

Novel woodland patches in a small historical Mediterranean city: Padova, Northern Italy

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Abstract Woodland fragments, in small historical cities, are commonly regarded as temporary voids in an urban matrix, yet to be allocated a land-use, under city planning regulations. However, they could display relevant plant diversity, and contribute to urban ecosystem services. This study combined surveys at 100 m², and at patch level, with the aim to investigate how patch size, stand and urbanization, affected the structure of plant communities in thirty woodland fragments (0.1–2 ha), spontaneously developing in the small, historical city of Padova (Northern Italy). Trees, shrubs and other perennial species dominated the plant communities in these patches. Alien species were common, in both the understory (freq.=97 %, mean richness=4.33) and tree layer (freq.=90 %, mean richness=1.50). Species typical of native communities also occurred. Understory communities were associated with ancient forest, nitrophilous, and ruderal species; highlighting an overall heterogeneity. Road and railway density was moderately correlated with total species richness in the understory, whereas, urbanity (i.e. the concentration of built environment excluding road and railway density), and tree density were not. Furthermore, alien tree dominance negatively influenced total and native tree layer species richness and, moderately positively, native understory species richness. These results highlight that spontaneous novel woodland patches, even if they are minor fragments in small historical cities, maintain diverse green infrastructures that may supply an array of urban ecosystem services, when adequately recognised by city plans.

Keywords Biodiversity · Spontaneous afforestation · Urban planning · Urban forest · Vegetation

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Introduction

Understanding of urban woodlands is increasing (Croci et al. 2008; Vallet et al. 2010; Trentanovi et al. 2013), this follows significant developments in the field of urban ecology, having understood the services that can be provided by these ecosystems at local, regional, national and global levels (Breuste et al. 2013). Urban woodlands are a product of the uniqueness of the urban environment; there are complex interactions of abiotic and biotic processes (Vallet et al. 2010; Werner 2011) creating ubiquitous ecological conditions (Rebele 1994). Woods are often fragmented in urban areas (Werner 2011); forming patches within the urban matrix, they are one of the most common natural habitats in European towns (Croci et al. 2008). There are different types of canopy, vegetation and plant establishment processes, on abandoned or neglected land and sites disturbed by humans (Kowarik 2005; Mathey and Rink 2010).

In urban landscapes, vegetation is influenced by features of urbanisation, such as, the neighbouring built-up area, surrounding household density (e.g., Kühn and Klotz 2006; McDonnell and Hahs 2008), road and railway density (e.g., von der Lippe and Kowarik 2008; Penone et al. 2012). In turn, these factors are intrinsically shaped by city planning (Sukopp et al. 1995), they mainly regard the development of residential, and industrial areas, in greenfield and brownfield sites, and the related construction of roads. However, in the case of urban forests, other stand-level factors may play an important role in determining the vegetation communities (e.g., Gilliam 2007; Barbier et al. 2008), together with the size of the patch (e.g., Hobbs 1988; Iida and Nakashizuka 1995).

The majority of historical cities are from the Mediterranean basin and Asia; areas subjected to human influence for millennia. Therefore, results from outside these regions may contrast with those observed within. Authors have outlined that hot spots of species richness are found in European cities (e.g., Zerbe et al. 2003; Kowarik 2011), there is a positive relationship between settlements and/or buildings age and plant species composition (Celesti-Grapow et al. 2006).

Spontaneous vegetation can form a part of urban woodlands (Kowarik 2005; Celesti-Grapow et al. 2006) and suburban areas (Barbati et al. 2013); the ecosystem services that can potentially be provided by spontaneous vegetation are considerable, such as habitat provision, wildlife dispersal, climate regulation and carbon sequestration (Robinson and Lundholm 2012; Barbati et al. 2013). The influx of alien species into European cities has been widely documented (e.g., Pyšek 1998; Wittig 2004), an overstorey dominated by alien tree species, may have an influence on understorey communities (e.g., Richardson et al. 1989; Sitzia et al. 2012). Species which are favoured by human disturbance, and fragmentation, tend to prevail in spontaneous woodland patches (Kowarik 2005; Del Tredici 2010; Kowarik et al. 2013; Trentanovi et al. 2013). Newly established plant assemblages, formed by alien species can be addressed as ‘novel ecosystems’ (Hobbs et al. 2006; Kowarik 2011).

Current research in Europe on urban woodlands focuses on large cities - for example; Rome (Celesti-Grapow et al. 2006) and Berlin (Trentanovi et al. 2013), or on mixed habitats (e.g., Celesti-Grapow and Blasi 1998; Chocholoušková and Pyšek 2003), woodlands which range from ‘wild’ to managed (Croci et al. 2008), or relatively old and/or studying the effects of rural to urban gradients (Lehvävirta and Rita 2002; Vallet et al. 2010). Species richness in small patches of spontaneous urban woodlands in small cities is relatively unknown, as well as the existence of these novel patches within the urban planning context, and for the people living in and around them.

The purpose of this paper is to develop knowledge on small novel transient woodland patches in a small historical city in Mediterranean Europe, firstly, to understand the composition of plant species assemblages, and secondly, to understand what factors are shaping plant species richness in these patches. Patches were selected randomly, and their boundaries defined. Their main vegetation characteristics were studied, native and alien species were recorded in the understory and tree layers at the sampling plot level (100 m²), and for woody species at the patch level. Then, we assessed the effect of adjacent land-uses, which are commonly allocated in urban plans (i.e., built-up area and road and railway density), and factors important at the stand level (i.e., tree density and alien tree dominance), on the species richness.

Methods

Study area

The small sized historical city of Padova (English: Padua), founded around X-IX sec. BC, is a municipality of 92.85 km² (210,000 residents) with an ancient town centre of 4.54 km² (Comune di Padova 2012); it is located in the Veneto region, Northeast of Italy (45°23'N, 11° 52' E). The climate is sub-Mediterranean; the annual precipitation is 846 mm and the mean annual temperature is 12.9°C. Land use is mainly built up urban residential settlements (~55.5 %) with areas mixed with agricultural uses (~41.5 %); most of the territory is modelled artificially. Woody vegetation is very limited and mostly confined to the margins of rivers. According to ARPAV (2013), spontaneous wooded areas in Padova are almost non-existent. Road and railway networks extend for 982 and 31.5 km within the territory, respectively (Comune di Padova 2012).

Data collection

Sampling was performed from the start of June, to the first weekend of August 2013, with most of the work being performed in July. Within the municipality boundary, we searched woodland patches ≥ 1000 m² to avoid those that would have been dominated by edge effects (Matlack 1994). We excluded patches that showed strong active management, or no spontaneous vegetation, or no trees ≥ 3 cm diameter breast height (DBH), and height ≥ 5 m. A sample of thirty of these patches were randomly selected (Fig. 1). From observing signs of spontaneous vegetation in historical images, the age of these patches ranged between 10 and 30 years. Only sporadic cuts were observed in certain patches and their boundaries were often limited by human elements or activities, like roads, buildings and cultivation. The interior of these patches was frequently used by people, where shelters and tracks were frequently observed (Fig. 2). A working protocol was adopted to collect information on these patches and to easily enable future replications. In all the patches, all woody species, including seedlings, were identified. Within these patches, a 100 m² plot was surveyed, to record the plant species of the understory and tree layer vegetation. The cover-abundance scale of Braun-Blanquet and Pavillard (1928) (r=solitary small individual; +=few individuals; 1=<5 %; 2=5–25 %; 3=25–50 %; 4=50–75 %; 5=>75 %) was used to estimate understory species cover. The basal area was calculated from all trees with DBH ≥ 3 cm.

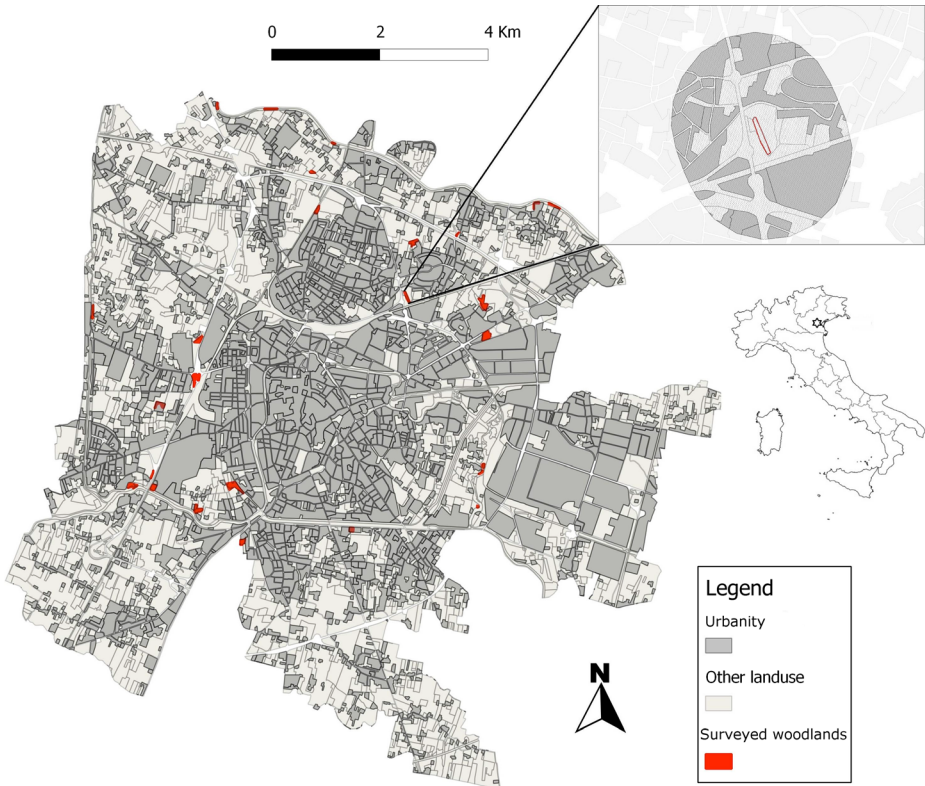


Fig. 1 Study area location and distribution of the woodland patches surveyed in the city of Padova

Data analysis

Cover-abundance values of recorded species were converted into Tüxen and Ellenberg (1937) percentage values ($r=0.02$; $+=0.1$; $1=2.5$; $2=15$; $3=37.5$; $4=62.5$; $5=87.5$).

First we identified life-form; life-span and chorological type, using Pignatti (1982) and other databases, for each species recorded in the understory, and then the overall proportion of these life traits was calculated. Secondly, we ascertained that there was not any spatial autocorrelation present in the species richness values running the command Moran.I of the package “ape” in R (Paradis et al. 2004), using the inverse Euclidean distance matrix among patches’ centroids. Then, to investigate drivers of species richness, richness values were calculated at patch, and plot level, for total, native and alien species. In our study, alien species were identified according to Celesti-Grapow et al. (2009) and Masin and Scortegagna (2012) and considering also those species intentionally planted and unlikely to occur spontaneously.

The Bray-Curtis similarity distance matrix, from the understory species cover values at each site, were subjected to agglomerative hierarchical clustering analyses by using Ward’s clustering method. We then identified three groups of sites that adequately represented the observed flora. To investigate which plant species defined these groups, we performed Indicator Species Analysis (ISA) (Dufrière and Legendre 1997). “Multipatt” function of the “indicpecies” package in R software (De Caceres et al. 2010) was used as the indicator value method



Fig. 2 Pictures showing: the interior of a patch (a), an example of use by people (b), the spontaneous expansion by the alien black locust in the urban-agricultural fringe (c), and along a central urban road (d)

(IndVal) and the statistical significance was tested with the Monte Carlo test, based on 9999 randomisations. This method combines data on both abundance and frequency. The resulting association index, IndVal.g, is the square root of the IndVal index in Dufrêne and Legendre (1997), it is at maximum (=1) when all occurrences of a species are found in a single group of sites, and when the species occurs in all sites of that group. To understand what factors affect the response of understory species richness, two groups of predictor variables, land use (urbanity, road and rail density) and stand (mean DBH, basal area and alien dominance) characteristics, were used. To calculate the land use variables, Quantum GIS (Quantum GIS Development Team 2012) was used. A 500m buffer was established for each patch, this buffer size has been shown to yield the best predictor set, compared to 100m and 200m buffers (e.g., Knapp et al. 2009; Westermann et al. 2011). Urbanity, as described by Trentanovi et al. (2013), was derived by subtracting rail and road density from urban land-use, based on Corine Land Cover classification (Bossard et al. 2000), calculating its proportion in the buffer. For road and rail density, the total length within the buffer was divided by the total buffer area. Basal area was used because it is a common parameter of tree density and canopy cover, particularly in reference to overstory-understory relationships (Mitchell and Popovich 1997), it is understood

that, with increasing basal area, there is a decrease in light transmittance to the forest floor (Korhonen et al. 2006). The alien tree dominance was computed as the proportion of alien species basal area. The nature and strength of covariation between richness values and urbanity, road and rail density, basal area and alien tree dominance was tested through the Pearson product-moment correlation coefficient, after removal of outliers, if any were identified with the diagnostics method performed by the function “influence.measures” in R software (Belsley et al. 1980) or log-transformation of variables with skewed distributions. Where variables exhibited strong departures from normal distribution, we used Spearman rank correlation test. We also investigated the influence of patch size on the total richness of woody species in the patch. Linear regression analysis was used to find the best-fit line relating patch size to woody species richness. R software (Version 3.0.1) (R Development Core Team 2013) was used for all statistical analyses.

Results

The thirty surveyed patches had a mean size of 0.645 (SD: 0.50; min: 0.12; max: 2.32) ha, a mean tree basal area of 42 (SD: 30.1; min: 6; max: 157) m²/ha. Yet the highest basal area values were due to the presence of sizeable, old trees, pre-existent to the land use abandonment.

A total of 106 species were identified, of which 38 were alien (Suppl. Material). Table 1 shows the most frequent species recorded at the plot level (total: 92, aliens: 34). Species richness in the understory and tree layer (Table 2), and for woody species at the patch level (Table 3) underlined the importance of the alien component.

Phanerophytes and perennial species were dominant in the understory. The chorological spectrum highlighted the relevancy of species with Asiatic, additionally to those with European, origin (Fig. 3).

Understory assemblage

The IndVal analysis, conducted for the three groups derived from the cluster analysis, produced a total of eight indicator species (Table 4). Group A was associated with *Hedera helix* and *Bryonia dioica*, species common in most types of woodlands and sheltered sites, with preference for heavy, fertile soils (Harding and Hilton 1992; Metcalfe 2005). When

Table 1 First three most frequent native and alien plant species in thirty 100m² plots each representative of a woodland patch of Padova (Northern Italy) urban area

	Alien species	Freq. (%)	Native species	Freq. (%)
Understory	<i>Robinia pseudoacacia</i>	60	<i>Cornus sanguinea</i>	80
	<i>Laurus nobilis</i>	50	<i>Rubus fruticosus</i> agg.	73
	<i>Ligustrum sinense</i>	47	<i>Hedera helix</i>	73
	<i>Acer negundo</i>	47	<i>Acer campestre</i>	60
Tree layer	<i>Robinia pseudoacacia</i>	67	<i>Ulmus minor</i> subsp. <i>minor</i>	40
	<i>Acer negundo</i>	17	<i>Sambucus nigra</i>	33
	<i>Prunus cerasifera</i>	13	<i>Salix alba</i>	23
			<i>Cornus sanguinea</i>	23

Table 2 Plant species richness (total, native and alien) observed in thirty 100m² plots (understory and tree layer) each representative of a woodland patch of Padova (Northern Italy) urban area. Mean % is the mean proportion calculated from each site

Vegetation layers		Total	Native	Alien
Understory	Mean	13.70	9.33	4.33
	SD	4.53	3.13	2.15
	Mean %	100	69.23	30.77
	Total	85	55	30
Tree layer	Mean	3.57	2.07	1.50
	SD	1.63	1.34	0.82
	Mean %	100	52.06	47.94
	Total	30	16	14

occurring in woodland, the *Hedera helix* is frequently dominant in the field layer (see review by Metcalfe 2005), which was also verified here.

Ulmus minor subsp. *minor* was significantly associated with group B, it is a fast growing tree species able to colonise abandoned land, a species which is now re-establishing after gaining resistance to Dutch elm disease (Solla et al. 2005; Sitzia et al. 2012).

Group C was characterised by two ruderal and nitrophilous species: *Rubus fruticosus* agg. and *Parietaria officinalis*, also present was *Brachypodium sylvaticum*; a species regarded by some authors as an ancient forest species (Hermy et al. 1999).

Groups A and C shared a common indicator species, *Sambucus nigra*, a species typical of disturbed, highly eutrophic soils, subjected to disturbance, either naturally, on floodplain terraces and woodland margins, or anthropogenically, in derelict gardens, farmyards and post-industrial wasteland (Atkinson and Atkinson 2002).

Richness and correlated factors

Surprisingly, no relation between species richness, and both urbanity and basal area was found. Road and railway density moderately correlated to understory total ($r=0.41$, $p=0.023$) species richness, but not native or alien species richness. Understory native species richness seemed also to be moderately positively correlated with alien dominance ($r=0.37$, $p=0.042$). As expected, alien tree dominance negatively correlated to species richness, at a limited extent, tree layer total ($\rho=-0.39$, $p=0.035$) and, strongly, native ($\rho=-0.71$, $p<0.001$) species richness.

The diversity of woody species on patches was related to the size of the patch, and the relationship, after removal of two outliers, conformed to: woody species richness = 7.179 (patch size in hectares) + 13.188 ($R^2_{\text{adj}}=0.43$, $F=21.515$, $p<0.001$).

Table 3 Woody species richness (total, native and alien) present over the entire area of thirty woodland patches of Padova (Northern Italy) urban area

	Total	Native	Alien
Mean	17.73	10.43	7.30
SD	5.85	3.43	3.03
Mean %	100	59.00	41.00
Total	66	33	33

Mean % is the mean proportion calculated from each site

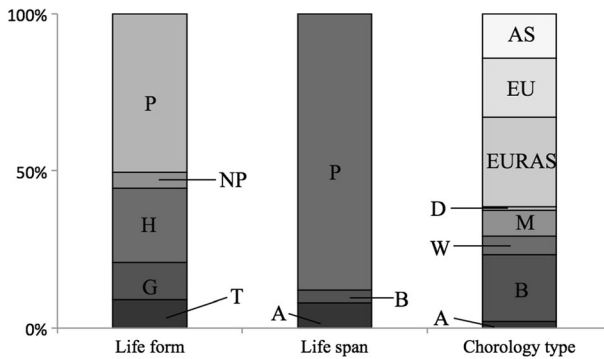


Fig. 3 Life traits for the recorded understory species in thirty woodland patches of Padova (Northern Italy). The life form (phanerophytes: P; geophytes: G; hemicryptophytes: H; nano-phanerophytes: NP; therophytes: T), life span (annual: A; biannual: B; perennial: P) and chorological type (*AS* asiatic, *EU* European/Caucasic, *EURAS* eurasiatic, *D* dubious origin, *M* Mediterranean, *W* widely-distributed, *B* circumboreal, *A* Atlantic) are reported

Discussion

Prior work has acknowledged the occurrence, and relevance, of the spontaneous development of vegetation communities in urban areas (Millard 2000, 2004). Nevertheless, studies of biodiversity in the urban environment do not normally use forests as the main foci, or they focus mainly on forest remnants (e.g., Guntenspergen and Levenson 1997; Godefroid and Koedam 2003; Doody et al. 2010). The importance of secondary woodlands spontaneously growing on abandoned lands in urban areas has been recognised (see Kowarik 2005), but studies in southern Europe are lacking and, to date, research has neglected spontaneous forests within small historical urban cities. In this study we have partially filled the research gap, by analysing vegetation assemblages within relatively young, spontaneously developing woodland patches, on neglected land, within a small historical city. We found that, in particular in the tree layer, alien species have an important role, and that the understory shows a relatively heterogeneous composition and richness.

A high proportion, and dominance of alien species, is generally observed in urban plant assemblages (Pyšek 1998; Chocholoušková and Pyšek 2003) and in particular also in wild urban woods (Kowarik 2005). In our context, their high number and relevancy may also be explained by a number of factors: the small patch area, because edge proximity favours alien

Table 4 Indicator species of three relevé groups identified by cluster analysis of the understory in thirty 100m² plots in woodland patches of Padova (Northern Italy) urban area, and related indicator (IndVal.g) and p-values (A: 11, B: 8 and C: 11 plots)

Relevé group	Species	IndVal.g	p value
A	<i>Hedera helix</i>	0.926	0.0001
	<i>Bryonia dioica</i>	0.525	0.0271
B	<i>Ulmus minor</i> subsp. <i>minor</i>	0.68	<0.0001
C	<i>Rubus fruticosus</i> agg.	0.542	0.0027
	<i>Parietaria officinalis</i>	0.481	0.0109
	<i>Brachypodium sylvaticum</i>	0.447	0.0294
C+A	<i>Sambucus nigra</i>	0.463	0.0234

species both in the understory, and overstory (LaPaix et al. 2012); by the long historical influence of the city, and by the moderate levels of urbanization (McKinney 2008).

As suggested by other studies (e.g., Prach and Pyšek 2001; Celesti-Grapow and Blasi 2003), ours highlights that woody species are important invaders of abandoned urban land. Our study emphasises the dominance of perennial species in the understory. Analysis of the understory composition highlighted the presence of groups of patches characterised by ruderal, and forest-related species. These findings, in accordance with Kowarik (2011), underline the presence of transient novel forest assemblages, in the studied urban context, a product of inadvertent action by humans, which feature a pronounced alien component. Some patches were also dominated by native trees known to be colonising species, or species typical of the Po plain forests, such as *Ulmus minor*, *Quercus robur*, *Carpinus betulus* and *Salix alba*. This heterogeneity of the composition, both in the tree layer and understory, indicates the high value of spontaneous woodland patches for biodiversity in the urban matrix.

As highlighted for parks and woodlots in general (Alvey 2006), even in small spontaneous patches, woody species richness tends to increase with patch size. The limited relationship between explanatory variables and the understory and tree layer plant richness strengthens the discourse that the city is an integrated ecosystem (Rebele 1994); where it is not possible to define one variable in particular that is affecting species richness. There is a degree of chaos theory involved, promoting heterogeneity. Richness is a result of complex interactions of abiotic and biotic processes at different scales (Werner 2011).

The fact that we did not consider forest edge and forest interior as two distinct habitats hinders any quantitative assessment of edge effect which are probable in small woodlands (Gonzalez et al. 2010). However, in addition to road and railway density, and alien dominance, as highlighted by our results, it is possible that other factors may play a role, even obscuring, or filtering, those that we analysed, such as, habitat history and configuration (De Sanctis et al. 2010), which, in turn, may influence edge effects and seed source availability from neighbouring roadside and river vegetation (von der Lippe et al. 2008; Säumel and Kowarik 2010), or residential gardens. Edge effects are related to the adjacent urban matrix and forest trails and paths (LaPaix et al. 2012), a higher number of alien species have been found in forest edges adjacent to urban areas compared to agricultural areas (Gonzalez-Moreno et al. 2013). Edges and their aspect effects light radiation to the forest floor, influencing species composition and richness. North-facing forest margins may not show edge effects on plant composition, or, its spatial penetration within forests may be reduced, while edge effects may be pronounced in south-facing aspect margins (Hamberg et al. 2010). Recreational pressure, presence of paths, related trampling, concentration of nutrients and pollutants, and other kinds of microhabitat features might also explain a portion of the observed species richness variability (Malmivaara-Lämäs et al. 2008; Hamberg et al. 2010). Furthermore, as colonisation is an on-going process, transient communities, and the factors shaping these communities, may be better explained by a study with a longer temporal scale (Lososová et al. 2012).

This study reveals that in small historical cities, small woodland patches that spontaneously develop within an urban landscape can play an important role for biodiversity, by forming both new communities of species, which did not exist in the past, and native habitats that had previously disappeared. They may have the opportunity to convey a set of services; the spatial concentration of people in cities increases the demand for ecosystem services (McDonald 2015). Urban trees and woodlands have a wide range of benefits and uses (e.g., Konijnendijk 2008; Jim and Chen 2009; Escobedo et al. 2011), such as carbon sequestration and the positive effects on humans' wellbeing. Small spontaneous forest patches may act as an added value in

respect to the existing and recognised green infrastructures of small urban parks (Nordh and Østby 2013) and roadside wild vegetation (Weber et al. 2014), enhancing ecosystem services in small historical cities, in particular those related to recreation. Given the small size of woodlands, it is feasible to plan recreational trails at fine-scale resolutions, and carefully assess their environmental impact (Sitzia et al. 2014). The acknowledgement of spontaneous woodland patches is important for the planning and development in small sized cities. The opportunities provided by spontaneous, “unofficial” vegetation; described by Mabey (1973) or “unintentional”; as by Kühn (2006), vegetation for urban landscape design is now being understood, with novel perspectives and innovative approaches being proposed and applied (Millard 2000; Prach and Pyšek 2001; Kowarik and Langer 2005; Kühn 2006; Ignatieva et al. 2010). A key problem is the anomaly of these patches in town planning; they can be subjected to land use change before their value is fully comprehended. Temporary measures, suitable for these habitats, could be implemented in greenfield and brownfield sites, potentially on a medium term basis, until the foreseen building development is realised (see Kattwinkel et al. 2011).

Our study underlines the great potential for urban planning, and the importance of plant communities in small historical cities, further research is needed on vegetation composition and dynamics. Specifically, future studies will help to increase understanding of how these novel transient woodlands will develop, positing what potential vegetation communities can be hosted by these unmanaged woodlands. Furthermore, as forest succession on abandoned urban land is common and brownfields rehabilitation is an option in many small cities in Europe (Acosta et al. 2005; Laforteza et al. 2008), in North America (Greenberg et al. 2001), and also likely in other regions of the world where forests are spontaneously expanding (see review by Sitzia et al. 2010), it is important to trigger the awareness of planners and designers of the opportunities that these areas can give. A call, for new planning approaches, for transient novel woodlands in small historical cities, is required.

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Conflict of interest The authors have no conflict of interest to declare.

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