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BIMBY's first steps: a pilot study on the contribution of residential front-yards in Phoenix and Maastricht to biodiversity, ecosystem services and urban sustainability

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Abstract Large parts of urban space around the world exist of small-scale plots such as domestic gardens. These small-scale urban spaces carry potential for enhancing biodiversity, sustainability and ecosystem services in and beyond cities. However, domestic gardening and residential garden designs are often guided by aesthetics and ease more than by the aim to create habitat and biological diversity. Yard-management decisions impact socio-ecological systems in various ways, for example through irrigation patterns, fertilization or the use of pesticides or through the choice for exotic species that may become invasive over time. Yard-management decisions can also positively influence the presence of pollinators, improve soil quality or even foster small scale 'Wildlife Habitats' that can function as ecological stepping stones to the wider environment. In this paper a pilot assessment is presented of the contribution of residential front-yards in Phoenix (Arizona) and Maastricht (The Netherlands) to biodiversity, ecosystem services and sustainability by applying the BIMBY (Biodiversity in My (Back) Yard) framework.

Keywords Biodiversity · Domestic yards · Sustainability · Ecosystem services · Garden design · Residential environment

Introduction

As more than half of the world population lives in cities (UNEP 2014) it will be increasingly important to reconcile ecological aspects, design, and human lifestyle-practices in urban environments (Rosenzweig 2003; Cilliers 2010). Large parts of urban space in many countries exist of gardens, patios, courtyards, balconies and roof-terraces (Lubbe et al. 2010). This

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means there is a great—and still largely unexplored—social, cultural and ecological potential for residential gardens to contribute to biodiversity, ecosystem services and sustainability in urban realms and beyond (Galluzzi et al. 2010; Goddard et al. 2010; Lubbe et al. 2010; Chowdhury et al. 2011; Cook et al. 2012; Heezik et al. 2012; Zwaagstra 2014; Beumer and Martens 2015). Citizens can become important agents in creating thriving, well-connected living environments (Rudd et al. 2002). Still, residential garden designs and maintenance styles are often guided by aesthetics and ease more than by the aim to create habitat, to increase biodiversity, to build capacities for (urban) sustainability, or for the delivery of ecosystem services (Cranz and Boland 2004; Martin 2008; Ignatieva 2010; Beumer 2014; Beumer and Martens 2015).

In this paper a pilot assessment is presented of the way front-yards in Phoenix (Arizona, US) and Maastricht (The Netherlands) contribute to biodiversity, ecosystem services and sustainable (urban) environments through applying the BIMBY indicator framework (Biodiversity In My (Back) Yard) (Beumer and Martens 2015). With this framework we intend to contribute to a young field of study that aims to bridge ecological and socio-cultural disciplines (Chowdhury et al. 2011; Cook et al. 2012; Uren et al. 2015). There is still a gap with regards to an integrated understanding of domestic urban space and how it is constituted through an interaction of natural and human factors (Larson et al. 2010; Lubbe et al. 2010; Chowdhury et al. 2011; Cook et al. 2012; Beumer and Martens 2015; Uren et al. 2015). On a societal level, the framework aims to foster a transformational dialogue (Lang et al. 2012; Wiek et al. 2012) on the question: how can we reconcile living comfort, aesthetics and ease at the one hand and the protection of biodiversity, ecosystem services and a sustainable living environment at the other hand, in the way we design our residential areas (Rosenzweig 2003)?

Most earlier research on the household-parcel scale has focused on either ecological garden-structures and -features (e.g. Cornelis and Hermy 2004; Gaston et al. 2005; Hope et al. 2006; Baker and Harris 2007; Burghardt et al. 2008; Loram et al. 2008; Martin 2008; Kendal et al. 2012), or on factors that influence human choices and preferences for certain types of yards (Nassauer 1995; Larsen and Harlan 2006; Larsen and Swanbrow 2006; Lyytimäki et al. 2008; Larson et al. 2009; St. Hilaire et al. 2010; Zheng et al. 2011; Heezik, et al. 2012; Kurz and Baudains 2012; Uren, et al. 2015). Although urban residential landscapes and domestic gardening preferences, values and drivers are increasingly studied in the context of sustainable development and biodiversity conservation (Miller and Hobbs 2002; Gaston, et al. 2005; Larsen and Harlan 2006; Mathieu et al. 2007; Loram et al. 2008; Galluzzi et al. 2010; Goddard et al. 2010; Larson et al. 2010; St. Hilaire et al. 2010; Chowdhury et al. 2011; Zheng et al. 2011; Cook et al. 2012; Heezik et al. 2012; Kurz and Baudains 2012) there is still much to be learned on how cultural elements and human preferences represented in domestic gardens (e.g. design style, maintenance need, artefacts) influence habitat value, biodiversity, ecosystem services, and sustainability in and beyond human settlement areas (Dunn et al. 2006; Galluzzi et al. 2010; Larson et al. 2010; Chowdhury et al. 2011; Cook et al. 2012; Heezik et al. 2012). Integrative approaches that combine ecological and cultural factors in domestic landscaping practices and design are available but scarce (Larson et al. 2010; Lubbe et al. 2010; Cook et al. 2012; Uren et al. 2015).

Through a combination of observational field-visits, photo-analyses and literature study (Noss 1990; Costanza et al. 1997; Opschoor 1998; Bolund and Hunhammar 1999; Hermy and Cornelis 2000; Savard 2000; Nunes and van den Bergh 2001; Appleton 2002; Groot et al. 2002; McKinney 2002; Nagendra 2002; Spellerberg and Ferdor 2003; Zerbe et al. 2003; Cornelis and Hermy 2004; Gaston et al. 2005; Keylock 2005; McNeely et al. 2005; MEA 2005; Larsen and Harlan 2006; Baker and Harris 2007; CBD 2007; Hart 2007; Norton and

Noonan 2007; Loram et al. 2008; Lyytimäki et al. 2008; Martin 2008; Sukopp 2008; Dearborn and Kark 2009; TEEB 2009; Caro 2010; Galluzzi et al. 2010; Hancock 2010; Larson et al. 2010; Müller et al. 2010; St. Hilaire, et al. 2010; Tzoulas and James 2010; Beatley 2011; Farinha-Marques et al. 2011; Müller and Kamada 2011; Cook et al. 2012; Jaganmohan et al. 2012; Jim 2012; Jorgensen and Keenan 2012; Kendal et al. 2012; Kurz and Baudains 2012; Shin 2012; Qviström 2013), the results presented in this paper deliver insights into patterns of yard-contributions to biodiversity, related ecosystem services and disservices, and the sustainability of the urban and even regional environment. Our understanding of ecosystem services is based on the work of Costanza and his colleagues (1997, 2014), the framework provided by the Millennium Ecosystem Assessment (MEA 2005), and the more recent TEEB research (TEEB 2009, 2011). Biodiversity can be defined as the variety of living species, populations, communities and genetic material and their functional relations (CBD 2010; IUCN 2013). It is constitutive to the supporting services within the ecosystem services framework, contributing to provisioning, regulating and cultural services (MEA 2005). With the ambiguous term 'sustainability' we refer to an ideal of long-term socio-ecological well-being grounded in environmental resilience (Gunderson and Holling 2002; Folke et al. 2004; Olsson and Folke 2007; Rees 2010; Tidball 2012; Meijer et al. 2013).

Methodology

The methodology used for the pilot study is based on observational field visits of front-yards (N=512) in Phoenix, Arizona and in Maastricht, the Netherlands, photo-analyses, and a qualitative evaluation of the data in the context of ecosystem services and sustainability. Phoenix and Maastricht were chosen as case cities because different determinants give them different characters (see Table 1).

Next to the differences, both cities have residential areas with often spacious front- and back-yards. Both cities are also surrounded and intercepted by natural and/or semi-natural

Table 1 Case city comparisons

Determinant	Maastricht	Phoenix
Climate	Temperate	Arid Desert
Vegetation	Deciduous green	Warm desert scrub
Number of inhabitants	120.000 inhabitants (small)[a]	1.500.000.000 inhabitants (large)[b]
Population	High population density	Dispersed residential environment
City age	Roman and Medieval European history	Young city founded in 1861
City size	60.06 km^2	1338 km^2
Urban space	Compact city	Urban sprawl
Residential areas	Planned neighbourhoods and agglomerate villages	Suburbs
Urban downtown character	Historical core	Metropolitan high-rise
Dominant culture	Western European	North American & Latin American influences

[a] Data from CBS (2013)

[b] Data from USCB (2013)

landscapes and parks that give habitat to native wildlife and plant-species. These natural areas also provide access-routes for wild animal species into the residential areas. Within each city a broad comparability of socio-economic status in the neighbourhoods (High, Mid-Range, Average, and Low) was chosen as a selection criterion for the neighbourhoods (Hope et al. 2006; Martin 2008) (see Table 2). The information on socio-economic status was derived from real-estate websites. House prices were compared to each country's modal income.

The data were gathered by the lead author through sensory observation and by taking photos of the front-yards in April and May 2013. The sensory information (visual, auditory, scents, temperature, moisture, neighbourhood context) was gathered by observation on the level of the visited neighbourhoods, paying attention to present animal species, sounds of animals or potential disturbances (i.e. traffic sounds, motorised yard maintenance noise), smells (i.e. air pollution, flowers, artificial fertiliser), temperature (subjective temperature and comfort), moisture (i.e. wet or moist irrigated lawns, dusty barren soil) and neighbourhood context (i.e. close to busy roads, parks). This information was gathered in a notebook and it served as contextual information to help interpret the contribution of front-yards to biodiversity and ecosystem services on the neighbourhood scale.

Next to the sensory observation, photos of the yards have been taken for later analysis. Photos have been used before in qualitative and quantitative ways: in preference studies (Ewing 2001; White et al. 2009) and in (socio)-ecological research both inside and outside urban residential areas (Mathieu, et al. 2007; Ahrends et al. 2009; Zheng et al. 2011). Ecologists often use aerial photographs (Vellend et al. 2013; Zarco-Tejada et al. 2013; Beck et al. 2014; Zwaagstra 2014). Aerial photos lack a lot of detail and three-dimensionality that only becomes visible on the ground. In our study multiple photos were taken inside each front-yard of random streets in the neighbourhoods. The pictures were taken from different viewpoints: at least one picture provided a general overview of the front-yard. This overview picture had to capture the approximate size of the garden, the distribution of green coverage versus sealed soils, the vertical diversity of the plantation, and a general view of the garden design style. Complementary pictures were taken to zoom into relevant details (e.g. specific plant species and varieties, furniture, gardening equipment or tools, irrigation systems, damages, signs of herbicide or pesticide use, animal species, forage stations, nesting, water features). The amount of pictures taken for each yard depended on the amount of relevant details. The information delivered by the sensory observations and the photographs were categorized according to the BIMBY indicator framework (Beumer and Martens 2015) and analysed using IBM SPSS Statistics 19. This resulted into an indication of the contribution or dis-contribution of the yards to biodiversity on a neighbourhood level and on the city level (*Total Diversity*).

Table 2 Selection of neighbourhoods in Maastricht and Phoenix

Socio-economic status	Maastricht	Number of yards	Phoenix	Number of yards
High	Sint Pieter	N=80	Palmcroft	N=44
Mid-range	Vroendaal	N=51	Santo Tomas	N=56
Average	De Heeg	N=121	Fairview Place	N=73
Low	Blauwdorp	N=76	Lancaster Manors	N=11
	Total	N=328	Total	N=184

The number of the photographed front-yards varies per neighbourhood due to neighbourhood size, density of yards and safety of entering the neighbourhood. The latter resulted into a low number of photographed yards (n=11) for Phoenix Low (see Table 2). The lead author did not feel safe there as certain residents shouted and signed to move on. The decision has been made to keep Phoenix Low in the sample, being aware that the neighbourhood data are not statistically representative. They still provide some valuable information that qualitatively contributes to the assessments in this paper.

In order to prepare the analysis on the city level[1] and on the neighbourhood level levels, the goodness of fit of a normal model to the data was assessed with descriptive statistics in IBM SPSS 19 for these levels and for the total sample as well by making histograms and normal Q-Q plots (Pallant 2005) (see Appendix 1). The tests showed a normal distribution with the exception of a deviation in Phoenix Low (small sample) and Phoenix Average (two outliers) (see Fig. 1).

Assessing the range of the *Total Diversity* (TD) of the neighbourhoods and the outliers in Phoenix Average (see Fig. 1) made us decide to keep them in the sample. Yard number 297 gives a value for a particular and highly diverse garden with a permaculture-edible design. The garden has an official certification as Wildlife Habitat (NWF 2013). These certificates are provided by the National Wildlife Federation in order to stimulate and restore habitat in residential and commercial urban areas (NWF 2013). The quantitative value given to this garden lies in the range of possibilities, but hasn't been realised in any other assessed yard. The other outlier—yard number 294—is also a highly diverse yard. It includes an edible design and many cultural yard-factors contributing to high diversity. Statistically, on the overall sample level and on the city level the values for these yards don't influence the mean much (also see Pallant 2005, p.62). At the neighbourhood level the two outliers explain some peculiarities in the data.

The descriptive statistics for the total sample level (N=512) have been used to calculate the *Total Diversity* (TD) score bar that represents possible score levels for the contribution and dis-contribution to biodiversity delivered by the gardens (see Table 3 and Fig. 2). The score bar shows a minimum contribution to diversity of −5 (causing damage) to a maximum contribution to diversity of 47 (very high contribution to diversity)—based on a median of 15 (close to a mean of 15.6) and a standard deviation of 8.9.

Points leading to the TD score were distributed by analysing the photos using the BIMBY indicator set (see Appendix 2 and Beumer and Martens (2015)). Firstly, the way the individual yards fit to the climatological zone was defined by contextually comparing the habitat type to the regional climate (e.g. *xeric* or *mesic*). This resulted into a *Regional Biome Match* point (1 point for match and 0 points for no-match).[2] Secondly, the value for the amount of green coverage, the type of soil cover other than green, and the permeability were added. Next the points were distributed for plant abundance, plant richness, and the vertical diversity of the individual yards (Hart 2007; Beumer and Martens 2015). Finally points were distributed for anthropogenic contribution factors and points were deduced for disturbance factors (see Appendix 2 for the weights given to the variables) (Beumer and Martens 2015). The TD

[1] When talking about the 'city level' the four neighborhoods in each city are meant. In accordance with this the samples are not representative for the state of the entire cities. The results only say something about the assessed neighbourhoods.

[2] In the analyses, xeric can also mean that the soil is bare or the coverage is composed of pavement. This means the way the term 'xeric' is used can be in contrast with the native desert landscaping style called '*xeriscaping*' in the Phoenix area.

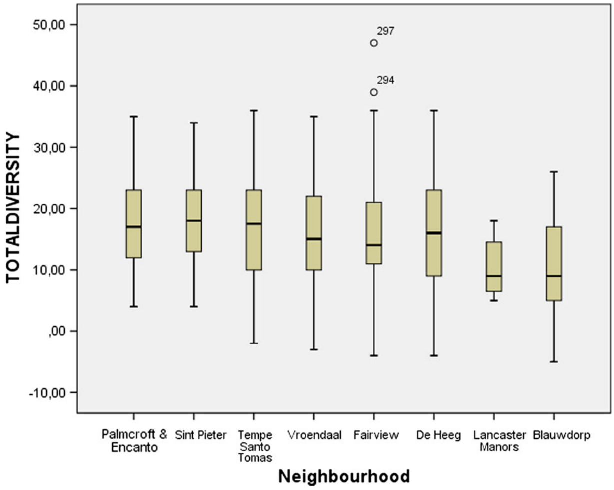

Fig. 1 Range of TD for each neighbourhood

score delivers an indication of the socio-cultural-ecological contribution or dis-contribution of the front-yards to biodiversity on the neighbourhood and the city level. Together with the sensory observations and the contextual knowledge of the assessed area, the outcomes were linked to sustainability and ecosystem services delivered on the neighbourhood level in a qualitative way.

Limitations

The intention of the BIMBY framework is to contribute to an integrated socio-cultural-ecological understanding of domestic urban space and how it is constituted by an interaction of natural and human factors. A further intention is to enhance societal dialogue on

Table 3 Descriptive statistics Total Diversity on total sample level $N=512$

		Statistic	St. Error
Mean		15.5801	0.39378
95 % confidence interval for mean	Lower bound	14.8065	
	Upper bound	16.3537	
5 % trimmed mean		15.6050	
Median		15.0000	
Variance		79.391	
Std. deviation		8.91015	
Minimum		−5.00	
Maximum		47.00	
Range		52	
Interquartile range		12.00	
Skewness		0.69	0.108
Kurtosis		−0.150	0.215

< -5	-9 0	1 10	11 20	21 30	31 40	41 47 >
Damage	Discontribution	Low	Average	Modest	High	Very High

Fig. 2 Total Diversity score bar: levels of contribution or dis-contribution to biodiversity

biodiversity, ecosystem services and sustainability. The pilot assessment presented in this paper has been able to contribute to the first aim to a great extent as many valuable results were fostered. Some important indicators (i.e. animal species, fertilizer use, irrigation, tilling, damages, pests, and diseases) however, were hard to measure without consulting the residents. There were restraints that prevented an immediate response to this limitation. Therefore, we were not able to include all the indicators of the BIMBY framework in this pilot study.[3] For meeting al aims of the framework in future research, it will be necessary to conduct interviews with the residents and to involve them into the assessments of their own gardens. Such a direct involvement will help garden owners see their yards with different eyes and it will stimulate a dialogue about the contribution of residential gardens to biodiversity, sustainability and ecosystem services (Beumer 2014; Beumer and Martens 2015).

Results

Table 4 presents the TD scores of Maastricht and Phoenix. Maastricht (32 %) scores higher on the dis-contribution level (Total Dis) compared to Phoenix (23.3 %). In the contributing categories (Total Con) Phoenix (76.6 %) scores higher compared to Maastricht (68 %). Overall, Phoenix can be said to contribute more to TD compared to Maastricht. A significant percentage of 28.9 % of the total sample can be considered as 'lost urban space' for biodiversity and ecosystem services (Table 5).

Comparing the medians on the neighbourhood level (see Fig. 1) reveals that there are also relevant differences in the TD scores across the neighbourhoods. With a median of 18 for example, Maastricht High turns out to be the most contributing neighbourhood of the sample, followed by Phoenix Mid-Range with a median of 17.5. The scores of these neighbourhoods fall within the higher side of the average contribution category. Phoenix Low and Maastricht Low score a median of 9.0 both, which can be depicted as a low contribution to diversity. Except from these neighbourhoods all the assessed neighbourhoods can be said to contribute to diversity averagely. The median from Phoenix Average (14.0) differs from the mean (17.1) significantly. This can be attributed to the two outliers in this neighbourhood that influence the mean (see Fig. 1).

Regional biome match

Matching the front-yard soil coverage with the regional biome, both cities show just a slightly larger amount of matching yards compared to mismatching ones: Phoenix 56.5 % of matching xeric yards; Maastricht 52.7 % of matching mesic yards. Maastricht High scores best with a mesic match score of 75 %. Phoenix Mid-Range displays the highest match to the arid Arizona biome with almost 93 %. Phoenix High and Maastricht Low have a large biome mismatch. In Phoenix High 75 % of the yards have a mesic character contradicting the surrounding Sonoran desert environment. Maastricht Low shows a mismatch of 73.7 %, which means there is a high amount of xeric yards in this neighbourhood.

[3] The included indicators (see Appendix 2) are shades whereas the ones we were not able to include are white.

Table 4 Contribution levels of Phoenix and Maastricht to Total Diversity (TD)

City		Discon	Low	Total Dis	Average	Modest	High	Very high	Total Con	Total Yards
Phoenix	Count	3	40	43	87	45	8	1	141	184
	% within City	1,6%	21,7%	23,3%	47,3%	24,5%	4,3%	0,5%	**76,6%**	100,0%
Maastricht	Count	23	82	105	125	80	18	0	223	328
	% within City	7,0%	25,0%	**32%**	38,1%	24,4%	5,5%	0,0%	68%	100,0%
Total	Count	26	122	148	212	125	26	1	364	512
	% of Total	5,1%	23,8%	**28,9%**	41,4%	24,4%	5,1%	0,2%	**71,1%**	100,0%

The orange column (Total Dis) represents the total points for discontribution (negative contribution) of the gardens to biodiversity, sustainability and ecosystem services. The green column (Total Con) represents the total points for positive contribution to biodiversity, sustainability and ecosystem services. The bold numbers inside the highlighted green and orange section indicate the highest level of respective contribution and discontribution

Soil cover

Lawns The assessed neighbourhoods in Phoenix have relatively many yards with the highest amount of lawn (37 %) compared to Maastricht (11 %) (see Table 6). Most of them are located in Phoenix High (65.9 %). Phoenix Mid-Range is contrasting this trend with only 5.4 % of the yards covered with lawn for 50 to 100 % and 91.1 % of yards with no lawn coverage at all.

Table 5 Contribution levels on the neighbour hood level to Total Diversity (TD)

Neighbourhood		Discon	Low	Total Dis	Average	Modest	High	Very high	Total Con	Total Yards
Phoenix High	Count	0	9	9	20	14	1	0	35	44
	% within Neighb.	0%	20,5%	20,5%	45,5%	31,8%	2,3%	0%	79,6%	100,0%
Phoenix Mid-Range	Count	2	13	15	23	16	2	0	41	56
	% within Neighb.	3,6%	23,2%	26,8%	41,1%	28,6%	3,6%	0%	73,3%	100,0%
Phoenix Average	Count	1	12	13	39	15	5	1	60	73
	% within Neighb.	1,4%	16,4%	17,8%	53,4%	20,5%	6,8%	1,4%	**82,2%**	100,0%
Phoenix Low	Count	0	6	6	5	0	0	0	5	11
	% within Neighb.	0%	54,5%	**54,5%**	45,5%	0%	0%	0%	45,5%	100,0%
Maastricht High	Count	0	9	9	40	24	7	0	71	80
	% within Neighb.	0%	11,3%	11,3%	50,0%	30,0%	8,8%	0%	**88.8%**	100,0%
Maastricht Mid-Range	Count	1	13	14	22	11	4	0	37	51
	% within Neighb.	2,0%	25,5%	27,5%	43,1%	21,6%	7,8%	0%	72,5%	100,0%
Maastricht Average	Count	13	25	38	41	35	7	0	83	121
	% within Neighb.	10,7%	20,7%	31,4%	33,9%	28,9%	5,8%	0%	68,6%	100,0%
Maastricht Low	Count	9	35	44	22	10	0	0	32	76
	% within Neighb.	11,8%	46,1%	**58,4%**	28,9%	13,2%	,0%	0%	42,1%	100,0%
Total	Count	26	122	148	212	125	26	1	364	512
	% within Neighb.	5,1%	23,8%	**28,9%**	41,4%	24,4%	5,1%	0,2%	**71,1%**	100,0%

The orange column (Total Dis) represents the total points for discontribution (negative contribution) of the gardens to biodiversity, sustainability and ecosystem services. The green column (Total Con) represents the total points for positive contribution to biodiversity, sustainability and ecosystem services. The bold numbers inside the highlighted green and orange section indicate the highest level of respective contribution and discontribution

Table 6 Soil coverage categories in Phoenix and Maastricht

City * Lawn							
			No	<10 %	10–50 %	50–100 %	
City	Phoenix	Count	94	1	21	68	184
		% within city	51.1 %	0.5 %	11.4 %	37.0 %	100.0 %
	Maastricht	Count	270	0	22	36	328
		% within city	82.3 %	0.0 %	6.7 %	11.0 %	100.0 %
Total		Count	364	1	43	104	512
		% within city	71.1 %	0.2 %	8.4 %	20.3 %	100.0 %
City * Gravel							
City	Phoenix	Count	107	12	30	35	184
		% within city	58.2 %	6.5 %	16.3 %	19.0 %	100.0 %
	Maastricht	Count	237	15	33	43	328
		% within city	72.3 %	4.6 %	10.1 %	13.1 %	100.0 %
Total		Count	344	27	63	78	512
		% within city	67.2 %	5.3 %	12.3 %	15.2 %	100.0 %
City * Pavement							
City	Phoenix	Count	116	41	18	9	184
		% within city	63.0 %	22.3 %	9.8 %	4.9 %	100.0 %
	Maastricht	Count	97	78	55	98	328
		% within city	29.6 %	23.8 %	16.8 %	29.9 %	100.0 %
Total		Count	213	119	73	107	512
		% within city	41.6 %	23.2 %	14.3 %	20.9 %	100.0 %
City * BareSoil							
City	Phoenix	Count	126	13	27	18	184
		% within city	68.5 %	7.1 %	14.7 %	9.8 %	100.0 %
	Maastricht	Count	286	15	22	5	328
		% within city	87.2 %	4.6 %	6.7 %	1.5 %	100.0 %
Total		Count	412	28	49	23	512
		% within city	80.5 %	5.5 %	9.6 %	4.5 %	100.0 %
City * Summary greencoverpoints							
City	Phoenix	Count	23	78	62	21	184
		% within city	12.5 %	42.4 %	33.7 %	11.4 %	100.0 %
	Maastricht	Count	80	89	78	81	328
		% within city	24.4 %	27.1 %	23.8 %	24.7 %	100.0 %
Total		Count	103	167	140	102	512
		% within city	20.1 %	32.6 %	27.3 %	19.9 %	100.0 %

Phoenix High, Maastricht High and Phoenix Average have a substantial amount of yards combining lawn with a significant amount of other soil covering elements.

Gravel The majority of the assessed yards in both cities have no gravel coverage at all (67.2 %) (see Table 6). Phoenix Mid-Range scores highest gravel coverage (41.1 % of the yards). This means that the low amount of lawns in there is compensated by the relatively high amount of gravel yards, which explains the xeric character of this neighbourhood.

Pavement Comparing Maastricht to Phoenix shows there is a large difference between the amounts of paved yards in the two cities: The highly paved yards Phoenix and Maastricht differ significantly (see Table 6). Phoenix has only 4.9 % of its yards paved between 50 % and 100 %; Maastricht has a high pavement score of 29.9 %. On the neighbourhood level Maastricht Low (51.3 %) and Maastricht Average (32.2 %) score highest for pavement. Phoenix Low has the highest amount of yards with no pavement (81.8 %). The other neighbourhoods in Phoenix also have a majority of front-yards with no pavement at all. Phoenix Mid-Range contributes with 14.3 % most to the yards with 50 to 100 % pavement in Phoenix. Front yards there are occasionally used as parking space, sometimes adorned with plantation-strips at the edges.

Bare soil Both cities do not have a high amount of bare soil. This is indicated by the high scores for the 'no bare soil' category (see Table 6). Only Phoenix Low has a fair amount of yards (36.4 %) with a 50 to 100 % bare soil structure. In Phoenix, bare soil often indicates negligence and often leads to dusty circumstances, degrading the soil even more. Contrarily, in Maastricht bare soil often indicates the elimination of weeds by a higher care level.

Green cover In Phoenix only 11.4 % of the yards are highly abundant with green coverage other than lawn. This is especially apparent in Phoenix High (40.9 %) and Phoenix Mid-Range (51.8 %) in the less than 10 % green coverage category. The highest amount of yards with no green coverage can be found in Maastricht Low (39.5 %), Phoenix Low (36.4 %) and Maastricht Average (25.6 %). This corresponds to the high pavement levels in the Maastricht neighbourhoods and the high bare soil percentage in Phoenix Low (see above).

Abundance, richness and vertical diversity

The plant diversity values have been composed of the combination of the points given for green coverage (see above), the abundance of perennials and annuals, on the richness of native and exotic species and on the presence of vertical diversity (Hart 2007; Beumer and Martens 2015). The calculation resulted into values ranging from 0 to 31. Based on a statistical assessment of normality we labelled the values as in Fig. 3.

Most of the assessed yards of the total sample are in the average category (61.9 %). Maastricht has with 33.5 % significantly more yards with low plant diversity compared to Phoenix (21.7 %). Both cities score almost equal in the high diversity category (Phoenix 8.7 % and Maastricht 8.5 %). Only Phoenix has one yard in the extraordinary category (one of the outliers). At the neighbourhood level Phoenix Low (54.5 %) and Maastricht Low (56.6 %) in have least plant diversity. Phoenix Average turns out to be the neighbourhood with the highest amount of averagely diverse yards (76.6) together with Maastricht High (71.3 %). In the category high diversity Phoenix High scores best with 15.9 % (often with exotics and annuals).

Another important indicator for biodiversity is the vertical diversity. This was measured by looking at the availability of flowers, shrubs, trees and weeds. One point was added up for the presence of each of these elements. This resulted in 'Vertical Points' (see Table 7). On the city

0 10	11 20	21 30	31 40
Low	Average	High	Extraordinary

Fig. 3 Scale of plant diversity

Table 7 Vertical diversity in Phoenix and Maastricht

			Vertical points					Total
			0.00	1.00	2.00	3.00	4.00	
City	Phoenix	Count	6	21	42	71	44	184
		% within city	3.3 %	11.4 %	22.8 %	38.6 %	23.9 %	100.0 %
	Maastricht	Count	26	72	104	80	46	328
		% within city	7.9 %	22.0 %	31.7 %	24.4 %	14.0 %	100.0 %
Total		Count	32	93	146	151	90	512
		% within city	6.3 %	18.2 %	28.5 %	29.5 %	17.6 %	100.0 %

level Phoenix scores highest in the categories of high vertical diversity: three (38.6 %) or four (23.9 %) points. In the case of four points it means that all the vertical features are available. Overall, most yards of the total sample score highest in the categories where two or three points are distributed (respectively 28.5 and 29.5 %). Only a small amount of yards, but still a significant 6.3 % present none of the features adding to vertical diversity.

On the neighbourhood level Phoenix Average (30.1 %), Phoenix High (30.4 %) and Maastricht High (27.5 %) score best in the category where four points are given for vertical diversity. Maastricht Low (1.3 %) and Phoenix High (6.8 %) score least in this category. However, Phoenix High scores extremely high in the category for three vertical diversity points (61.4 %), including everything except for native wild plants or 'weeds'.

Trees need some special mentioning in the context of vertical diversity: they are best represented in Phoenix High where 90.9 % of all the yards have one or more private trees. Maastricht Average (33.1 %) and Maastricht Low (13.2 %) score lowest in private trees. However, this doesn't mean that these neighbourhoods are devoid of trees. In these neighbourhoods trees are integrated in the urban planning design, which can also be said for most of the other visited neighbourhoods, except for Phoenix Low and Phoenix Mid-Range. In these latter neighbourhoods low level of private trees are combined with the absence of municipal trees.

Anthropogenic factors

Using anthropogenic factors as indicators for biodiversity (as contributors or disturbers) isn't very common. Here we demonstrate that including anthropogenic variables reveals interesting patterns. For each occurring anthropogenic feature one point was distributed. In total not more than eight points were given to an individual yard. This point only occurred in the permaculture yard in Phoenix Average.

Contributors

Although Maastricht Low scores rather low in the biotic contributions to biodiversity and high in the zero-category of a-biotic contributions, it has the highest amount of public and private bird-nesting opportunities. Coloured nest-boxes are on many of the street trees and home walls in this neighbourhood (13.2 %). A social-housing company of the neighbourhood carried out a project where these nest-boxes were made by artists with children and patients of a psychiatric care facility (Woonpunt 2012). A common garden in the neighbourhood would have added another large amount of nest-boxing facilities to this neighbourhood. Maastricht Average follows Maastricht Low in the lead on nest-boxes with 5.8 %. Nevertheless, these percentages are low. Insect-hotels weren't present in any of the visited yards. Phoenix High takes the lead with bird-feeders (13.6 %), closely followed by Phoenix Average (12.3 %). Most of them are intended for hummingbirds. Possibly, it can be attributed to the visiting season (spring and early summer), but wild food was also low in most of the neighbourhoods. Phoenix Average had most available wild-food (17.8 %). This can be related to the presence of the two edible yards there. Bird-bathing facilities were hardly available anywhere. Phoenix High had the most of these facilities with only 6.8 %. Most of the baths were not filled with water though. Phoenix High (52.3 %) and Phoenix Average (49.3 %) present the highest amount of plant-containers. These can be tiny 'micro-climates' with other soil temperatures, structures and moisture levels than surrounding yard-features. They can be favourable nesting places for insects like carpenter bees. Also, very often the containers are used to house exotic plant species that are potentially attractive to native animal species as well (Burghardt et al. 2008; Kirmer and Tischew 2010; Heezik et al. 2012). Compost and other organic matter can hardly be found in any of the front-yards in the visited neighbourhoods. Visible irrigation systems show a significantly higher abundance in Phoenix yards (28.3 %) compared to Maastricht (1.2 %). Especially Phoenix Average with 38.4 % and Phoenix High with 31.8 % have many yards with visible irrigation systems. Based on the sensory information, the use of irrigation seems to be higher in Phoenix High compared to Phoenix Average.

Disturbances

With regards to potential disturbances, artificial light scores high in Phoenix, with Phoenix High in the lead: 52.3 %. Phoenix Mid-Range scores also high with 48.2 %, followed by Phoenix Average (34.2 %). The Dutch neighbourhoods have significantly less light installations, ranging from zero in Maastricht High to 3.3 % in Maastricht Average. Artificial light has often been qualified as a disturbance for urban wild animals (Stone et al. 2012; Lewanzik and Voigt 2014; Perkin et al. 2014). However, other research indicates that some spiders species fare well by these features as light attracts their food sources (Lowe et al. 2014). Many front-yards have benches or tables installed to facilitate social time in the yards. In Phoenix Low (45.5 %), Phoenix Average (35.6 %), Phoenix High (25 %) most furniture can be found. Maastricht Mid-Range (5.9 %) and Phoenix Mid-Range (5.4 %) have least furniture. The most frequently observed disturbance after the light installations and furniture is the habit of people to park vehicles like bicycles, motorbikes, baby-buggies and cars in their front-yard. Overall, the yards in Maastricht are more often used for parking vehicles than the ones in Phoenix. This can be attributed to the many bicycles that are given a parking-spot in Dutch yards.

Design style

Design styles can be indicative for the way yards contribute to biodiversity and ecosystem services or disservices (Orians 1980; Schulz 1985; Lohr 2007; Chou et al. 2011). Although there are globally many more styles, we only included the ones that were meaningfully identified during the field visits and photo analyses (see Fig. 4).

At the city level desert gardens (*xeriscape*) (Norris-Bernzel and Edinger 2005; Larsen and Harlan 2006) are most popular in Phoenix. These account for 26 % of all the analysed yards in

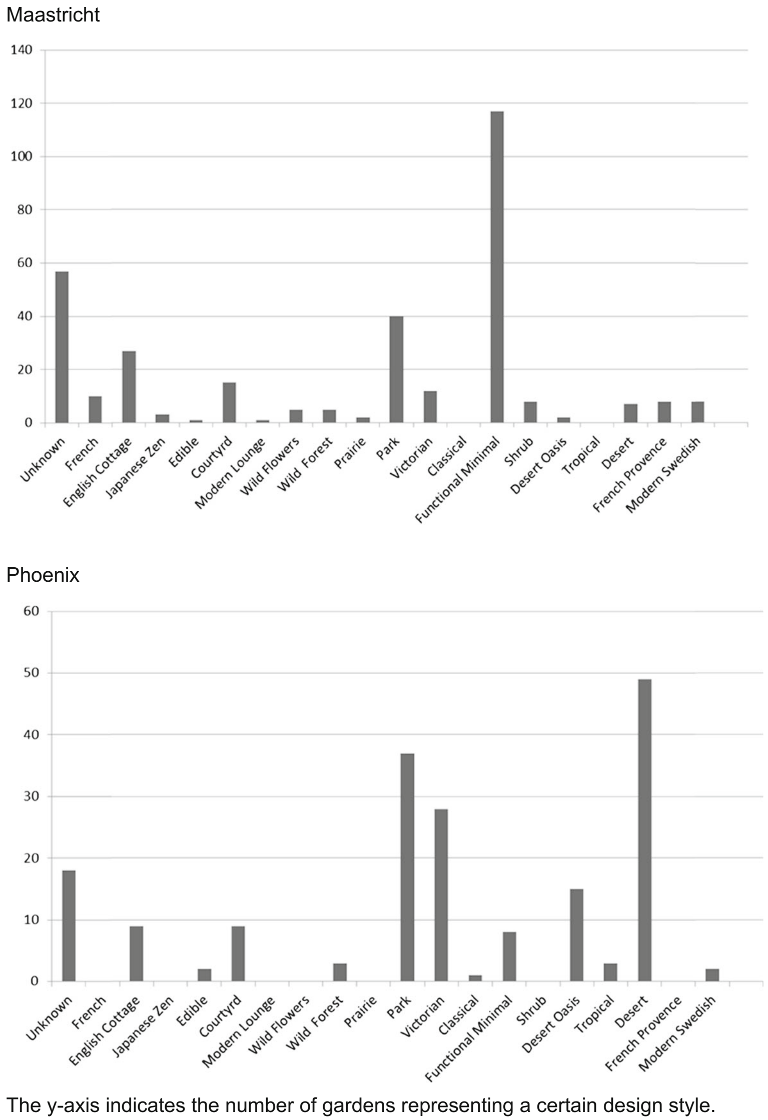

Fig. 4 Design inspiration in Phoenix and Maastricht

Phoenix. However, the green English style *picturesque* or 'park' gardens (20.1 %) (Szilagy 2011) and the gardenesque—or Victorian gardens (Ignatieva 2010)—both garden types with lawns, shrubs and trees (and in the Victorian gardens flower beds with usually exotic flowers) together make up for 35.3 % of the yards in Phoenix. These gardens add biodiversity to the otherwise native desert environment, but bring along many sustainability problems like water shortages (Larsen and Harlan 2006; Martin 2008; Larson et al. 2009; St. Hilaire et al. 2010; Smetana and Crittenden 2014) and pollution through the higher use of pesticides and herbicides in lawns (Khachatryan and Zhou 2014; Smetana and Crittenden 2014). In Maastricht 'desert-gardening' is also popular. We called these yard-types 'functional minimalist' because they combine low maintenance needs with a low occurrence of any type of green and a high occurrence of pavement or gravel. Often these yards are used for parking vehicles or for equipped for social activities (BBQ and/or furniture). The more maintenance intensive version of this type of yard often reflects elements from 18th century Régence Gardens with fantastic and intricate forms of topiary, referred to in the literature as '*Dutch Taste*' (Hopper 1981). The functional minimalist yard occurs 35.7 % of all the yards in Maastricht.

Each individual neighbourhood can be said to have a general most popular design that distinguishes it from the others. In Phoenix High the gardenesque (45.5 %) and picturesque (20.5 %) yards prevail. Phoenix Mid-Range is characterised by native desert (xeriscape) gardens (58.9 %). Phoenix Average favours park-gardens most (30.1 %) and Phoenix Low also has prevalence for the *picturesque* park idea (54.5 %). In Maastricht High the most occurring yard types can be described as park (22.5 %) and cottage style (20 %). Maastricht Mid-Range has a high occurrence of park (33.3 %) and functional minimalist (21.6 %) yards. Also a relatively high level of Versailles style gardens occurs (7.8 %), which is a style based on neatly kept geometric patterns and structures, most commonly combining (buxus) hedges with lavender, roses or hydrangea. Maastricht Average is characterized by a high level of functional minimalism (42.1 %). This is the same for Maastricht Low (56.6 %).

Levels of intentional design

The level of intentional design indicates how 'strictly' people apply structures and features (e.g. geometrically planted patterns, and fantastic forms of topiary, pavement-designs, swimming pools etc.) in their yards, complementary to giving yards space to some spontaneous 'wilder' plant growth. Overall most gardens are occurring in the category of high intentional design (45.7 % of all the yards in our sample). The highest percentage of yards with high intentional designs occurs in Maastricht Mid-Range (72.5 %). This can be explained by the fact that this is a young neighbourhood (built in 2000) where design intentions are still very visible. Phoenix Low is the only neighbourhood where a low intentional design overrules medium or high intention. In Maastricht High a medium intentional design is most common, pointing towards the high occurrence of cottage style yards (20 %) in this neighbourhood that give some space to (seemingly) spontaneous growth. Also the relatively high 'allowance' for weeds (in 43.8 % of the yards) contributes to this value in the neighbourhood.

Care level and care need

Some yards are designed to have low maintenance needs and some need high maintenance to fulfil their design. The level of care that is needed for individual design styles can differ depending on climate, e.g. rainfall and temperatures. A lawn in Phoenix needs much more care (e.g. irrigation, fertilizers) (Martin 2008) compared to a lawn in Maastricht. A garden full of wild flowers may seem care-intensive and time consuming to maintain, but in both regions, whilst native plants are considered in the design, this doesn't have to be the case. Comparing care levels and care needs also provides information on how engaged people are in the activity of gardening. The level of high maintenance yards in Phoenix (41.3 %) is much higher compared to Maastricht (14.6 %). This can be attributed to the high occurrence of park and gardenesque styles in Phoenix that—especially in a desert area—need a lot of care and work. In the medium maintenance need level Maastricht scores higher, whereas the low maintenance yards are almost equally distributed across the two cities.

Interestingly, Phoenix Low has the highest percentage of yards with a high maintenance need design. Nevertheless the actual care level in this neighbourhood is very low (45.5 %), which results into an image of negligence. Phoenix Average (56.2 %) and Phoenix High (50 %) also have high percentages of high care needs in their yard designs. The actual level of care is higher in Phoenix High (79.5 %) compared to Phoenix Average (46.6 %). Maastricht Mid-Range has the highest need for care designs (27.5 %) in Maastricht. Least in this category scores Maastricht Low with only 2.6 %. Maastricht Mid-Range and Phoenix High have least yards with low actual care levels (respectively 7.8 and 4.5 %).

Discussion

Ecosystem services and disservices: A qualitative evaluation of the results

Based on biogeography, and Species Area Relationships (SARs), more biodiversity is usually considered to be better (Rosenzweig 2003; Whittaker and Fernandez-Palacios 2007). Halting the loss of biodiversity is crucial for sustaining the well-being of all inhabitants of the planet, but bringing it back to places where people once 'eliminated it' can also have adverse effects on human well-being and the environment (Lyytimäki et al. 2008). Nuisance, available time, health issues (pollen, pests, venomous plants, prickly plants, allergies etc.) and safety risks (dark parks, falling tree branches, aggressive wild animals etc.) related to gardening practices and designs should not be underestimated (Lyytimäki et al. 2008). In this discussion section we focus on the role of the socio-cultural-ecological garden features that contribute to biodiversity. The results described above are now placed in a context of sustainability (Newman 1999; Dresner 2002; Giddings et al. 2002; Banerjee 2003; Castro 2004; Robinson 2004; Williams and Millington 2004; Martens 2006; Rees and Wackernagel 2008; Rees 2010) and ecosystem services (Costanza et al. 1997; Opschoor 1998; Bolund and Hunhammar 1999; Lyytimäki et al. 2008; TEEB 2009, 2011; Ignatieva et al. 2011; Mitchell et al. 2013; Costanza et al. 2014). The most important services and disservices identified on the level of the neighbourhoods are described. This 'contextualisation' has been done qualitatively, taking into account the indicator-results, the sensory neighbourhood observations and the contextual knowledge—based on empirical experience and literature—of both regional environments. A schematic summary and systematic categorisation of the ecosystem services and dis-services of each neighbourhood can be found in Appendix 3.

Phoenix

In Phoenix there occurs a tension between neighbourhoods that contribute to biodiversity in relatively high levels—like *Phoenix High*—while at the same time causing sustainability problems. Research done by others in the Phoenix area confirms these findings (Martin 2008). With the ideal of maintaining a once propagated image of Phoenix as an oasis in the desert (Larsen and Swanbrow 2006) many species that are brought into the city are contrasting the native desert environment. Phoenix High is a post WWII suburban neighbourhood for the wealthier, displaying a variety of historic architectural styles. There are Home Owners Associations (HOA) that urge residents to conform their gardens to the aesthetical standards of the historic area. The green in this neighbourhood is designed to be friendly to people: it gives people a 'break' from the harsh desert by providing a cooler, shady sub-climate through places with high evapotranspiration (Martin 2008), a regulating service. Phoenix High looks like a ‘patchwork’ of small green oases where one can almost forget to be in a desert. This green character adds higher levels of diversity to the whole Phoenix region (Martin 2008). However, lush and green gardens in a desert environment are time, fertilizer, costs- and water intensive (Zube et al. 1986; Nassauer 1995; Larsen and Harlan 2006). More than 70 % of the household-water in Phoenix is spent on watering lawns like the ones prevailing in Phoenix High (Mee 2011).

Phoenix Mid-Range was built in the 1970’s and has a rather uniform character of homes with patios, small front yards and adobe-walled gardens that give the neighbourhood architecture a Mexican flavour. It has a high amount of *xeriscape* yards (Norris-Bernzel and Edinger 2005; Mee 2011) although some green lawn yards can also be found here. With its relatively high vertical diversity and many native plants it potentially contributes to a functional connectivity to the desert (Rudd et al. 2002). The neighbourhood reflects an ideal of contributing to the local environment through the abundant planting of native species and water saving measures (Mee 2011). The relatively high maintenance level of these intentionally lower maintenance yards reflects a wealthy and neat neighbourhood image. The downsides of the front-yard designs can partly be found in the walled character. The adobe-walls provide shade on the streets and in the backyards. However, due to the plaster on most of the walls they don’t provide habitat to small, insects or other animals and they mainly fragment the neighbourhood and decrease the structural connectivity (Rudd et al. 2002). Research pointed out that the environmental advantages of saving water in drought tolerant yards are undone by the heightened use of pesticides in such yards (Larson et al. 2010). Other research demonstrated that the dripping-systems that are installed in xeric yards often operate at higher frequencies than is actually necessary for the survival of the desert plant species (Martin 2008). The net benefits for urban resilience and sustainability are at least questionable.

Phoenix Average is a central Phoenix historic district built in the 1920’s with various architectural styles (Fairview 2009). Most homes have front and backyards. The neighbourhood is flanked by a rose garden and the oasis-like Encanto Park on the East. Phoenix Average is characterized by a high diversity of yard design styles which contributes delivers many ecosystem services and increases biological diversity of the nearby environment. A significant number of yards theoretically contribute to the functional connectivity to the native desert (Rudd et al. 2002). Other yards contrast the desert with lush green abundance. There are two yards with edible designs based on the principles of permaculture (Mollison 1988; Hemenway 2009). One of these yards even contributes to biodiversity as a certified *Wildlife Habitat* (Rosenzweig 2003; NWF 2013). The yards with lawns and trees provide climate regulation: cooler micro-climates and higher well-being through evapotranspiration (Martin 2008). The neighbourhood also expresses an interest in social encounter by the many seating facilities in the front-yards, by art-works, and by the educational and inspirational character of the permaculture Wildlife Habitat. Disservices are especially caused by the neglected yards where soil erosion creates dust problems and little ‘deserts within a desert’. These yards can also cause a drop in property value for the surrounding homes and create potential image problems for the block.

Phoenix Low is a deprived neighbourhood with small homes built in the 1940’s and 1950’s. It is located near Phoenix Sky Harbor Airport, the open air Pueblo Grande Museum and not too far away from the semi-wild urban desert Papago Park that houses the Desert Botanical Garden (DBG 2013). All homes in the area have front and backyards. The front-yards don’t contribute much to biodiversity. However, there are some positive aspects related to sustainability here: the low level of care indicates that not much water is spent. Signs of social encounters are present through playing equipment and furniture in some of the yards. However, the visible lack of care results into diminished aesthetic qualities and property values and causes a potential feeling of unsafety. The prevalent bare soil structures and the lack of trees cause a strong heat island effect and dusty air. Research points out that residents living in deprived areas such as Phoenix Low generally have less access to green and lack the financial means to enrich their own yards with abundant life (DesJardins 2006; Hope et al. 2006; Martin 2008; Mitchell and Mueller 2009; Pearsall and Pierce 2010; Beatley 2011). A lack of experience of green can also feed back into the ongoing loss of biodiversity, considering the assumption that "people are most likely to take action for biodiversity if they have direct contact with nature (Müller et al. 2010, p.26)."

Maastricht

Compared to Phoenix, Maastricht has a high amount of xeric yards that create a barren urban landscape. Although people may consider such yards time- and money- efficient, they have many adverse effects: they contribute to landscape fragmentation and habitat loss; to soil and water degradation (through the use of herbicides); to an increased urban heat-island effect during hot summers; to decreased CO2 sequestration; and they may cause flooding-problems during strong rainfall due to the loss of soil permeability. Functional minimalist yards also lack the psychological and health benefits that are coupled to lush green environments (Kaplan 1995; Maas et al. 2006; Nasar 2011; Van den Berg et al. 2014).

The wealthy *Maastricht High* quarter seems most contradictive to the functional minimalist trend. Maastricht High used to be an independent village just outside the Maastricht inner-city walls and became part of the municipality in 1920. Natural areas connected to the neighbourhood are the Pietersberg and Jekerdal with the Jeker Creek. At the East side Sint Pieter is flanked by the river Meuse. At the north side the ring road around Maastricht separates the neighbourhood from the picturesque inner-city park. The homes are an eclectic assemblage of architecture from the early 20th century and the late 19th century. Also more recent and even modern architectural styles can be found. Through its relatively high diversity of yards the neighbourhood contributes comparably much to food and habitat for a diversity of animal species. The diversity and lush features and the open character of many yards make them nodes in a network of functional connectivity (Rudd et al. 2002). Cultural services are delivered by the aesthetic quality of the neighbourhood, contributing to well-being, sports and recreation in the adjacent natural parks. The high quality of life contributes to high property values and the neighbourhood being a very popular area for affluent residents and visitors. Potential harm to the local environment can be caused by the spreading of invasive alien species from the yards to proximate nature. The higher maintenance levels of many yards, especially the gardenesque ones and the yards with geometric Versailles designs, can cause disturbance to nesting, feeding or sheltering animal species. High maintenance levels also often imply regular soil disturbance (Hemenway 2009).

In the newly built *Maastricht Mid-Range* (2000) people may feel safe and sound. The neighbourhood is located at the edge of the historic forest Savelsbosch. Various real estate websites promote the neighbourhood as being 'close to nature.' Close to nature in this case means 'separated' from it as well: Maastricht Mid-Range is characterized by yard-types that form a contrast to the very proximate forest which is a home to badgers, foxes, dear, squirrels and an abundance of many other animal species. Many of the yards have hedges that potentially provide habitat, shelter, connectivity and nesting facilities for birds, hedgehogs and other species. However, they are usually well trimmed and pruned, which can cause disturbance, anxiety and the loss of habitat functions (Martin 2008). Soil health may be low or decreasing in this neighbourhood due to high maintenance-, lawns-, and pavement patterns. The maintenance of lawns and hedges potentially also causes nuisance for neighbours due to machine noise and fumes (Tint et al. 2012).

Maastricht Average is a neighbourhood with two faces: a green face and a grey face. The high amount of pavement and other soil covering structures creates 'desert patches' devoid of any life. At the other side, there is tolerance for individual expression and there are quite a number of yards with highly diversely planted designs. The municipal design of the neighbourhood is green and spacious with many trees, shrubs, grass patches and a picturesque style park meandering through the whole length of the area. The maintenance of the park by sheep grazing contributes to a higher diversity of wild flowers and grasses. The neighbourhood delivers many cultural services, such as garden-watching, children and dog-playing opportunities, watching and stroking the sheep, and picnic areas. Some yards are nodes in the functional and structural connectivity to the park and the nearby Savelsbos (Rudd et al. 2002). The municipal trees, shrubs and the flowered yards provide an abundance of habitat food for small animals like hedgehogs, pollinators and birds. The municipal design of the neighbourhood compensates for many potential disservices delivered by the high amount of paved yards: water-runoff; urban heat-island effect; loss of aesthetic value; loss of (social) well-being. However, the park also causes disservices reflected by residents: reduced feeling of safety due to abundant municipal hedges and a lack of illumination during the dark hours. Because of the lack of private 'ownership' of trees, there is a higher potential for experiencing nuisance related to falling leaves of the municipal trees.

Maastricht Low provides little benefits to biodiversity. The high level of pavement and gravel contribute to 'desertification' of the area. With the perspective of a changing climate and stronger peak rains and hotter summers ahead (Steffen et al. 2005; Simonis 2011; IPCC 2013), the high amount of paved gardens adds to higher municipal and health care costs due to physical and psychological discomfort, heat stress, water-runoff and flooding (Huynen et al. 2004; Alcoforado and Andrade 2008; Huynen 2008; Theeuwes et al. 2012; Rahola et al. 2014; Zwaagstra 2014). The grey-ness of the district does not contribute to a positive image and it reduces a feeling of comfort and safety. However, there is a high level of social use of the front-yards. This can be seen as a disturbance to wildlife but also as leading to higher social cohesion and neighbour contacts. Costs for people to maintain their yards are low, which is the same for the time they may spend on care and maintenance. There may be issues of environmental justice (Mitchell and Mueller 2009; Pearsall and Pierce 2010) due to a lack of resources and knowledge on facilitating a greener neighbourhood.

Conclusion

Through a pilot assessment of front-yards in Phoenix and Maastricht using the BIMBY indicator framework we were able to show how ecological, cultural and social factors like plantation, garden design, garden use, and maintenance levels relate to a contribution or dis-contribution to biodiversity, ecosystem services, urban and even regional sustainability.

Comparing the two case cities showed that the assessed front-yards in Phoenix contribute to biodiversity more compared to the ones in Maastricht. Maastricht High turned out to be the most contributing neighbourhood, followed by Phoenix Mid-Range. The neighbourhoods with a socio-economical low status scored least for their contribution to biodiversity. Curiously, although the Average neighbourhoods in both cities did not score best in their contribution to biodiversity and sustainability, they showed the greatest diversity in their garden design, plantation, maintenance, and use styles on the neighbourhood level. Overall the neighbourhoods contributed to biodiversity in very different ways and styles that can be related to their history, dominant design, social conformation (i.e. the HOAs in Phoenix), and the socio-economic status of the neighbourhood.

It seems logical to assume that gardens that contribute to biodiversity in a stronger way also deliver more ecosystem services to people and contribute to urban and regional sustainability to a higher extent. In the case of Phoenix this logical assumption needs to be questioned at least. The high amount of green gardens adds diversity in the form of 'exotic' species and an 'oasis landscape' to the local and regional desert biome. However, these green park-like gardens consume more water than can be considered sustainable for the long-term existence of the city. This again needs to be traded off against the ecosystem services—especially cultural and regulatory services—delivered by the green gardens that provide the desert-city dwellers a more comfortable, less prickly, and cooler living environment. Such services are delivered only to a lesser extent by the xeric garden designs such as in Phoenix Mid-Range.

In Maastricht many gardens add to differentiation of the regional biome and the urban landscape. This can be attributed to the high individual freedom for home owners to design and maintain their yards. Many lush green gardens represent native and perennial vegetation and function as nodes in a green infrastructure that extends urban space. However, the highest amount of gardens in this city does not contribute to biodiversity and sustainability at all. This can be ascribed to the popularity of the functional minimalist garden. In Maastricht many residents seem to be guided by the choice for ease and time-efficiency when it comes to gardening and garden designs. The installation of pavement or fully gravelled yards results in the 'desertification' of an otherwise green eco-region. Here, a discussion could be started on whether this ideal of low-maintenance has to be covered by 'paved deserts'. Perhaps there are other options that combine time concerns, aesthetic concerns, and environmental concerns in the design. With the perspective of a changing climate (stronger peak rains and hotter summers) ahead, the high amount of paved gardens adds to an unsustainable and uncomfortable living environment that inevitably will lead to higher healthcare costs and repair costs of flooded homes and damaged infrastructures.

It can be concluded that a universal blueprint for a sustainable yard design does not exist. The contribution of domestic gardens to a sustainable living environment is highly dependent on the regional biome and on the social and cultural context. In order to better understand how gardening designs, preferences and maintenance styles in diverse socio-cultural contexts contribute to biodiversity, the delivery of ecosystem services, and urban and regional sustainability, future research using the BIMBY indicator framework needs to include the experiences, observations and perspectives of garden owners. Active engagement of citizens will also lead to help building a societal dialogue on these issues, which is fundamental if we want to transform our cities into long-term thriving living environments.

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Compliance with ethical standards The authors of this paper hereby declare to the journal Urban Ecosystems that we are in compliance with Ethical Standards with regards to the contents of the manuscript. In addition, there is no conflict of interests regarding the conduct of this research and we did not use humans or animals as test subjects while conducting the study.

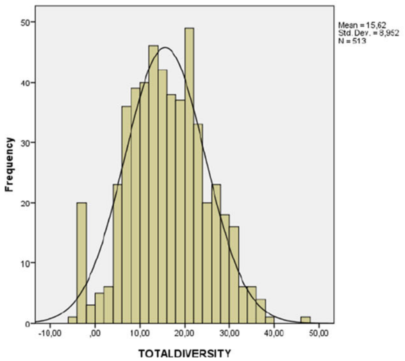
Appendix 1. Tests for normal distribution

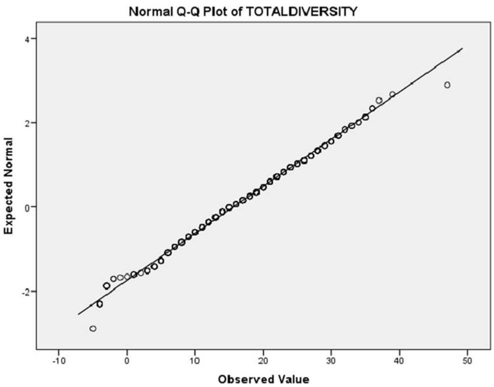
a. Total sample level

Tests of normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Total diversity	0.049	513	0.004	0.993	513	0.013

[a]Lilliefors Significance Correction





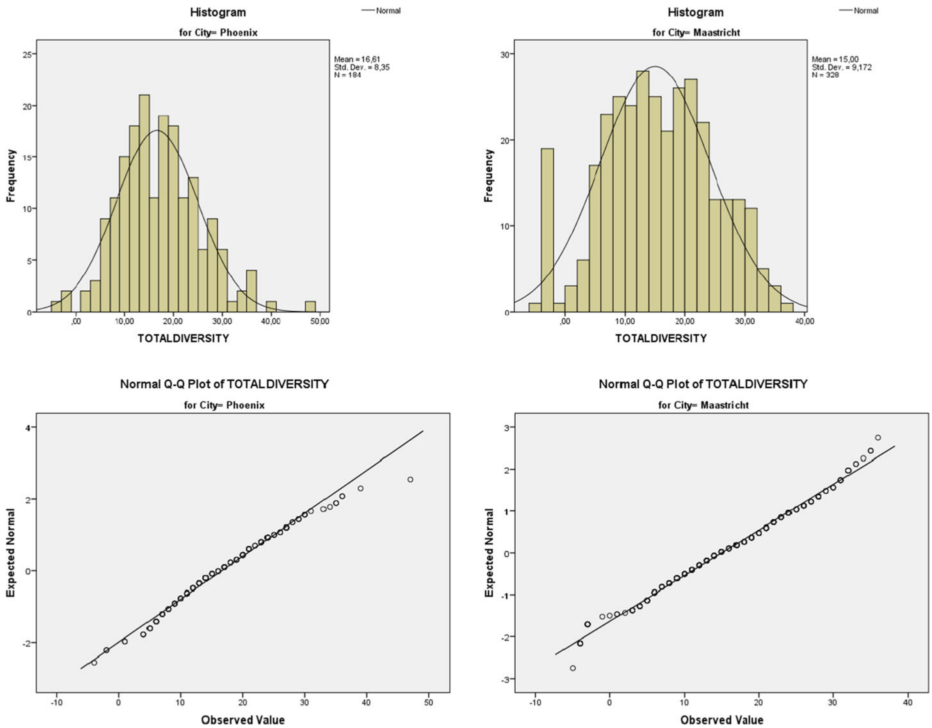
b. City Level

Tests of Normality

	City	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Total diversity	Phoenix	0.068	184	0.036	0.985	184	0.048
	Maastricht	0.047	328	0.084	0.987	328	0.004

[a]Lilliefors Significance Correction

c. Neighborhood level



Appendix 2. BIMBY indicator set

Table 8 BIMBY indicator set

Spheres	Variable	Description	Value	Treatment in analysis	Indicator
Contextual	City and neighbourhood	Context and location of yard	Nominal	Qualitative contextualization with Virtual Maps like Google Earth	Context of infrastructure, surrounding land use, habitat, fragmentation or connectivity
	Yard size	Size of the yard or outside space	0=< 10 m2; 1=10 m2-30 m2; 2=30 m2 >	Dependent on other variables: points: 0 = discontribution, 1 = small contribution, 2 = contribution	Potential contribution or discontribution to local environment & biodiversity
Ecological	Habitat type	Hydric, Mesic, Oasis, Xeric	0=no; 1=yes	Dependent on native vegetation-climate zone: 1 point for match 0 points for mismatch local environment	Habitat; water need; design; biome match
	Ground cover	Water, Aquatic Foliage, Lawn, Mulch, Granite, Bare Soil, Pavement, Rocks	0=no; 1=< 10 %; 2=10 %–50 %; 3=50 %–100 %	Dependent on vegetation-climate zone, points: 0 = no diversity 1 = medium diversity, 2= high diversity, 3 = high diversity & match with local environment	Habitat; soil life; water run-off; abundance
	Green coverage abundance	Percentage of plant species covering yard, other than ground cover	0=no; 1=< 10 %; 2=10 %–50 %; 3=50 %–100 %	Points: 0 = none, 1 = medium, 2 = high	Plant abundance, habitat, food availability
	Permeability	Soft surface, medium surface, hard surface, mixed surface	0 = hard = low; 1 = medium; 2 = soft = high 3 = mixed	Points: 0 = hard = low; 1 = medium; 2 = soft = high 3 = mixed	Soil Life
	Plant species abundance	Occurrence of annual and/or perennial PLANTS	Estimate number of annual/perennial PLANTS 0=0; 1=1–5; 2=5–10; 3=10–25; 4=25–50; 5=50–100; 6=100 >	Points: as number in category and additionally: 0 = none; 1 = only annuals; 2 is only perennials; 3=annuals and perennials	
	Plant species richness	Occurrence of exotic and/or native SPECIES	Estimate number of native and/or exotic SPECIES: 0=0; 1=1–3; 2=4–10; 3=11–20; 4=21–30; 5=30 >	Points: as number of category and additionally: 0 = none; 1 = only exotics; 2 is only natives 3 = natives and exotics	Reproduction, Habitat and food for native wild-life
	Plant species composition		0 = no; 1 = yes		

Table 8 (continued)

Spheres	Variable	Description	Value	Treatment in analysis	Indicator
		Occurrence of trees, shrubs, flowers		Points: 0 = none, 1 = 1 of them, 2 = 2 of them, 3 = all three	Vertical diversity, Habitat, Food, Shelter
	Weeds	Occurrence of non-desirable plant species	0 = no; 1 = yes	Points: 0 = no weeds; 1 = weeds	Perspective on Wildness
	Animal species abundance	Birds, mammals, insects, arthropods, molluscs, worms, reptiles, fish	0 = no; 1=1; 2=2–5; 3=5 >	Points: 0 = none; 1=1; 2=2–5; 3=5>Additionally 1 point for each occurring	Species Groups & Abundance
	Animal species richness	Counting number of animal species	0=no; 1=1–5; 2=5–10; 3=10>	Points: 0=none; 1=1–5; 2=5–10; 3=10>	Species Richness
Anthropogenic	Infrastructure	Boulders, walls, fences, hedges, water	0 = no; 1 = yes	Evaluate in context: points 1 for + contribution, −1 for fragmentation	Positive or negative contribution to habitat and connectivity
	Features contributing	Containers, compost, organic matter, wild food, feeders, nesting, insect hotels, bathing	0 = no; 1 = yes	1 point for each	Positive or negative contribution to habitat, food, mobility, connectivity, or disturbance
	Features disturbance	Furniture, swimming pool, play equipment, vehicles	0 = no; 1 = yes	−1 point for each	
	Pets	Dogs, cats, rodents, domestic birds	0 = none 1 = dogs, 2 = cats, 3 = rodents, 4 = birds	−1 for dogs and cats; + 1 for rodents and domestic birds	Disturbance or attraction by presence of domestic species
	Irrigation	Sprinklers, hoses, dripping, deep irrigation, no	0 = no; 1 = yes	Points: 0 = no; 1 = yes	Attraction of Animal Species for water, coolness, bathing, food (not related to water use)
	Maintenance need of yard design	High; medium; low	0 = low; 1 = medium; 2 = high	Low = Wild: 2pts, High = controlled: 0pts Low = Paved: 0 pts, High = Lush: 2pts	Dependent on level of 'wildness' or 'barrenness'
	Maintenance Level	High; Low	0 = low; 1 = high	Low = Wild: 2pts, High = controlled: 0pts Low = Paved: 0 pts, High = Lush: 2pts	Dependent on level of 'wildness' or 'barrenness'
	Signs of conflict	Artificial fertilizer, pests, pesticides, herbicides, damage, disease	0 = no; 1 = yes	−3 points for each	Sustainability, Habitat, Hood, Ecosystem Health, Disturbance

Table 8 (continued)

Spheres	Variable	Description	Value	Treatment in analysis	Indicator
	Level of intentional design	Signs of intentional human control, structures and patterns	0 = low; 1 = medium; 2 = high	Points: 0 = low; 1 = medium; 2 = high	Relates to: perspective, lifestyle, time, preferences,
	Design inspiration	French/Versailles, English, Japanese, Vegetable Garden, Modern Garden, Prairie Garden, Wild Garden/ Flowers, Wild Garden/ Forest, Healing Garden, Desert Garden, Courtyard, Paved Yard.	Nominal	Nominal	Relates to: perspective, lifestyle, time, preferences,
Subjective contextuality	Contextual diversity	Perception of (Biotic & Abiotic) diversity compared to surrounding local environmental context	0 = lower; 1 = average; 2 = higher	Points: 0 = lower; 1 = average; 2 = higher	Participants' perception of contribution to green space
	Diversity within yard	High/Medium/Low combination of: habitat types, soil coverage types, permeability levels, native and exotic species, vertical diversity, variety of plant and animal species, features	0 = low; 1 = medium; 2 = high	Points: 0 = low; 1 = medium; 2 = high	Biotic and Abiotic diversity in the yard
	Diversity across neighbourhood	High/Medium/Low variety of Habitat Types, Levels of Intentional Yard Design and Design Styles accross a neighbourhood	0 = low; 1 = medium; 2 = high	Points: 0 = low; 1 = medium; 2 = high	Neighbourhood Diversity

Appendix 3. Ecosystem services and dis-services on the neighbourhood level

Ecosystem services delivered in front-yards in four neighbourhoods in Phoenix

Ecosystem Services	Phoenix High	Phoenix Mid-Range	Phoenix Average	Phoenix Low
Supporting	Adding to soil life by high level of plant abundance	Adding to soil life by high level of plant abundance	Organic matter and weeds as nutrients for soil	
	Adding to biodiversity of the region	Functional connectivity to native environment		
Regulating	Cooler oasis micro-climates through lawns and trees	Dust-prevention through lush plantation	Decomposed granite and green coverage preventing soil-erosion and dust.	No visible irrigation: saving of water
	Dust-prevention through lush plantation	Low water run-off during monsoon season	Cooler micro-climates through lawns and trees	
	Low water run-off during monsoon season	Shady places through adobe-walls	Trees contributing to air quality close to highway	
			Water retention	
Provisioning	Habitat & food for many animal species: native and exotic	Habitat & food for many animal species: especially native	Native wild food	
	Irrigation attracts birds and insects		Irrigation attracts birds and insects	
Cultural	High contrast to desert	Ideal of contributing to native environment		Social encounter & family life
	Aesthetic diversity	Aesthetic diversity		Low maintenance costs
	Expression of historic values	Rehabilitation of desert image		
	Higher property value	Higher property value		
	Feeling of safety	Privacy (adobe walls)		

Ecosystem dis-services in front-yards in four neighbourhoods in Phoenix

Ecosystem Services	Phoenix High	Phoenix Mid-Range	Phoenix Average	Phoenix Low
Supporting		Fragmentation and loss of structural	Bare soils: dust and erosion	Bare soils: dust and erosion

	Decreasing soil life by use of pesticides and artificial fertilizers on lawns.	connectivity through high presence of adobe walls.		
	Non-native species: less contribution to functional connectivity of native environment.	Low soil life through low plant abundance and xeric soil cover structures	Low soil life in bare soil yards	
Regulating	Water pollution through use of pesticides and artificial fertilizer on lawns	Urban heat island effect	Urban heat island effect	Urban heat island effect
		Risk of over-irrigation	'Deserts within a desert'	'Deserts within a desert'
			Dust	Dust
Provisioning	Disturbance of habitat through strong maintenance	Light pollution disturbance	Light pollution disturbance	Disturbance by intensive social use with lack of care for biotic environment.
	Light pollution disturbance			
	Water sustainability issues			
Cultural	High maintenance needs and costs	Low social interaction through adobe walls	Potential of negative image of neighbourhood and dropping property value through lower maintenance/ care in some yards	Negative image of neighbourhood and dropping property value through lower maintenance/care in most yards
	Social pressure on maintenance through Home Owner Associations		In green gardens: high maintenance needs and costs	Feeling of safety for visitors
Ecosystem services in front-yards in four neighbourhoods in Maastricht				
Ecosystem Services	Maastricht High	Maastricht Mid-Range	Maastricht Average	Maastricht Low
Supporting	Functional connectivity to nature park Sint Pietersberg	Structural connectivity to nature park Savelsbos	Diversity of yard styles contributes to biodiversity	
	Rich soil life		Functional and structural connectivity to Savelsbos	
	High (native) biodiversity		Diversity of soil structures	
Regulating	High permeability	Overall permeable soil	Little private trees but abundance of public trees reduce noise and air pollution from nearby highway.	Little private trees but public trees reduce noise and air pollution from city centre.
	Strong water-retention potential	Water retention	Water retention diversified	
		High carbon capture in young trees		

	Air quality improvement close to city centre and major road.			
Provisioning	Food and habitat for native species	Habitat through hedges and (berry) shrubs	Food & habitat diversity	Many bird nesting facilities
Cultural	Aesthetic diversity	Status through aesthetic 'uniformity'	Green image	Social encounter
	Space for individual expression	Image of neatness and tidiness while living close to nature	Individual expression and creativity	Leisure time
	Social encounter	Property value	Multiple services by diversity of gardens	
	Good property value	Feeling of safety	Educational services	Low maintenance need
	Close to city, close to nature	Medium maintenance needs	Social encounter	Low maintenance costs

Ecosystem dis-services in front-yards in four neighbourhoods in Maastricht

Ecosystem Services	Maastricht High	Maastricht Mid-Range	Maastricht Average	Maastricht Low
Supporting	Less soil nutrients through high maintenance levels	Less soil nutrients through high maintenance levels	Dis-contribution to soil life by high amount of paved yards.	Dis-contribution to soil life by high amount of paved yards.
		Monotonous use of popular plants, low flower abundance, low diversity.		
Regulating	Potential of invasive alien species spreading to proximate nature	Water run-off in many paved sections	Water run-off in many paved sections	Water run-off in many paved sections
			Local urban heat island effect	Local urban heat island effect
			Desertification of parts of neighbourhood	Desertification of parts of neighbourhood
Provisioning	Disturbances by bicycles in yards.	Disturbances by car-parking, use of machines to trim hedges, high maintenance.	Disturbance by car-parking and social use	Disturbance by car-parking and social use
				Light pollution
Cultural		Little individual expression & creativity, complying to a neat and tidy image.	Grey image	Grey image
			Lower property value	Lower property value
		Distinction from proximate natural landscape	Potential lack of feeling safe	Potential lack of feeling safe
		Annoyance from maintenance machine use.	Potential annoyance by 'green litter' of municipal plantation.	
			Annoyance from noise of municipal green maintenance.	

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