaccard index (dJ) measures similarity using presence/absence data and was calculated with the following formula:

$$dJ = M/(M + N)$$

where M is the number of matches and N is the total number of columns with a presence in just one row (Battisti at al., 2019b).

Instead, Bray-Curtis index (dBC) measures similarity using abundance data and was calculated with the following formula:

$$d_{BC} = 1 - \frac{\sum_i |x_{ji} - x_{ki}|}{\sum_i (x_{ji} + x_{ki})}$$

where X_{ji} is the entry in the *i*th row and *j*th column of the data matrix, X_{ki} is the count for the *i*th species in the k^{th} sample (Battisti et al., 2019b).

Both indices assume values from 0 to 1 where 1 means that the two compared communities share all their species, while a value of 0 means they share none.

RESULTS AND DISCUSSION

In Table 1 species diversity indices are reported. The values obtained from Simpson index are particularly high, always higher than 0.8, indicating a great diversity in terms of woody species. This result is particularly evident in neighborhoods 2 and 16 where the values are the closest to 1. Conversely, the results of the Buzas and Gibson's evenness index are always very low, indicating a low evenness value in every Turin neighborhoods, especially in neighborhood 1 that has the closest value to 0. This could be due to the fact that the large avenues, with lot of trees, are mainly made up of only one or few species, such as *Platanus orientalis* L., *Celtis australis* L. and *Tilia* × *europaea* L.

Table 1. Species richness, Simpson diversity index and Buzas and Gibson's evenness index of trees in Turin neighborhoods (modified by Battisti et al., 2019a). Data for neighborhoods 21 and 22 are not available.

Neighborhoods	Individuals	Species richness	Simpson diversity index	Buzas and Gibson's evenness index
1. Centro	3961	75	0.86	0.18
2. San Salvario	2860	81	0.95	0.39
3. Crocetta	3924	42	0.78	0.21
4. San Paolo	2036	52	0.88	0.26
5. Cenisia	2374	71	0.88	0.21
6. San Donato	2469	56	0.88	0.25
7. Aurora	2616	53	0.87	0.25
8. Vanchiglia	3261	59	0.89	0.26
9. Nizza Millefonti	1299	52	0.89	0.32
10. Mercati generali	3056	70	0.92	0.31
11. Santa Rita	4247	78	0.86	0.21
12. Mirafiori Nord	4699	74	0.91	0.28
13. Pozzo Strada	4692	73	0.88	0.21
14. Parella	4003	98	0.92	0.24
15. Le Vallette	3673	68	0.91	0.25
16. Madonna di Campagna	2089	81	0.93	0.30
17. Borgata Vittoria	1371	55	0.90	0.31
18. Barriera di Milano	1435	52	0.88	0.29
19. Falchera	2268	66	0.89	0.26
20. Regio Parco	2203	69	0.92	0.32
23. Mirafiori Sud	5165	77	0.89	0.23

Table 2 reports Jaccard index and Bray-Curtis index values of Turin' neighborhoods. Generally, it is not possible to state that there are high levels of similarity between neighborhoods. However, it is possible to observe how the Jaccard index identifies a good similarity in terms of species presence between neighborhoods 9-23, 10-11, 10-12, 10-23 and 12-23. On the other hand, the Bray-Curtis index identifies a good similarity in terms of species abundance between neighborhoods 3-1, 8-5, 12-8, 12-11, 23-11, 14-12, 23-12, 23-13, 15-14, 15-19 and 15-23.

Therefore, data showed that the level of biodiversity in Turin is medium-high. This level needs to be improved with correct policies choices. However, primary overarching issues for biodiversity planning and management are gaps between science and policy, local government access to research findings, and communication of research to stakeholders. To conserve biodiversity diverse stakeholders – including ecologists, managers, developers, students, and citizens – should be encouraged to join in collaborative networks to share data, engage in interdisciplinary research, and discuss urban biodiversity management, design, and planning. (Aronson et al., 2017). Turin needs an urban green areas management plan that takes into consideration woody species. The mapping of trees and above all shrubs must be improved. Future goal is to increase biodiversity and, consequently, the level of neighborhoods' equitability.

Table 2. Jaccard index (*italic*) and Bray-Curtis index values of Turin neighborhoods. Data for neighborhoods 21 and 22 are not available.

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**23**
1	1.00	0.47	**0.66**	0.48	0.56	0.49	0.53	0.52	0.30	0.51	0.60	0.53	0.57	0.51	0.59	0.35	0.22	0.37	0.49	0.39	0.54
2	*0.53*	1.00	0.38	0.45	0.43	0.38	0.48	0.41	0.30	0.48	0.45	0.44	0.43	0.50	0.47	0.44	0.34	0.41	0.49	0.47	0.41
3	*0.44*	*0.35*	1.00	0.32	0.44	0.50	0.41	0.33	0.31	0.35	0.44	0.44	0.43	0.39	0.50	0.25	0.23	0.31	0.39	0.37	0.41
4	*0.48*	*0.41*	*0.42*	1.00	0.63	0.48	0.55	0.60	0.45	0.57	0.49	0.51	0.47	0.49	0.44	0.44	0.32	0.43	0.60	0.48	0.43
5	*0.60*	*0.49*	*0.38*	*0.50*	1.00	0.62	0.62	**0.65**	0.42	0.61	0.54	0.56	0.53	0.51	0.55	0.43	0.32	0.53	0.58	0.48	0.50
6	*0.44*	*0.38*	*0.38*	*0.40*	*0.48*	1.00	0.55	0.57	0.52	0.53	0.53	0.61	0.51	0.55	0.61	0.42	0.37	0.45	0.58	0.59	0.50
7	*0.45*	*0.41*	*0.42*	*0.50*	*0.51*	*0.47*	1.00	0.60	0.36	0.51	0.51	0.58	0.54	0.51	0.48	0.38	0.29	0.42	0.57	0.39	0.56
8	*0.47*	*0.47*	*0.35*	*0.46*	*0.51*	*0.40*	*0.42*	1.00	0.40	0.58	0.51	**0.67**	0.50	0.53	0.47	0.41	0.26	0.45	0.54	0.45	0.56
9	*0.43*	*0.45*	*0.40*	*0.46*	*0.48*	*0.46*	*0.44*	*0.48*	1.00	0.45	0.32	0.35	0.28	0.38	0.35	0.45	0.30	0.29	0.46	0.50	0.30
10	*0.61*	*0.54*	*0.38*	*0.54*	*0.62*	*0.54*	*0.52*	*0.55*	*0.61*	1.00	0.58	0.55	0.54	0.56	0.49	0.48	0.34	0.45	0.61	0.47	0.51
11	*0.61*	*0.54*	*0.40*	*0.53*	*0.62*	*0.51*	*0.49*	*0.51*	*0.53*	***0.66***	1.00	**0.65**	0.72	0.57	0.58	0.38	0.29	0.35	0.53	0.44	**0.67**
12	*0.59*	*0.53*	*0.36*	*0.54*	*0.61*	*0.44*	*0.48*	*0.58*	*0.54*	***0.66***	*0.62*	1.00	0.62	**0.66**	0.58	0.39	0.33	0.35	0.58	0.51	**0.75**
13	*0.54*	*0.56*	*0.46*	*0.51*	*0.55*	*0.48*	*0.42*	*0.55*	*0.51*	*0.59*	*0.62*	*0.60*	1.00	0.54	0.54	0.38	0.27	0.33	0.50	0.41	**0.67**
14	*0.59*	*0.52*	*0.36*	*0.40*	*0.51*	*0.47*	*0.40*	*0.47*	*0.46*	*0.57*	*0.63*	*0.56*	*0.61*	1.00	**0.68**	0.43	0.31	0.38	**0.68**	0.57	**0.65**
15	*0.43*	*0.42*	*0.38*	*0.45*	*0.54*	*0.51*	*0.44*	*0.48*	*0.50*	*0.57*	*0.55*	*0.58*	*0.52*	*0.55*	1.00	0.37	0.29	0.38	0.58	0.55	0.60
16	*0.49*	*0.42*	*0.35*	*0.43*	*0.50*	*0.52*	*0.41*	*0.46*	*0.45*	*0.54*	*0.51*	*0.53*	*0.48*	*0.54*	*0.60*	1.00	0.39	0.32	0.41	0.43	0.34
17	*0.44*	*0.35*	*0.33*	*0.51*	*0.54*	*0.50*	*0.46*	*0.43*	*0.35*	*0.44*	*0.51*	*0.52*	*0.49*	*0.42*	*0.46*	*0.46*	1.00	0.32	0.36	0.36	0.24
18	*0.49*	*0.39*	*0.38*	*0.46*	*0.46*	*0.37*	*0.44*	*0.44*	*0.39*	*0.49*	*0.51*	*0.45*	*0.45*	*0.44*	*0.40*	*0.41*	*0.43*	1.00	0.48	0.42	0.33
19	*0.60*	*0.48*	*0.46*	*0.53*	*0.56*	*0.49*	*0.49*	*0.58*	*0.51*	*0.62*	*0.57*	*0.57*	*0.56*	*0.56*	*0.54*	*0.56*	*0.48*	*0.53*	1.00	0.59	0.52
20	*0.52*	*0.47*	*0.44*	*0.46*	*0.56*	*0.40*	*0.47*	*0.52*	*0.44*	*0.51*	*0.53*	*0.51*	*0.49*	*0.52*	*0.52*	*0.47*	*0.44*	*0.53*	*0.61*	1.00	0.48
23	*0.63*	*0.53*	*0.37*	*0.50*	*0.59*	*0.51*	*0.44*	*0.55*	*0.55*	***0.67***	*0.63*	***0.74***	*0.63*	*0.62*	*0.58*	*0.55*	*0.45*	*0.43*	*0.63*	*0.54*	1.00

CONCLUSIONS

The following preliminary conclusions can be drawn from the study:

- Woody species can contribute to increase the biodiversity in urban cities and improve the supporting ecosystem services supply;
- In Turin there are neighborhoods characterised by higher or lower biodiversity level and more or less similar themselves. Where the biodiversity level is high, similarity among neighborhoods is a positive aspect;
- For future planning policies the objective is choose woody species (trees and shrubs) capable of provide ecosystem services and limit potential disservices.

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