Urban Agricultural Practice in Residential Areas of Pune (India) and the Contribution to Urban Sustainability

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Abstract:

Urban agriculture (UA) is regarded as an emerging tool and strategy for sustainable urban development as it addresses a wide array of objectives, such as climate change adaptation, social equality, food security or the restauration of environmental and living conditions. This is particularly important in the case of rapidly growing cities and metropolitan regions of developing and transition countries. Therefore it gains increasing attention among the academic and planning community. We have carried out a survey among 120 gardeners in residential neighbourhoods of the city of Pune (India). We investigated prevailing UA cultivation practices, socio-economic situations, motivation, knowledge and networking of individual household and external framework conditions to analyse the contributions to the environmental, economic and socio-cultural dimensions of urban sustainability. An analytical framework using composite indicators with index values was applied to enable comparability between the two UA types of terrace / rooftop and backyard / kitchen gardens. Our results show that both types contribute differently to urban sustainability at indicator level, but rather similarly at the aggregated level of the sustainability dimension. Sustainability benefits can be expected for the environmental and socio-cultural side, especially for urban biodiversity conservation and aesthetic green urban spaces, but less for economic contributions.

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Keywords:

Urban agriculture, cultivation practice, built environment, impact assessment, sustainability, interview survey, food production

1 Introduction

With the majority of humankind living in urban areas, especially the rapidly growing cities in developing and transition countries are confronted with the challenges for a sustainable development to enhance food security, human health and wellbeing, social equality and inclusion, sustainable economic growth and environmental quality (UN Habitat, 2016). To comply with these challenges, further transformations are needed to improve self-reliance in food (Grewal and Grewal, 2012) and reduce the ecological footprint by improving resource efficiency, shortening food supply chains and closing nutrient cycles (Viljoen et al., 2005; Wascher et al., 2015).

Beyond the rudiments of commercial farming activities at the peri-urban fringes (Krikser et al., 2016; Zasada, 2011), agriculture and gardening in urban densified residential areas have been increasingly recognised as promising concepts to address multiple urban sustainability and resilience objectives in developing countries (Dubbeling et al., 2009; Mougeot, 2005; Orsini et al., 2013). These types of urban agriculture (UA) are particularly important as they provide benefits directly in the near living realm of urban dwellers (Gorgolewski et al., 2011).

UA has been found relevant regarding nutritional self-sufficiency and access to affordable and fresh food especially for socially disadvantaged and food-insecure groups and beyond (Eigenbrod and Gruda, 2015; Gerster-Bentaya, 2013; Zezza and Tasciotti, 2010), improving dietary quality and diversity as well as human health (Armar-Klemesu, 2000; Potutan et al., 2000). Draper and Freedman (2010) and Ferris et al. (2001) highlight the physical and mental health as well as recreational benefits derived from the gardening activity itself.

As managed green spaces, urban gardens provide multiple ecosystem services, such as micro-climate regulation, air purification, cooling and reduction of heat-island effects as well as the purification of water and treatment of organic waste (Alexandri and Jones, 2008; Calvet-Mir et al., 2012; Qiu et al., 2013). There are also comprehensive ecological benefits, such as the provision of habitat for species and biodiversity conservation (Das and Das, 2005; Galluzzi et al., 2010; Smith et al., 2010). Others also highlight aesthetical values of UA and their design and management potential for housing neighbourhoods (Litt et al., 2011).

As an environmental movement UA is also recognised for its strong community orientation (Mok et al., 2014). Urban gardeners as local stewards of their living environment (Andersson et al., 2014) encourage social interaction and civic engagement (Sumner et al., 2010) and can also play an important role for social integration, e.g. of minority or migrant groups (Mazumdar and Mazumdar, 2012). Within social networks around the UA activities, human and social capital is created (Macias, 2008), knowledge and management capacities from socio-cultural memories are established and conserved, enhancing resilience of the urban social-ecological system (Barthel et al., 2010; Leys and Vanclay, 2011).

However, there is a strong diversity of agricultural practice in urban areas, depending on the scale, intensity and type of food production (Pearson et al., 2010). Particularly, differences exist between more extensive farming practice in green open spaces within urban areas and small and micro-scale UA, which is usually closely bound to buildings, e.g. vertical and rooftop farming (Alexandri and Jones, 2008; Specht et al., 2013) or they are located in close vicinity, such as domestic and backyards gardens (Calvet-Mir et al., 2012; Smith et al., 2010). In this study, we focus on the latter micro-scale form of

UA. Beyond their difference to other forms of UA regarding the benefits for urban sustainability, significant differences between the various micro-scale UA applications can be expected and need to be taken into consideration for urban planning and development.

The research objective of this paper is to investigate the UA practice and community within their different built-up environments and to analyse their contribution to urban sustainability for the case of the city of Pune (India). Applying a theoretical framework to depict potential sustainability benefits of UA and using survey data from gardeners, we focus on the two main types of UA in local residential neighbourhoods – (i) backyard / kitchen gardens (BKG) and (ii) terrace / rooftop gardens (TRG) – aiming to compare their contributions to the different dimensions of urban sustainability – environmental, economic and socio-cultural. Due to opportunities and restrictions associated with the surrounding urban morphological and building structure, major differences in size and cultivation practice can be expected, which will subsequently effect the beneficial contribution to urban sustainability.

After introducing the theoretical framework, we present the case study of UA in Pune (India) and the empirical approach to assess its sustainability. In the result section, we first analyse descriptive statistics about socio-demographic characteristics of the gardeners as well as to the cultivation practice, differentiated for BKG and TRG. In a second step, out of 15 sustainability indicators (five indicators for each of the three dimensions) represented by composite indicators are generated for each dimension of sustainability, compared and discussed.

2 Theoretical Framework

The expected growth of the global population will be concentrated in cities (UNFPA, 2007), however, they are complex socio-ecological systems that are highly vulnerable when failing to adapt to substantial changes (Zhang and Li, 2018). Since the functioning of ecosystems but also the well-being of humankind is highly influenced by the extent and pace of urban growth, it is crucial to follow sustainable pathways when shaping cities (Alberti, 2010). Consequently, sustainability has been mainstreamed as a guiding principle in the urban development debate, which follows an integrative approach to include environmental, economic and social aspects in urban planning and management. The United Nations Habitat Conference (HABITAT II & III) has brought forward the New Urban Agenda (UN Habitat, 2016), which focuses on the development of urban settlements in a *sustainable* way. The UN have also included the development of *sustainable* cities and communities as one of the Sustainable Development Goals (SDG 11). Through their multiple benefits, the development of (productive) urban green spaces has been identified as key approach to achieve urban sustainability (Jennings et al., 2016). This type of urban green spaces are at the core of a number of urban development visions and paradigms, which have occurred in the urban sustainability debate, such as a "fair", "beautiful", "creative", "green" city, "diverse" and "community-promoting" city (Vásquez-Moreno and Córdova, 2013). Their contributions include health and nutrition issues, social equality and justice, visual quality and diversity of urban green, creativity, ecosystem services, training and skills acquisition or alternative and local market development (Vásquez-Moreno and Córdova, 2013). To operationalise the benefit analysis of urban agriculture (UA), the authors combined these aspects within a four dimensional theoretical framework of urban sustainability, based on a literature analysis and stakeholder interaction. Their framework, consisting of environmental, economic, social and cultural dimensions further differentiates potential UA benefits within each of the sustainability dimensions. It thus acknowledges the multifaceted character of sustainability (Vásquez-Moreno and Córdova, 2013).

With a more narrow scope on a specific type of UA, namely those carried out in residential neighbourhoods, we have adapted this framework to a reduced set of 15 potential benefits for urban sustainability (see Tab.1). The theoretical framework takes specific regards to the micro-scale type of UA and its environmental value, nutrition, cost and income at household level as well as local markets and the personal well-being, cultural practices and community-building.

Table 1. Theoretical model: potential benefits of urban agriculture UA) for urban sustainability.

Dimensions of urban sustainability		
Environmental	*Economic*	*Socio-cultural*
Contribution to circular metabolism of nutrients and water in the city – composting of organic waste, rainwater use or reuse of grey water at household and local levels (Env1)	Development and diversification of local economies through alternative markets, use of local resources and inputs (Econ1)	Community building and empowerment, gender equity and social inclusion (SoCu1)
Promotion of green areas in a built environment and associated environmental services (microclimate, air quality, carbon sequestration, noise reduction, increased rainwater infiltration) (Env2)	Improvement of food proximity and food cost reductions (Econ2)	Provision of recreational spaces and personal well-being and skill acquisition (SoCu2)
Environmental education and awareness-raising (Env3)	Reduction in the cost of solid waste and wastewater disposal /treatment (Econ3)	Contribution to the aesthetics of green open spaces (SoCu3)
Contribution to local biodiversity conservation (Env4)	Efficient and productive use of vacant and small plots of urban land (Econ4)	Cultural connection to traditional practices and local knowledge (SoCu4)
Clean production with little or no use of agrochemicals (Env5)	Impact on employment generation and household income (Econ5)	Conservation of ancestral production systems (SoCu5)

Source: Adapted from Vásquez-Moreno and Córdova (2013).

3 Research Design and Methodology

3.1 Case Study

The city of Pune, located in Western Indian state of Maharashtra is one of the fastest-growing cities in the country and the Asian-Pacific region as a whole. According to official census data (1991, 2011), the city's population nearly doubled between 1991 and 2011, increasing from 1.57 to 3.12 million inhabitants. The UN World Urbanization Prospects (2014) estimated that the city's population will further increase to 8.09 million in 2030. Due to the population growth, built-up areas in Pune expanded from an area coverage of 21 % in 1990 to 43 % in 2008 (Fernandez et al., 2012), mainly on the expense of farmland and other green area. In addition also the percentage of impervious surface in already built-up areas, such as the inner city strongly increased (Fernandez et al., 2012), related with the loss of soil functionality and ability to provide required ecosystem services.

Traditionally, agricultural and gardening activities represent an important element in Pune, taking very different forms (Behmanesh, 2009, 2010). On the one hand, larger numbers of residual farms in urban and peri-urban areas are found which are now under pressure from urban encroachment. Also the municipality and agricultural research institutions operate larger farms. On the other hand, there is a liveable community of homestead farmers and gardeners. This type of urban agriculture (UA), which has been partly rooted in the idea of composting and solid waste management, has been established as an alternative approach to UA within residential environments. The majority of micro-scale and low-cost farming practice take shape either as backyard / kitchen gardens (BKG) or terrace / rooftop gardens (TRG) (Behmanesh, 2010).

The individual UA projects and activists are embedded in larger community networks, such as local gardeners' clubs, which promote the distribution of knowledge about cultivation practice and exchange of experiences. They are accompanied by research institutions and private consultancies, which complement the local knowledge system and improve professionalization of the UA practice.

Figure 1a, b. Examples of a terrace / rooftop garden (left) and backyard / kitchen garden (BKG) in within housing areas in Pune. Photos: Ingo Zasada

BKG as the first main type of small-scale UA are frequently associated with bungalow housing areas. Due to the morphologic structure in some parts of the city, which consist mainly of bungalows and other types of low-density residential areas, larger green space on private grounds exits, which allows for the establishment of green productive spaces from BKG to even less extensive fruit tree orchards. Here, food cultivation typically takes place in the soil of unsealed surfaces, for example in vegetable patches. In contrast, TRG are directly bound to building structures and the available spaces on top of houses and on terraces. To a large extent, this second UA type is found in complexes of densified multi-storey housing blocks, which have been built mainly in the last two decades and are often characterised by the underproduction of green spaces. Supported by the frequent construction of flat and accessible roofs, residents use raised-beds and planters to establish small gardens on these sealed surfaces.

3.2 Variable Selection and Survey Design

Based on a literature review and interviews with local experts, we defined a variable set for the 15 different sustainability benefits, which are included in the theoretical framework. These cover characteristics of the land use and cultivation practice as well as the linkages to the urban (agricultural and gardening) community. Most of the selected variables are affecting multiple urban sustainability benefits, such as the example of compost use, which is related to the circular metabolism of nutrients (Env1), cost reduction of solid waste disposal (Econ3) and the efficient and productive use of vacant and small plots of urban land (Econ4). At the same time, individual sustainability benefits are represented by composites of several variables. For an overview of the variable aggregation to composite indicators and summary statistics see the annex at the end of the paper.

For the analysis of UA benefits we conducted an empirical study among urban gardeners between January and May 2014. Based on the theoretical framework and indicator selection a questionnaire was prepared. The first part of the questionnaire focussed on socio-economic information of the household (9 variables) and the spatial context of the housing and gardening setting (4). The second part was dedicated to the gardening practice including questions about inputs (9), cultivation techniques (11), activities (4) and cropping patterns (10). Further questions refer to the embeddedness into the local (gardening) community (6), motivation (5), knowledge (3), activities and restrictions (4).

The sampling started with interviewing members of an organised gardening club (INORA, www.inoraindia.com). It was rolled out using a snowball sampling method as interviewed gardeners were asked for further potential interviewees. As there is no central register or database on local UA activities, it was not possible to obtain robust information about the whole population of the urban gardeners. Nevertheless, based on information from preliminary interviews, we found that the local UA community was to a large extent organised in gardening clubs. Therefore, we did not assume strong sample selection bias, when approaching mainly club members. The survey was carried out as face-to-face interview with mainly close-ended questions (single and multiple responses). In total, 120 survey responses were collected, of which only 108 fully completed questionnaires and which could be assigned to either a BKG (N=65) or to a TRG (N=43). Other gardens included a larger community, municipal or educational gardens, which do not belong to the scope of this study and have been excluded accordingly.

3.3 Statistical Analysis and Composite Indicator Aggregation

Descriptive statistics are given for individual variables showing the differences between the garden types. Two-sided student t-tests were used to test differences. For the construction of the composite indicators, we followed the guideline by the OECD (2008). Before aggregating into the composite indicator, the variable values – nominal [yes, no], interval or metric scaled – were normalised if necessary by their range to the interval [0, 1]. In addition, all variables have been tested for positive correlation to prevent double counting. All variables are given equal weighting within each composite indicator. For the variable aggregation, a linear additive approach of the summation of the normalised individual indicators was applied using the following formula:

$$CI = \frac{1}{Q}\sum_{q=1}^{Q} I_q$$

, where CI = composite indicator, I=indicator, q=individual indicator value, Q number of indicators used. The composite indicators reflect the individual contributions to the respective sustainability benefits taking on values from 0 ('not contributing') to 1 ('fully contributing'). In total 49 individual variables have been aggregated into 15 composite indicators. All data transformation, normalisation and analysis were carried out using the statistical software package Stata14.

4 Results

4.1 Spatial and Socio-demographic Characteristics

Multi-storey apartment buildings and bungalows as the main types of residential buildings in Pune – excluding slums – define to a large extent the type of the attached garden. 67 % of the terrace / rooftop gardens (TRG) are linked to an apartment building, whereas only 28 % to a bungalow. On the other side, only 14 % of the backyard / kitchen gardens (BKG) are associated to an apartment building, but in 80 % of the cases to a bungalow. The remaining 5 % of TRG and 6 % of BKG are related to other building types such as attached buildings. Mean values of the area size of the gardens differ ($t=|1.80|$, $p=0.075$) between 103 m² (TRG) and 189 m² (BKG), whereas the latter type is also characterised by a wide distribution (Std. Dev 288 m²). Across types, urban agriculture (UA) activities are well-established in Pune. In 30 % of the cases, the garden exists for more than 10 years and respectively in 33 % for more than 20 years.

The UA community is characterised by a dominance of female gardeners (72 %), older age groups (52 % between 46-65 year; 27 % >65 years) and high education levels (40 % with higher secondary school/high school; 51.4 % university graduation). More than 85 % of the interviewees lived in Pune for more than 20 years. A slight majority of 56 % of the gardeners have no occupation, being either pensioners or unemployed. The average household comprises of 3.8 persons, below the value of 4.6 for Indian urban areas according to official statistics. Although, most respondents only need to spend a minor share of their income for food (37 % spend less than 20 %; 45 % spend 20-40 %), for 43 % and 30 % of them, the garden plays a moderate or even important role for their own nutrition.

4.2 Urban Agricultural Practice

Depending on the type and size of garden up to 70 different varieties of herbs and vegetable and 30 different types of fruit trees are cultivated in the urban gardens. Hereby there is a strong focus on local varieties and a high average diversity of produced crops (12.6 types of vegetable/herbs; 6.5 fruit tree types). Hence, urban gardeners apply specific types of crop arrangement, including crop rotation (35 %), non-conflicting (39 %) or supporting crop arrangements (25 %). The main majority of gardeners apply compost as substrate (82 %), apply fertiliser (93 %), do pest control (80 %), and weeding (95 %). Only a minority use chemical inputs (21 % pest control, 19 % fertiliser, and 8 % weed control). Due to the monsoon climate with pronounced dry seasons, all gardens are additionally irrigated, mainly from public water supply. 8 % of the gardeners also keep livestock, mainly honey bees.

4.3 Contribution to Urban Sustainability

For the analysis of the contribution of the gardening types to urban sustainability, we have aggregated gardening practice variables into five composite indicators for each of the three sustainability dimensions. At the aggregate sustainability dimension level both UA types show very similar values.

For both types the economic dimension has substantially lower values (0.37 for TRG/0.37 for BKG) than the environmental (0.49/0.49) and socio-cultural dimension (0.52/0.51). However, when looking at the individual composite indicators, larger variations are observed between TRG and BKG. The mean indicator value is 0.45. Figure 2 shows the boxplots of the individual composite indicator values including mean values and standard deviations.

Our figures show that UA in Pune contributes most to the socio-cultural side of sustainability, led by the aesthetic design of green open spaces (SoCu3) for which mean values of 0.62 (TRG) and 0.67 (BKG) are calculated. Especially gardeners in larger backyards frequently grow additional non-edible plants, like flowers, bushes or trees and apply facilities, which increase habitation quality, such as for sitting. Regardless of the gardening type, the active individuals are frequently embedded in a larger gardening community either by sharing knowledge, input resources or harvest itself. They also have extensive networks of friends and family, who are also involved in the UA activities. Subsequently, similar high values for both UA types (TRG: 0.56; BKG: 0.59) are found for the indicator 'Community building and empowerment, gender equity and social inclusion' (SoCu1). Substantially lower values are given for the composite indicators for recreation, personal well-being and skill acquisition (SoCu2; TRG: 0.51; BKG: 0.48), cultural connection to practices and knowledge (SoCu4; TRG: 0.50; BKG: 0.46) as well as for the conservation of ancestral production systems (SoCu5; TRG: 0.40; BKG: 0.34).

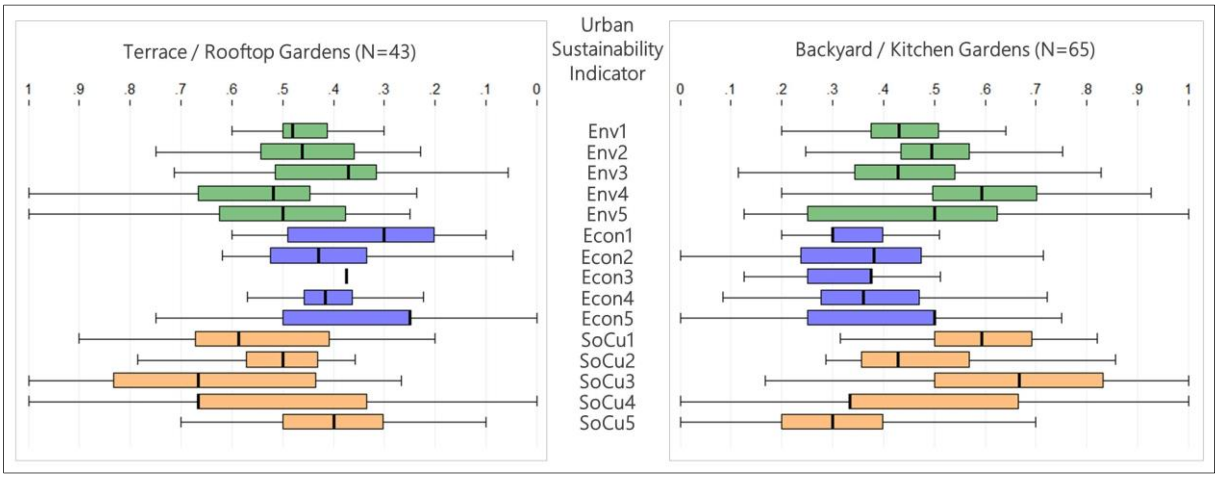

Figure 2. Contribution of terrace / rooftop gardens (TRG) and backyard / kitchen gardens (BKG) to urban sustainability. Note: outside values exclude.

For environmental sustainability, 11-14 % higher mean values are found for TRG (0.47; 0.56) than for BKG (0.42; 0.49) regarding the circular metabolism of nutrients and water in the city (Env1) which is statistically significant ($p<0.05$) and environmental production (Env5) indicators. However the standard deviation of this indicator is comparably high for both types. The management of TRG are often optimised regarding input efficiency and specific cropping techniques are deliberately applied. Especially due to the equipment with educational facilities, such as demonstration beds or educational trails, which are more frequent in the more spacious BKG, this type (0.44) shows slightly higher composite indicator values for environmental education and awareness-raising (Env3) than TRG (0.41). With the frequent presence of trees and the possibility to cultivate directly in the open soil, BKG (0.51) contribute also to a larger extent to the promotion of green areas and ecosystem services (Env2) than TRG (0.45). This difference is statistically significant at the 5% level. Mainly through high numbers and diversity of edible and non-edible plants and trees, highest environmental contribution by both UA types TRG (0.56) and BKG (0.59) are found for the conservation of local biodiversity (Env4).

Within the field of economic sustainability, the contribution of UA to local economy (Econ1) is clearly under average for both types (TRG: 0.34; BKG: 0.36). Other results show especially low impact on employment and income generation (Econ5) for the TRG type (0.29). Through the more frequent employment of a gardener, a statistically significant higher composite indicator value (p=0.01) is found for BKG (0.39). In the case of contribution to the accessibility and affordability of food, TRG: (0.40) perform slightly better than BKG (0.37). Crucial here is also the reduction of cost for the gardening activity inputs, when costly water, seeds, fertiliser or herbicides are efficiently used, shared or even avoided. According to our figures, the contribution to cost reduction for solid waste and wastewater disposal /treatment (Econ3), is even lower for both types (TRG: 0.37; BKG: 0.33). The most profound economic impact is found for the efficient and productive use small plots of land (Econ4). An example is the utilization of sealed surfaces on roofs, terraces, balconies, etc. by the TRG type (0.43).

5 Discussion and Conclusion

In our study of urban agriculture (UA) in residential neighbourhoods in Pune (India), we analysed the urban sustainability impacts of two main UA types – terrace / rooftop gardens (TRG) and backyard / kitchen gardens (BKG). Therefore, we adapted an established theoretical framework to assess urban sustainability benefits, specifically designed for the UA context (Vásquez-Moreno and Córdova, 2013) and applied it empirically based on a survey data. Our findings show that first of all socio-cultural and environmental benefits are provided by UA activities, whereas contributions to economic sustainability are clearly less relevant. Particular high contribution by UA can be expected for the fields of aesthetic quality of urban green spaces, community building and empowerment, gender equity and social inclusion as well as for local biodiversity conservation and clean (food) production with low levels of agro-chemical application.

This reflects the motivations of participating urban residents for the gardening activities, which are driven by environmental considerations, improvement of individual well-being and quality of life in residential areas as well as a strong community-orientation, as the high degree of organisation in gardening clubs and the network embeddedness shows. Furthermore, a big share of the gardens has existed for one or two decades. This implies that the mentioned sustainability benefits can have a long term effect as well, because they are based on developed structures and routines and not on a short-term trend. Here, the results are also in line with findings from other studies (Macias, 2008). Economic and cost considerations, e.g. for the access to food play only a minor role. As most of the gardeners can be attributed to the Indian middle-class, food insecurity and poverty issues are less important. But despite the fact that garden configuration, spatial and building-structural restrictions especially of the TRG does not allow for large-scale food production (Safayet et al., 2018; Specht et al., 2013), UA contributes to substantial coverage of the required food supply. Our findings confirm that UA activity can nevertheless play a vital role in the planning, design and management of urban green areas as an integral part of an urban green infrastructure network to provide good environmental conditions for local residents and urban nature (Litt et al., 2011). However, as these types of UA are usually located on private property, public access and utilisation can be very limited. It is an important way to preserve and exchange local and traditional knowledge, e.g. on cultivation practice, as the ecological knowledge of emerging urban societies is at stake to decline which undermines future environmental conservation (Pilgrim et al., 2008).

Our analytical approach, which subdivides the three sustainability dimension into 15 sub-objectives allows for more detailed assessment of individual UA types and urban sustainability benefits. The results identify specific strengths and weaknesses of both UA types, although the aggregated benefit contribution is rather similar. TRG deliver urban sustainability values in the fields of metabolism and resource circular metabolism of nutrients and clean production. Hereby, the technical innovation and solution nature and highly controlled environment of this type of UG, that can induce an efficient use of inputs and a strong compost basis comes into effect. BKG on the contrary are more relevant for aesthetics and design of urban green – the highest single value – and in conserving biodiversity. These gardens are usually larger and are more directly parts of the urban ecosystem and green network. Due to their area size, the direct connection to the soil and the abundance and variation of plant types – from small herbs and flowering plants up to bushes and trees – BKG provide a larger diversity of species habitats and niches. They also have more pronounced ability to deliver other ecosystem services, including the soil functionality, local climate regulation and water infiltration.

Beyond differences between UA types, our findings also revealed large variations among the individual gardens. Depending from the spatial context within the built-up environment gardens vary in size – (from very few to a couple of hundred square meters), cultivation practice (cropping techniques, crop types) and utilisation (from an aesthetical add-on to serious food production). Therefore the adaption to specific urban situations, capacities and restrictions call for diverse design and management solutions to UG. Our results can provide orientation about the possible sustainability impacts and can inform urban and landscape planning and decision-making. Due to this variability and the opportunity to be disconnected from unsealed surface, UA can be a useful tool to conserve and manage urban green spaces in rapidly growing and densifying urban and metropolitan areas. UA offer urban sustainability benefits also for the public and urban community.

Together with the UG, our study also yielded insights into the gardening community, which is clearly female, highly educated and aged with many gardeners retired from work. There is also a broader range of motivation and knowledge sources and subsequently pursue different other activities beyond gardening work, such as socialising, cultural and nature-related activities. Based on other studies, which investigated the role of motivation, social values, community interaction or knowledge (Clayton, 2007; Krikser et al., 2016; Martinho da Silva et al., 2016; Nefs et al., 2013; Opitz et al., 2016; Scheromm, 2015), we also assume causal relationships to the gardening practice. In a next step we will use the survey data to analyse the effects of those gardeners' characteristics and social factors on the UA practice and urban sustainability benefits.

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Annex. Indicator composition and summary statistics.

Variable	*Measure / Coding (normalized)*	*Mean value*	*Std. Dev.*	*Composite Indicators*														
				Env1	*Env2*	*Env3*	*Env4*	*Env5*	*Econ1*	*Econ2*	*Econ3*	*Econ4*	*Econ5*	*SoCu1*	*SoCu2*	*SoCu3*	*SoCu4*	*SoCu5*
Multiple people involved in the gardening	0 (no); 1 (yes)	0.31	0.46	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Employment of gardener	0 (no); 1 (yes)	0.51	0.50	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0
Share of cultivation in soil	metric in % (0-1)	0.53	0.33	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Share of cultivation in beds, boxes and buckets	metric in % (0-1)	0.44	0.33	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Share of other cultivation (e.g. hydroponic)	metric in % (0-1)	0.02	0.11	1	0	0	0	0	1	0	1	0	0	0	0	0	0	0
Cultivation on sealed surface	0 (no); 0.5 (partly); 1.0 (yes)	0.35	0.41	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0
Compost use	0 (no); 1 (yes)	0.88	0.33	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0
Use of soil from elsewhere	0 (no); 1 (yes)	0.19	0.39	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Companion cropping	0 (no); 1 (yes)	0.29	0.45	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
Non-conflicting cropping	0 (no); 1 (yes)	0.45	0.50	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Crop rotation	0 (no); 1 (yes)	0.40	0.49	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
Organic fertilisation	0 (no); 1 (yes)	0.94	0.23	1	0	0	0	1	1	0	1	1	0	0	1	0	0	1
Non-organic/non-chemical fertilisation	0 (no); 1 (yes)	0.27	0.45	0	0	0	0	1	1	0	0	1	0	0	1	0	0	1
Biological pest protection	0 (no); 1 (yes)	0.19	0.40	0	0	0	1	1	1	0	0	1	0	0	1	0	0	1
Manual pest protection	0 (no); 1 (yes)	0.66	0.48	0	0	0	0	1	1	0	0	1	0	0	1	0	0	1
Manual/physical weed protection	0 (no); 1 (yes)	0.94	0.23	1	0	0	0	1	0	0	0	0	0	0	1	0	0	0
Can and sprinkler irrigation	0 (no); 1 (yes)	0.19	0.39	1	1	0	0	0	0	0	0	1	0	0	0	0	0	1
Rainwater use from the garden	0 (no); 1 (yes)	0.08	0.28	1	1	0	0	0	1	1	1	0	0	0	0	0	0	1
Rainwater use from neighbouring buildings	0 (no); 1 (yes)	0.02	0.14	1	0	0	0	0	1	1	1	0	0	0	0	0	0	1
Other non-public water source	0 (no); 1 (yes)	0.05	0.21	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Compost production	0 (no); 1 (yes)	0.84	0.37	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Garden as compost source	0 (no); 1 (yes)	0.75	0.44	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Organic waste from household as compost s.	0 (no); 1 (yes)	0.52	0.50	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Organic waste from neighbourhood as compost s.	0 (no); 1 (yes)	0.28	0.45	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Other organic waste sources for compost	0 (no); 1 (yes)	0.05	0.21	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0

Number of vegetable and herb varieties	in quartiles (0; 0.33; 0.66; 1.0)	0.53	0.38	0	0	0	1	0	0	1	0	1	0	0	0	0	0	0
Number of fruit tree varieties	in quartiles (0; 0.33; 0.66; 1.0)	0.55	0.36	0	1	0	1	0	0	1	0	1	0	0	0	0	0	0
Livestock keeping	0 (no); 1 (yes)	0.08	0.28	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0
Ornamental flowers/shrubs/bushes	0 (no); 1 (yes)	0.75	0.44	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0
Ornamental trees	0 (no); 1 (yes)	0.81	0.40	0	1	0	1	0	0	0	0	0	0	0	0	1	0	0
Number of non-edible trees	0 (0); 0.25 (1-2); 0.5 (3-5); 0.75 (6-10); 1.0 (> 10)	0.89	0.25	0	1	0	1	0	0	0	0	0	0	0	0	1	0	0
Presence of sitting facilities and artwork	0 (no); 1 (yes)	0.57	0.50	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
Presence of education facilities	0 (no); 1 (yes)	0.10	0.30	0	0	1	0	0	0	0	0	0	0	0	1	0	1	0
Presence of ecological elements	0 (no); 1 (yes)	0.67	0.47	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0
Presence of greenhouse	0 (no); 1 (yes)	0.05	0.21	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0
Garden work activity	0 (no); 1 (yes)	0.84	0.37	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Socialising activity	0 (no); 1 (yes)	0.39	0.49	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0
Nature watching activity	0 (no); 1 (yes)	0.56	0.50	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Art creation and meditation activity	0 (no); 1 (yes)	0.23	0.42	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
Educational programmes as knowledge s.	0 (no); 1 (yes)	0.30	0.46	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0
Consultancy as knowledge s.	0 (no); 1 (yes)	0.07	0.26	0	0	1	0	0	1	0	0	0	1	0	1	0	0	0
Friends and family as knowledge s.	0 (no); 1 (yes)	0.75	0.44	0	0	1	0	0	0	0	0	0	0	1	1	0	1	0
Books, internet and other knowledge s.	0 (no); 1 (yes)	0.63	0.49	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0
Community and own propagation as seed s.	0 (no); 1 (yes)	0.58	0.50	0	0	0	0	0	0	1	0	0	0	1	0	0	1	1
Shop and other seed source	0 (no); 1 (yes)	0.75	0.44	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0
Years of gardening	0.25 (< 5); 0.5 (6-10); 0.75 (11-20); 1.0 (> 20)	0.47	0.27	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Harvest sale	0 (no); 1 (yes)	0.07	0.26	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Harvest donation	0 (no); 1 (yes)	0.94	0.25	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Size of gardening community	0 (0); 0.25 (1-2); 0.5 (3-5); 0.75 (6-10); 1.0 (> 10)	0.59	0.30	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0