Plant diversity and grassland naturalness of differently managed urban areas of Torino (NW Italy)

Michele Lonati[a], Massimiliano Probo, Alessandra Gorlier, Marco Pittarello, Valentina Scariot, Giampiero Lombardi, and Simone Ravetto Enri
Department of Agricultural, Forest and Food Sciences, University of Torino, Largo Paolo Braccini 2, 10095 Grugliasco (TO), Italy.

Abstract

The interest in urban grassland management has markedly increased over the last years, due to its essential role for biodiversity conservation and ecosystem service provision. In the metropolitan area of Torino, we compared plant species richness and habitat naturalness of urban grasslands subjected to three cutting regimes (characterized by one, four, and eight cuttings per year, respectively). Habitat naturalness was assessed using a phytosociological approach, considering the total number and percentage cover of species belonging to three different vegetation groups: i) annual ruderal, ii) perennial ruderal, and iii) semi-natural grassland species. The one-cutting regime negatively affected both plant species diversity and habitat naturalness, since it favoured the highest cover of ruderal species, which reduced semi-natural grassland species cover. Conversely, the four-cutting regime showed comparable results to the eight-cutting regime, with higher species richness and Shannon diversity index values than the one-cutting regime. Moreover, under both regimes, the highest values for the total number and percentage cover of semi-natural grassland species were detected. Consequently, we suggest the four-cutting regime as the best grassland urban management option, thanks to its higher benefit-cost ratio.

Keywords: cutting regime, urban meadows, phytosociological approach, ruderal species, urban green management.

INTRODUCTION

Permanent grasslands are key ecosystems for biodiversity conservation (Dengler et al., 2014) and provision of ecosystem services, such as nutrient cycling, carbon sequestration, water quality, forage production and quality, and related animal-based food quality (Gorlier et al., 2013; Lonati et al., 2015; Ravetto Enri et al., 2017b). The botanical composition and ecological functions of semi-natural, agriculturally improved, and urban grasslands are strongly affected by anthropic activities, such as grazing and cutting regimes and fertilization rates (Iussig et al., 2015; Manninen et al., 2010; Pittarello et al., 2016a; Probo et al., 2014; Ravetto Enri et al. 2017a).

In particular, the interest in the evaluation of habitat diversity in urban grasslands has greatly increased over the last years, since these ecosystems display a pivotal ecological role for both human and wildlife well-being, and they represent an important habitat for a wide number of plant and animal species (Angold et al., 2006; Ranta, 2008; Tikka et al., 2000). Compared to semi-natural grasslands, urban grasslands are exposed to more frequent and intense disturbance regimes by periodic cutting (McKinney, 2002). Despite this, the vegetation of urban grasslands shows a high resilience, with often a very stable species composition under constant disturbance events. The adaptation to constant disturbances is also shown by the high number of alien, invasive, and ruderal species adapted to early successional stages and open environments (Ranta et al., 2015).

Nevertheless, the effects produced on biodiversity conservation by different urban grassland management strategies have been scarcely explored and only a few studies have

[a] E-mail: michele.lonati@unito.it

been recently conducted. For instance, Manninen et al. (2010) proposed a regular management with grass removal for the grasslands of Helsinki, since this strategy can mitigate the negative effects of nitrogen deposition on plant diversity and contrast ruderal species encroachment. Moreover, nowadays one of the major challenges is to find cost-effective management strategies. When the number of cuttings per years in urban grasslands and greenways is reduced, negative effects on city aesthetics, road border functionality, and biodiversity are generally observed (Fuller et al., 2007; Southon et al., 2017). These effects may be attributed to the decrease of plant species typical of semi-natural grasslands and to the consequent increase of ruderal species (Fischer et al., 2013).

In the present case study, we evaluated the effects of cutting frequency on plant species composition within an urban grassland area, comparing three management regimes with one, four, and eight cuttings per year, respectively. We hypothesised that different cutting regimes would differently affect plant species diversity and habitat naturalness, i.e. the number and cover of ruderal and semi-natural grassland species.

MATERIALS AND METHODS

Study area

The study was conducted in the urban grasslands of the Department of Agricultural, Forest and Food Sciences (University of Torino) campus, which is located in Grugliasco, within the metropolitan area of Torino, north-western Italy. The site is located at 300 m a.s.l. and characterised by sandy soils, with average annual temperature of 13.3 °C and precipitation of 888 mm (average values for the period 2004-2017, according to the weather station located in Rivoli).

Grasslands originated from anthropic sowing, carried out when buildings were completed (i.e. in the 1970s). Grasslands were dominated by *Festuca rubra* L., *Agrostis tenuis* Sibth., and *Agropyron repens* (L.) Beauv. The differences in plant species composition of the vegetation communities studied were not ascribable to differences in bedrock or topsoil layer, which were homogeneous in the whole study area, rather to differences in the cutting regime to which grasslands were subjected, i.e. in the number of cuttings per year.

Since 1996, grasslands have been managed under three different cutting regimes: lenient (one cutting per year, in June; MW1), intermediate (four cuttings per year, in May, June, July, and September; MW4), and intense (eight cuttings per year, two in May and June, one in July and August, and two in September; MW8). The cuttings were carried out approximately in the same days each year, by riding lawn mowers with a cutting height of approximately 5 cm, removing the mown vegetation.

Vegetation surveys and calculations

For each of the three cutting regimes, five 2x2 m plots were randomly established for three consecutive years (i.e. in 2015, 2016, and 2017). Vegetation surveys (n = 45) were carried out approximately in mid-May.

Plant species composition was evaluated using the phytosociological method (Braun-Blanquet et al., 1932). Taxonomic nomenclature followed Pignatti (1982). The Braun-Blanquet frequency-abundance values (Reichelt and Wilmanns, 1973) were converted into percentage cover values, according to Tasser and Tappeiner (2005).

Plant diversity was assessed for each survey by calculating species richness (i.e. the total number of the recorded species) and Shannon diversity index (Magurran, 1988).

Habitat naturalness was assessed using a phytosociological approach. Firstly, each plant species was associated to its phytosociological optimum (at the class level) according to Aeschimann et al. (2004). This approach has been largely used to evaluate vegetation response to management and disturbance regimes in different ecosystems (Lonati et al., 2013; Moris et al., 2017; Orlandi et al., 2016; Pittarello et al., 2016b; Vacchiano et al., 2016). Secondly, according to their phytosociological optimum, plant species were grouped into three vegetation units, according to an increasing gradient of habitat naturalness: i) annual ruderal species (i.e. the species belonging to *Stellarietea mediae* class), ii) perennial ruderal species (i.e. the species belonging to *Agropyretea intermedii-repentis* and *Artemisietea vulgaris* classes), and iii) semi-natural grassland species (i.e. species belonging to *Molinio-Arrhenatheretea* and *Festuco-Brometea* classes and to the fringe communities of *Trifolio-Geranietea sanguinei* and *Epilobietea angustifolii* classes). The species belonging to *Thlaspietea rotundifolii* and *Koelerio-Corynephoretea* classes accounted for a negligible percentage cover and were not included in further analyses. The complete species list and the corresponding phytosociological optimum are available in Electronic Appendix 1. The total number and the total percentage cover of species belonging to the three vegetation units were computed for each survey.

Statistical analysis

A mixed model was performed on species richness and Shannon diversity index, with plot as statistical unit, cutting regime as fixed factor, and year as random factor. The same analysis was performed on the total number and total percentage cover of species belonging to annual ruderal, perennial ruderal, and semi-natural grassland species. Assumptions of normality and homogeneity of variance were checked with Shapiro-Wilk and Levene's tests, respectively. After each mixed model, when significant differences were found, Tukey's *post-hoc* tests were performed. All statistical analyses were carried out using SPSS 24 (IBM Corp., 2016).

RESULTS AND DISCUSSION

A total of 80 plant species were detected during the three-years study (see Electronic Appendix 1), with an average species richness of 19 species and a Shannon diversity index of 3.2 per survey. Similar results were found by other research conducted over urban temperate grasslands (Hermy and Cornelis, 2000; Rudolph et al., 2017).

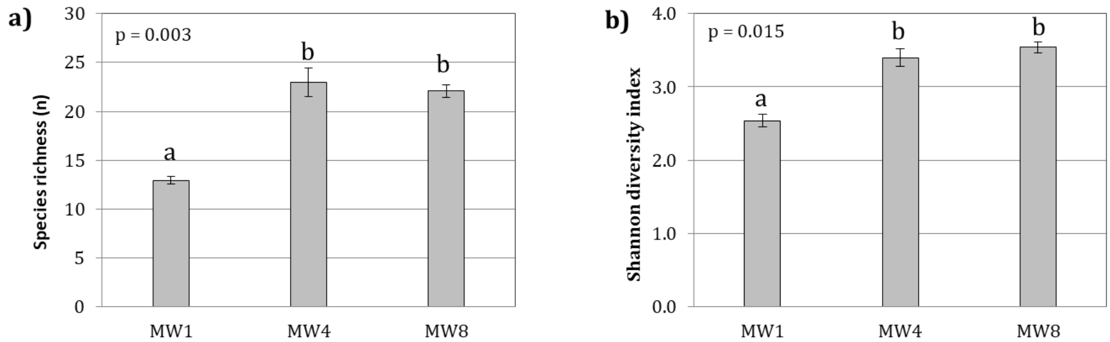

Figure 1. Species richness (a) and Shannon diversity index (b) of the studied urban grassland communities. MW1, MW4, and MW8 identify the one-, four-, and eight-cuttings per year regimes, respectively. Error bars represent the standard error of the averages, while letters above histograms indicate significant differences among cutting regimes according to Tukey's *post-hoc* test.

Plant species diversity was lower in MW1 than in MW4 and MW8, in terms of both species richness and Shannon diversity index (Figures 1a and 1b, respectively). Similarly, Manninen et al. (2010) compared in their study different cutting regimes and found that the number of plant species decreased with the reduction of management intensity of urban grassland.

Annual ruderal species were more abundant in MW4, but only in terms of species richness, whereas no differences for percentage covers among the three cutting regimes were detected (Figures 2a and 2b, respectively). Perennial ruderal species showed a lower species richness under the intense cutting regime (Figure 2c), but this result had a negligible ecological significance, since the difference was of +1.7 and +1.1 species in MW1 and in MW4, respectively, when compared to MW8. The percentage cover of perennial ruderal species was higher in MW1 than in MW4 and MW8 (Figure 2d), but the difference between the intermediate and the intense cutting management (that is, -6.6% of percentage cover) had minor ecological implications. Similarly to biodiversity indexes, semi-natural grassland species had the lowest species richness and percentage cover in the lenient cutting regime (Figures 2e and 2f, respectively).

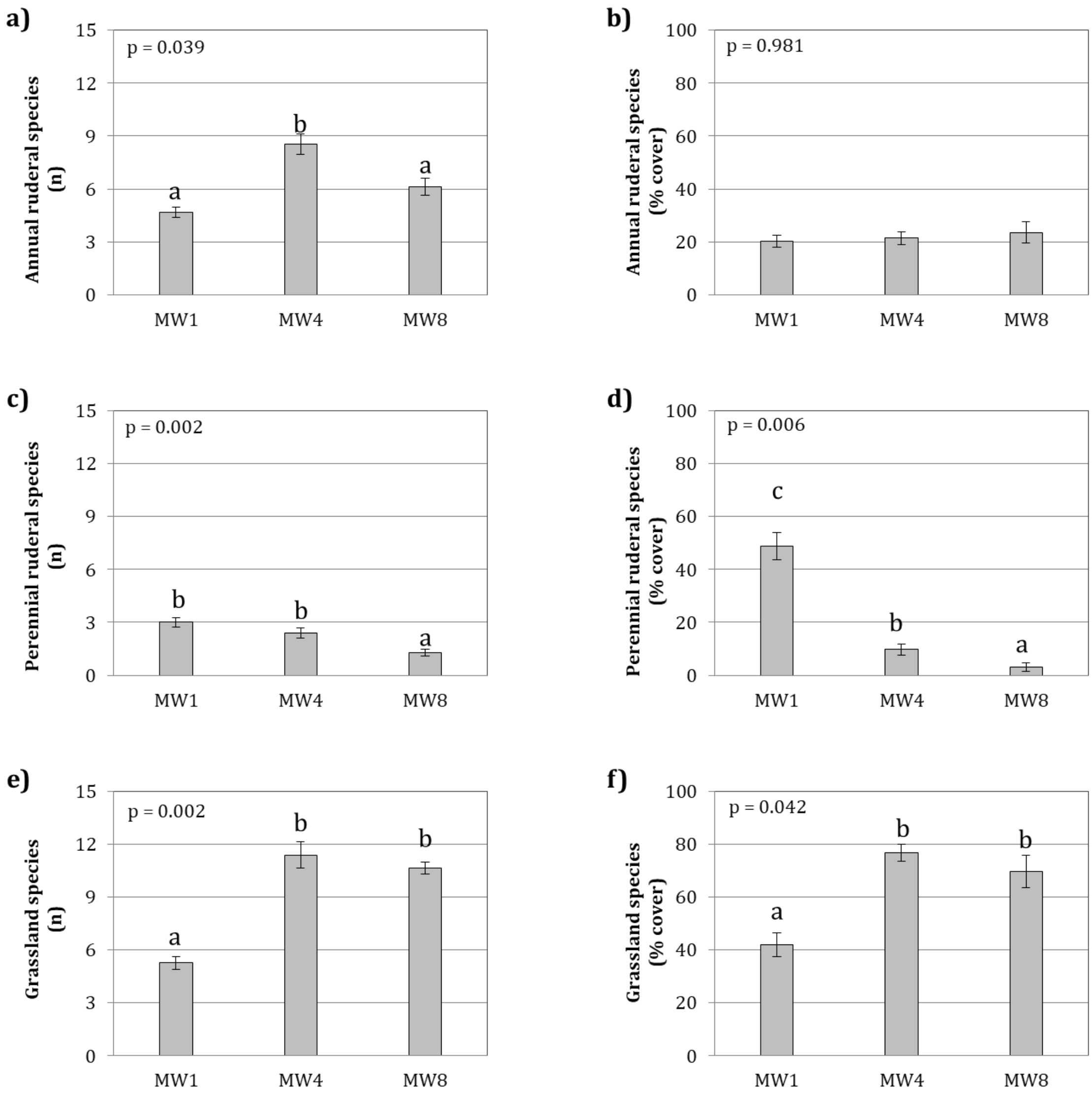

Figure 2. Species richness (a, c, and e) and percentage cover (b, d, and f) of the three selected vegetation units. MW1, MW4, and MW8 identify the one-, four-, and eight-cuttings per year regimes, respectively. Error bars represent the standard error of the averages while letters above histograms indicate significant differences among cutting regimes according to Tukey's *post-hoc* test.

As pointed out by other authors (Öckinger et al., 2009), we found that a low cutting frequency can negatively affect plant species diversity in urban managed grasslands, by allowing seed dispersal and encroachment of ruderal species (mainly the perennial ones). In our study area, these species (in particular *A. repens*) spread over large patches, where they dominated the vegetation communities, thus explaining the lowest biodiversity values found in MW1. In addition, our results highlighted that the levels of plant species diversity of the intense cutting regime (MW8) can be also achieved by an intermediate cutting regime (MW4), which could thus represent the best management trade-off, thanks to its higher benefit-cost ratio.

In contrast to our results, Venn and Kotze (2014) evaluated the effects of increasing frequency cutting regimes on plant species composition and diversity in Swedish urban grasslands and highlighted that the optimal management option was to apply a cutting once or twice per year, while leaving some unmanaged areas to maintain habitat heterogeneity. Consequently, due to contrasting results under different bio-climatic and vegetation conditions, additional research appears recommended at larger scale. Moreover, in further research, greater attention should be addressed to the effects of the cutting management on allergenic plant species, since it may considerably affect life quality in urban areas (Bosch-Cano et al., 2011; Werchan et al., 2017).

CONCLUSIONS

The present study highlighted that cutting frequency is an essential tool in urban grassland management, since it can significantly affect plant species diversity and habitat naturalness. A low cutting frequency (one cutting per year) decreased both biodiversity and habitat naturalness due to the dominance of perennial ruderal species within the sward. Our results suggest that a management regime with four cuttings per year represent the best management option, thanks to its higher benefit-cost ratio. Indeed, it could achieve the same results of a more intense management regime (eight cuttings per year), while considerably reducing management costs.

AKNOWLEDGMENTS

The authors thank all the students who participated to the vegetation surveys within the Laboratory of Geobotany and Phytosociology in the Academic years 2014/2015, 2015/2016, and 2016/2017.

Literature cited

Aeschimann, D., Lauber, K., Moser, D.M., Theurillat, J.P., 2004. Flora alpina: atlante delle 4500 piante vascolari delle Alpi. Zanichelli, Bologna, Italy.

Angold, P.G., Sadler, J.P., Hill, M.O., Pullin, A., Rushton, S., Austin, K., Small, E., Wood, B., Wadsworth, R., Sanderson, R., Thompson, K., 2006. Biodiversity in urban habitat patches. Sci. Total Environ., Urban Environmental Research in the UK: The Urban Regeneration and the Environment (NERC URGENT) Programme and associated studies. 360, 196–204. doi:10.1016/j.scitotenv.2005.08.035

Bosch-Cano, F., Bernard, N., Sudre, B., Gillet, F., Thibaudon, M., Richard, H., Badot, P.-M., Ruffaldi, P., 2011. Human exposure to allergenic pollens: A comparison between urban and rural areas. Environ. Res. 111, 619–625. doi:10.1016/j.envres.2011.04.001

Braun-Blanquet, J. (Josias), Fuller, G.D. (George D., Conard, H.S., 1932. Plant sociology; the study of plant communities; New York and London, McGraw-Hill book company, inc.

Dengler, J., Janišová, M., Török, P., Wellstein, C. 2014. Biodiversity of Palaearctic grasslands: A synthesis. Agr. Ecosys. Environ. 182, 1-14. doi: 10.1016/j.agee.2013.12.015

Fischer, L.K., Lippe, M. von der, Rillig, M.C., Kowarik, I., 2013. Creating novel urban grasslands by reintroducing native species in wasteland vegetation. Biol. Conserv. 159, 119–126. doi:10.1016/j.biocon.2012.11.028

Fuller, R.A., Irvine, K.N., Devine-Wright, P., Warren, P.H., Gaston, K.J., 2007. Psychological benefits of greenspace increase with biodiversity. Biol. Lett. 3, 390–394. doi:10.1098/rsbl.2007.0149

Gorlier, A., Lonati, M., Renna, M., Lussiana, C., Lombardi, G., Battaglini, L.M. 2012. Changes in pasture and cow milk compositions during a summer transhumance in the western Italian Alps. J. Appl. Bot. Food Qual. 85 (2), 216-223. doi: 10.5073/jabfq.2325.85.2.216

Hermy, M., Cornelis, J., 2000. Towards a monitoring method and a number of multifaceted and hierarchical biodiversity indicators for urban and suburban parks. Landsc. Urban Plan. 49, 149–162. doi:10.1016/S0169-2046(00)00061-X

IBM Corp., 2016. IBM SPSS Statistics for Windows, Version 24.0. IBM Corporation, Armonk, NY.

Iussig, G., Lonati, M., Probo, M., Hodge, S., Lombardi, G. 2015. Plant species selection by goats foraging on montane semi-natural grasslands and grazable forestlands in the Italian Alps. Ital. J. Anim. Sci., 14 (3), 484-494. doi: 10.4081/ijas.2015.3907

Lonati, M., Vacchiano, G., Berretti, R., Motta, R., 2013. Effect of stand-replacing fires on Mediterranean plant species in their marginal alpine range. Alp. Bot. 123, 123–133. doi:10.1007/s00035-013-0115-6

Lonati, M., Probo, M., Gorlier, A., Lombardi, G. 2015. Nitrogen fixation assessment in a legume-dominant alpine community: comparison of different reference species using the 15N isotope dilution technique. Alpine Bot., 125 (1), 51-58. doi: 10.1007/s00035-014-0143-x

Magurran, A.E., 1988. Ecological Diversity and Its Measurement. Princeton University Press, Princeton, NJ, USA.

Manninen, S., Forss, S., Venn, S., 2010. Management mitigates the impact of urbanization on meadow vegetation. Urban Ecosyst. 13, 461–481. doi:10.1007/s11252-010-0129-4

McKinney, M.L., 2002. Urbanization, Biodiversity, and Conservation. BioScience 52, 883–890. doi:10.1641/0006-3568(2002)052[0883:UBAC]2.0.CO;2

Moris, J.V., Vacchiano, G., Enri, S.R., Lonati, M., Motta, R., Ascoli, D., 2017. Resilience of European larch (Larix decidua Mill.) forests to wildfires in the western Alps. New For. 48, 663–683. doi:10.1007/s11056-017-9591-7

Öckinger, E., Dannestam, Å., Smith, H.G., 2009. The importance of fragmentation and habitat quality of urban grasslands for butterfly diversity. Landsc. Urban Plan. 93, 31–37. doi:10.1016/j.landurbplan.2009.05.021

Orlandi, S., Probo, M., Sitzia, T., Trentanovi, G., Garbarino, M., Lombardi, G., Lonati, M., 2016. Environmental and land use determinants of grassland patch diversity in the western and eastern Alps under agro-pastoral abandonment. Biodivers. Conserv. 25, 275–293. doi:10.1007/s10531-016-1046-5

Pignatti, S. 1982. Flora d'Italia. Edagricole, Bologna, Italy.

Pittarello, M., Probo, M., Lonati, M., Bailey, D.W., Lombardi, G. 2016a. Effects of traditional salt placement and strategically placed mineral mix supplements on cattle distribution in the Western Italian Alps. Grass Forage Sci., 71 (4), 529-539. doi: 10.1111/gfs.12196

Pittarello, M., Probo, M., Lonati, M., Lombardi, G., 2016b. Restoration of sub-alpine shrub-encroached grasslands through pastoral practices: effects on vegetation structure and botanical composition. Appl. Veg. Sci. 19, 381–390. doi:10.1111/avsc.12222

Probo, M., Lonati, M., Pittarello, M., Bailey, D.W., Garbarino, M., Gorlier, A., Lombardi, G. 2014. Implementation of a rotational grazing system with large paddocks changes the distribution of grazing cattle in the south-western Italian Alps. Rangeland J, 36 (5), 445-458. doi: 10.1071/RJ14043

Ranta, P., 2008. The importance of traffic corridors as urban habitats for plants in Finland. Urban Ecosyst. 11, 149. doi:10.1007/s11252-008-0058-7

Ranta, P., Kesulahti, J., Tanskanen, A., Viljanen, V., Virtanen, T., 2015. Roadside and riverside green – urban corridors in the city of Vantaa, Finland. Urban Ecosyst. 18, 341–354. doi:10.1007/s11252-014-0402-z

Reichelt, G., Wilmanns, O., 1973. Vegetationsgeographie, Westermann. ed. Braunschweig.

Ravetto Enri, S., Probo, M., Farruggia, A., Lanore, L., Blanchetete, A., Dumont, B. 2017a. A biodiversity-friendly rotational grazing system enhancing flower-visiting insect assemblages while maintaining animal and grassland productivity. Agr., Ecosys. Environ. 241, 1-10. doi: 10.1016/j.agee.2017.02.030

Ravetto Enri, S., Renna, M., Probo, M., Lussiana, C., Battaglini, L.M., Lonati, M., Lombardi, G. 2017b. Relationships between botanical and chemical composition of forages: a multivariate approach to grasslands in the Western Italian Alps. J. Sci. Food Agr. 97 (4), 1252-1259. doi: 10.1002/jsfa.7858

Rudolph, M., Velbert, F., Schwenzfeier, S., Kleinebecker, T., Klaus, V.H., 2017. Patterns and potentials of plant species richness in high- and low-maintenance urban grasslands. Appl. Veg. Sci. 20, 18–27. doi:10.1111/avsc.12267

Southon, G.E., Jorgensen, A., Dunnett, N., Hoyle, H., Evans, K.L., 2017. Biodiverse perennial meadows have aesthetic value and increase residents' perceptions of site quality in urban green-space. Landsc. Urban Plan. 158, 105–118. doi:10.1016/j.landurbplan.2016.08.003

Tasser, E., Tappeiner, U., 2005. New model to predict rooting in diverse plant community compositions. Ecol. Model. 185, 195–211. doi:10.1016/j.ecolmodel.2004.11.024

Tikka, P.M., Koski, P.S., Kivelä, R.A., Kuitunen, M.T., 2000. Can grassland plant communities be preserved on road and railway verges? Appl. Veg. Sci. 3, 25–32. doi:10.2307/1478915

Vacchiano, G., Meloni, F., Ferrarato, M., Freppaz, M., Chiaretta, G., Motta, R., Lonati, M., 2016. Frequent coppicing deteriorates the conservation status of black alder forests in the Po plain (northern Italy). For. Ecol. Manag. 382, 31–38. doi:10.1016/j.foreco.2016.10.009

Venn, S., Kotze, D.J., 2014. Benign neglect enhances urban habitat heterogeneity: Responses of vegetation and carabid beetles (Coleoptera: Carabidae) to the cessation of mowing of park lawns. EJE 111, 703–714. doi:10.14411/eje.2014.089

Werchan, B., Werchan, M., Mücke, H.-G., Gauger, U., Simoleit, A., Zuberbier, T., Bergmann, K.-C., 2017. Spatial distribution of allergenic pollen through a large metropolitan area. Environ. Monit. Assess. 189, 169. doi:10.1007/s10661-017-5876-8

Electronic Appendix 1: list of the plant species detected during the three-year study, grouped in the vegetation units identified and used for data analyses. For each species the phytosociological optimum (according to Braun-Blanquet et al., 1932) and the percentage cover (mean dominance value - Tasser and Tappeiner, 2005 - of the five plots per cutting regime over the three years) are provided. MW1, MW4, and MW8 identify the one-, four-, and eight-cutting per year regimes, respectively.

Plant species	**Phytosociological optimum**	**Percentage cover**		
		MW1	**MW4**	**MW8**
Annual ruderal species		20.15	21.35	23.45
Alopecurus myosuroides Hudson	*Stellarietea mediae*	8.11	-	-
Aphanes arvensis L.	*Stellarietea mediae*	-	0.43	3.37
Asperula arvensis L.	*Stellarietea mediae*	-	-	0.19
Bromus hordeaceus L.	*Stellarietea mediae*	1.39	0.21	0.04
Bromus sterilis L.	*Stellarietea mediae*	-	0.21	-
Capsella bursa-pastoris (L.) Medicus	*Stellarietea mediae*	-	0.87	0.25
Cardamine hirsuta L.	*Stellarietea mediae*	0.04	0.29	0.06
Cerastium glomeratum Thuill.	*Stellarietea mediae*	-	0.77	-
Cynodon dactylon (L.) Pers.	*Stellarietea mediae*	-	0.95	11.38
Erodium cicutarium (L.) L'Her.	*Stellarietea mediae*	-	0.02	0.45
Geranium columbinum L.	*Stellarietea mediae*	-	0.39	-
Hordeum murinum L.	*Stellarietea mediae*	-	0.02	-
Lamium purpureum L.	*Stellarietea mediae*	2.30	3.23	-
Oxalis fontana Bunge	*Stellarietea mediae*	0.02	0.18	0.83
Poa annua L.	*Stellarietea mediae*	-	4.95	0.02
Polygonum aviculare L.	*Stellarietea mediae*	-	0.43	-
Sagina saginoides (L.) Karsten	*Stellarietea mediae*	-	-	0.02
Senecio vulgaris L.	*Stellarietea mediae*	-	0.04	-
Stellaria media (L.) Vill.	*Stellarietea mediae*	5.15	2.28	0.71
Valerianella locusta (L.) Laterrade	*Stellarietea mediae*	0.12	0.27	2.07
Veronica arvensis L.	*Stellarietea mediae*	0.27	1.70	3.37
Veronica hederifolia L.	*Stellarietea mediae*	0.04	-	-
Veronica persica Poiret	*Stellarietea mediae*	2.70	4.07	0.51
Vicia sativa L.	*Stellarietea mediae*	0.02	0.04	0.19
Perennial ruderal species		48.67	9.68	3.06
Agropyron repens (L.) Beauv.	*Agropyretea intermedii-repentis*	41.17	7.91	1.93
Arctium lappa L.	*Artemisietea vulgaris*	0.37	-	-
Cirsium vulgare (Savi) Ten.	*Artemisietea vulgaris*	-	0.19	-
Convolvulus arvensis L.	*Agropyretea intermedii-repentis*	0.89	0.85	0.25
Daucus carota L.	*Artemisietea vulgaris*	-	-	0.02
Erigeron annuus (L.) Pers.	*Artemisietea vulgaris*	0.02	0.68	0.85
Lactuca serriola L.	*Artemisietea vulgaris*	0.02	-	-
Malva sylvestris L.	*Artemisietea vulgaris*	-	0.02	-
Medicago sativa L.	*Agropyretea intermedii-repentis*	0.21	-	0.02
Silene alba (Miller) Krause	*Artemisietea vulgaris*	0.02	0.04	-
Urtica dioica L.	*Artemisietea vulgaris*	5.98	-	-
Grassland species		42.06	76.98	69.74
Achillea millefolium L.	*Molinio-Arrhenatheretea*	0.02	0.23	9.03
Agrostis tenuis Sibth.	*Molinio-Arrhenatheretea*	-	1.41	0.02
Anthoxanthum odoratum L.	*Molinio-Arrhenatheretea*	-	0.19	-
Arrhenatherum elatius (L.) Presl	*Molinio-Arrhenatheretea*	2.45	4.41	0.21

(to be continued)

Plant species	**Phytosociological optimum**	**Percentage cover**		
		MW1	**MW4**	**MW8**
Grassland species *(continued)*				
Bellis perennis L.	*Molinio-Arrhenatheretea*	-	1.85	1.59
Carex pairaei F.Schultz	*Trifolio-Geranietea sanguinei*	-	-	0.56
Cerastium semidecandrum L.	*Molinio-Arrhenatheretea*	-	0.39	-
Dactylis glomerata L.	*Molinio-Arrhenatheretea*	-	0.19	5.52
Festuca arundinacea Schreber	*Molinio-Arrhenatheretea*	-	0.69	1.25
Festuca rubra L.	*Molinio-Arrhenatheretea*	-	2.73	-
Galium mollugo L.	*Trifolio-Geranietea sanguinei*	0.02	-	-
Geranium molle L.	*Molinio-Arrhenatheretea*	-	1.43	1.06
Holcus lanatus L.	*Molinio-Arrhenatheretea*	0.21	0.60	-
Hypericum perforatum L.	*Trifolio-Geranietea sanguinei*	-	-	0.23
Hypochoeris radicata L.	*Molinio-Arrhenatheretea*	-	1.05	5.09
Leucanthemum vulgare Lam.	*Molinio-Arrhenatheretea*	-	0.89	-
Lolium multiflorum Lam.	*Molinio-Arrhenatheretea*	5.28	0.02	-
Lolium perenne L.	*Molinio-Arrhenatheretea*	0.69	1.93	-
Lotus corniculatus L.	*Molinio-Arrhenatheretea*	-	-	1.53
Ornithogalum umbellatum L.	*Molinio-Arrhenatheretea*	0.02	-	-
Plantago lanceolata L.	*Molinio-Arrhenatheretea*	0.02	6.41	10.71
Poa pratensis L.	*Molinio-Arrhenatheretea*	-	9.88	15.79
Poa trivialis L.	*Molinio-Arrhenatheretea*	22.35	14.11	0.21
Potentilla reptans L.	*Molinio-Arrhenatheretea*	-	1.52	-
Prunella vulgaris L.	*Molinio-Arrhenatheretea*	-	0.68	-
Ranunculus acris L.	*Molinio-Arrhenatheretea*	-	0.67	-
Ranunculus sardous Crantz	*Molinio-Arrhenatheretea*	0.02	0.39	0.67
Rorippa sylvestris (L.) Besser	*Molinio-Arrhenatheretea*	-	0.24	-
Rumex acetosa L.	*Molinio-Arrhenatheretea*	0.02	0.19	-
Rumex conglomeratus Murray	*Molinio-Arrhenatheretea*	2.16	0.56	-
Rumex crispus L.	*Molinio-Arrhenatheretea*	0.23	0.93	-
Silene vulgaris (Moench) Garcke	*Festuco-Brometea*	0.02	-	1.97
Taraxacum officinale Weber	*Molinio-Arrhenatheretea*	7.43	19.32	0.25
Trifolium dubium Sibth.	*Molinio-Arrhenatheretea*	-	-	4.39
Trifolium pratense L.	*Molinio-Arrhenatheretea*	0.27	0.56	-
Trifolium repens L.	*Molinio-Arrhenatheretea*	0.85	3.49	9.59
Verbascum thapsus L.	*Epilobietea angustifolii*	-	-	0.02
Verbena officinalis L.	*Molinio-Arrhenatheretea*	-	0.02	0.06
Other species (not included in data analyses)		-	1.53	17.28
Arenaria serpyllifolia L.	*Koelerio-Corynephoretea*	-	-	1.33
Calamintha nepeta (L.) Savi	*Thlaspietea rotundifolii*	-	0.41	6.55
Cerastium semidecandrum L.	*Koelerio-Corynephoretea*	-	0.93	5.57
Myosotis ramosissima Rochel in Schultes	*Koelerio-Corynephoretea*	-	0.19	2.09
Potentilla argentea L.	*Koelerio-Corynephoretea*	-	-	1.72
Saxifraga tridactylites L.	*Koelerio-Corynephoretea*	-	-	0.02