



Indicators to support healthy urban gardening in urban management

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HIGHLIGHTS

- Urban gardening can contribute to human health by creating cohesive communities involved with their living environment.
- Healthy and sustainable food production links ecosystem health to human health in the case of urban gardening.
- Indicators may identify and pursue synergies between ecosystem and human health targets of different stakeholders.
- Standardized indicators can be used to compare, evaluate and monitor the effects of urban sustainable development actions.

GRAPHICAL ABSTRACT



Indicators of physical (orange boxes) and experience-based (green boxes) benefits of urban gardening.

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ABSTRACT

Urban gardening is part of a trend towards more parks and green areas in cities, consumption of organic, locally grown products, and a closer relationship with one's own living environment. Our literature review shows that urban gardens provide opportunities for physical activity and allow people to consume homegrown fruit and vegetables. Urban gardens may also reduce stress levels of gardeners and improve social cohesion. In this way, they can help to prevent health problems. Good quality of urban soil and the functioning of soil ecosystems are indispensable prerequisites for these. We developed a framework that shows how ecosystem health and human health are interconnected in urban gardening, by placing it in the context of urban green space management and valuation. This study yields a set of indicators, which can be used to assess soil ecosystem services and health impacts. They may provide a basis for the evolving dialogue in decision-making processes and partnership activities in urban management. Recognizing the potential effects and discussing what is important to whom, might be enough to find synergies. Importantly, the initiators of urban gardens are often citizens, who seek support from other stakeholders. The social network established by gardens may contribute to health-enabling, cohesive communities involved with their living environment. To maximize health benefits, it is useful to make the urban gardens accessible to many people. This study suggests that urban gardens deserve a position in urban green space management as they may help to address societal challenges like urbanization, health and well-being in aging populations and climate adaptation.

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1. Introduction

There is increasing interest in green space supporting healthy living because of rapid urbanization, climate change and aging of populations (EU, 2015; WHO, 2015a; WHO, 2015b; EEA, 2016; WHO, 2016). We

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previously showed that green spaces may contribute to human health and well-being by creating a living environment that promotes physical activity (Claessens et al., 2014). In addition, they facilitate stress reduction and social contacts (Claessens et al., 2014; Hartig et al., 2014; WHO, 2016). Recently, it has been suggested that urban gardens have similar and additional health benefits by facilitating healthy food consumption and socially cohesive communities (Alaimo et al., 2016; Al-Delaimy and Webb, 2017) although quantitative evidence is still scarce (Soga et al., 2017). In this paper, we define health indicators to assess and evaluate these benefits based on a literature review. We also identified health-relevant ecosystem and management indicators. Altogether, these indicators may identify and pursue potential synergies between ecosystem and human health targets of different stakeholders. Together, they can make a stronger case for urban green management actions.

The initiators of urban gardens are often citizens, who seek (financial) support from the local government. Urban managers are confronted with the costs of these activities and the potential risks of soil pollution. They have to motivate costs and land use in the context of competing land use and social services, e.g. the provisioning of adequate housing. The typical scenario has been for gardens to be established on land which is considered to have little market value. At the end of the crisis, however, governments might withdraw their support and focus instead on profitable real estate development on former garden plots. One way to motivate the preserve of the gardens, is to focus on the benefits that they may offer for the living environment, and thereby for public health. Like green spaces, they may contribute to an attractive environment to exercise, play, relax and meet people. Stimulating these kinds of activities is the aim of many evidence-based health interventions, as they are known determinants of public health (Staatsen et al., 2017). Healthy behavior may prevent the development of chronic diseases and associated health care costs. Another way is to point towards the optimal use of urban nature resources ('natural capital') which can facilitate the city and its citizens to advance socially and economically, which are also considered to be aspects of public health. Thus, urban gardening may be regarded as a behavior based environmental health intervention. But what is the evidence of these kind of positive effects of urban gardening and how do we measure them? Ideally, local governments and other stakeholders are able to weigh costs against social profits, including health. Defining indicators of positive effects is a first step towards such a valuation.

The World Health Organization recently proposed a set of indicators to provide cities with systematic approaches to quantifying and monitoring their green space access (WHO, 2016). We evaluated if the known health effects and associated indicators of green spaces also make sense for urban gardens, which we consider as a specific kind of urban green space. The food aspect of urban gardening may provide an extra link to healthy behavior, i.e. by stimulating the consumption of vegetables and fruits. It could also add to sustainability goals of cities, like 'responsible production and consumption' (<http://www.un.org/sustainabledevelopment>, visited November, 3 2017). Therefore, urban gardening may offer some extra or alternative benefits as compared to green space in general.

Indicator sets are often derived from a conceptual framework to define, frame and communicate the issue under consideration (EEA, 2005; WHO, 2015b; WHO, 2016). We aimed to develop a framework connecting concepts of health and ecosystems for urban gardening in the context of urban green space management. Provisioning of health was regarded as an 'ecosystem service', i.e. the contribution of ecosystems to human well-being. This approach is becoming more and more common and matches with the natural capital principle mentioned above (Tzoulas et al., 2007; Pretty, 2011; Reis et al., 2015). However, different academic traditions and research methods, specialized language and the lack of common theories constitute a major obstacle to interdisciplinary studies. Nonetheless, such studies are necessary if the challenges faced by those involved in urban planning and management are to be addressed fully (Tzoulas et al., 2007). One of these challenges is

to meet the Sustainable Development Goals of the United Nations. Indicators can be used to compare, evaluate and monitor the effects of policies addressing these goals.

The associations between green space and human health have been summarized in several frameworks (Tzoulas et al., 2007; James et al., 2009; URBAN-NEXUS, 2012; Claessens et al., 2014; Hartig et al., 2014). Hartig et al. (2014) described how exposure to green spaces may lead to health benefits (i.e. by improved air quality, more physical activity, social cohesion and stress reduction). However, we aimed to place these 'exposure-effect' relations in the broader context of urban management. An international project previously developed such a framework for green spaces, based on discussions between researchers, professionals and urban actors (URBAN-NEXUS, 2012). Their framework was adapted from Tzoulas et al. (2007) and James et al. (2009). It was based on perspectives of stakeholders with different backgrounds and it pointed out how to bring science into practice. Therefore, we chose this model and tailored it to urban gardening. Like the original framework, it defines four contexts; 1) physical factors including ecosystems, 2) health effects by the experience of urban gardening 3) management and 4) valuation. Management refers to urban planning and development and includes organizational aspects of urban gardening. Valuation refers to appraisal of social profits in cost-benefit analyses, for instance. Although we acknowledge the importance of this context, it was outside the scope of this article. Our literature review focused on the health effects of urban gardening. Results in terms of health-relevant management factors were also taken into account. The framework was used to structure our research and to define the indicators in a systematic way.

2. Methods

2.1. Definitions and framework development

We defined urban gardening as 'all noncommercial types of food production in or linked with the urban environment', see definitions below. Health was defined as 'the ability to adapt and self manage in the face of social, physical, and emotional challenges' (Huber et al., 2011). In line with this definition, health was categorized in 'physical health', 'psychological (or emotional) health' and social health, with the latter broken down in 'socio-economic health' and 'community health', like in the framework of 'URBAN NEXUS'. As described in the introduction, the framework was adapted to describe urban gardening as a specific type of urban green space use (see Fig. 1). Therefore, in the 'experience box' the word 'urban green space' was replaced by 'urban gardening', the word 'allotments' was added to 'green infrastructure' in the 'management box' and we added a box called 'lifestyle' to illustrate the behavioral change potential of urban gardening. The main keywords used in the literature research and the word 'soil pollution' were also added to further define the ecosystem and health benefits considered in this study (see italics). Indicators have been defined as 'an expression of the link between (living) environment and health, targeted at an issue of specific policy or management concerns and presented in a form which facilitates interpretation for effective decision-making' (Briggs et al., 1996). They serve as an interpretation and communication tool to support the development of policies and evaluate these policies once they are implemented. Not only indicators of health impacts were defined, but also of ecosystem services and management aspects that predict the potentials of urban gardening and may reveal supportive management actions.

2.2. Literature search for (indirect) health effects

A literature search of electronic databases [Scopus, Medline, Psycinfo and Embase] and Google Scholar was performed in June, 2014, and supplemented with a quick scan of major new publications in 2017. The focus was on articles or reports of (potential mechanisms of) health benefits in gardeners of urban gardens. The selection of key-words was based on the mechanisms described by Hartig et al. (2014), but we

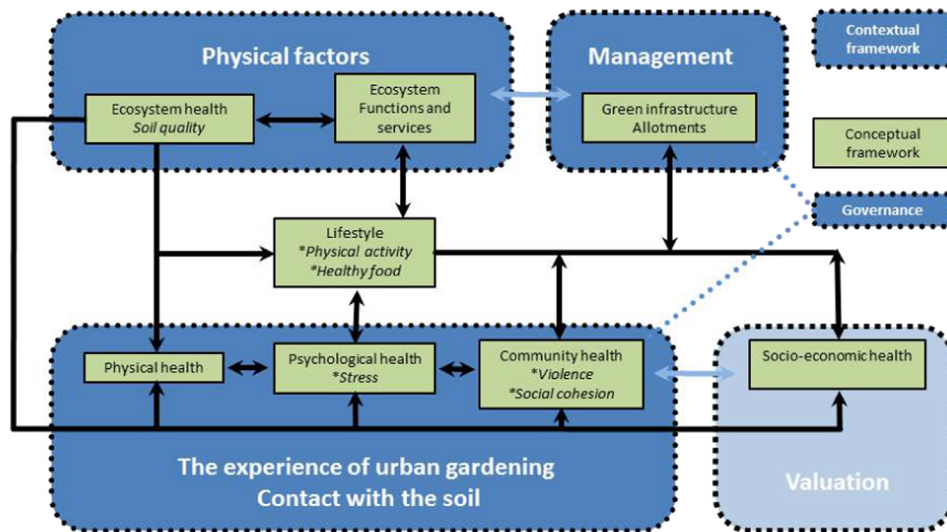


Fig. 1. Framework illustrating the associations between soil ecosystem services, ecosystem health and human health in urban gardening. The asterisks (*) show the topics that were addressed in the literature review. The valuation context was outside the scope of this paper. Adapted from (URBAN-NEXUS, 2012; James et al. 2009; Tzoulas et al. 2007).

excluded air pollution and we added healthy food consumption and community violence. For air pollution, we refer to previous work (Nowak et al., 2006; Dack, 2015; Al-Delaimy and Webb, 2017). Changes in the (perceived) safety of the neighborhood were included because it may be relevant, e.g. if residents have transformed vacant lots into urban gardens. Researchers in this field use different terms for urban gardening, such as allotment gardening or urban agriculture. Because the terms are often interchangeable, all articles regarding gardening, urban agriculture and/or allotments were carefully examined. The search included key words regarding social cohesion, lifestyle, obesity, stress, general health, perceived health, poverty, physical activity, food consumption, violence and well-being.

The literature search in 2014 yielded 232 papers regarding relationships between urban gardening and health. It also included one report on the evidence of the benefits of gardening and food growing for health (Davies et al., 2014). References of that report were hand-searched, but did not yield additional publications. Titles and abstracts from all papers were screened to evaluate whether they met the selection criteria. In case of doubt, the full paper was screened. Papers were selected if they:

- Concerned urban gardens;
- Focused on Europe (including Russia) or the United States;
- Included original quantitative data;
- Described potential health benefits or factors that could influence health indirectly by the mechanisms listed above;
- Did not evaluate specific workshops or educational programs;
- Were published after 1999;
- Described the general population.

Papers regarding subgroups, like people with ill health or ethnic minority groups, were not selected. Special attention was paid to the assessment of positive health effects and the indicators the authors used to describe the association between urban gardening and health. Please note that the literature search was confined to (indirect) health effects. The potential associations between urban gardening and ecosystems were not based on a literature research, but on previous work (Breure et al., 2012; Rutgers et al., 2012; Swartjes, 2015). The search neither included soil contamination nor associated risks because these have been described extensively before. Nowadays, most industrialized countries have implemented policies for contaminated land management including soil quality standards, risk assessment tools and soil remediation strategies (Swartjes, 2011; Swartjes, 2015). Still, local governments need to take soil quality into account before designating land to urban gardening. Therefore, we added this topic to the framework.

In 2017, we added a publication from a Dutch PhD thesis that we knew of by network contacts (Veen, 2016). A quick scan of new papers was performed in Medline in June 2017, using the key-words 'urban gardening' and 'health'. This yielded 6 additional relevant papers (Litt et al., 2015; Alaimo et al., 2016; Lewellen, 2016; Wood et al., 2016; Al-Delaimy and Webb, 2017; Soga et al., 2017).

3. Results

The literature search yielded 17 papers that met the selection criteria (Armstrong, 2000; Twiss et al., 2003; Glover, 2004; Wakefield et al., 2007; Allen et al., 2008; Quayle, 2008; Gorham et al., 2009; Ohmer et al., 2009; Teig et al., 2009; Alaimo et al., 2010; Van den Berg et al., 2010; Hawkins et al., 2011; Litt et al., 2011; Van Den Berg and Custers, 2011; Walsh, 2011; Hawkins et al., 2013; Northrop et al., 2013). The quick scan in 2017 yielded two additional papers meeting the criteria (Litt et al., 2015; Veen et al., 2016), including re-analysis of previously collected data (Litt et al., 2011). For each health determinant, 2–9 papers were available. Highest number of papers concerned vegetables and fruits consumption (9) and social cohesion (community level, 7). For violence, only 2 recent papers were available and the references of these papers were hand-searched for additional publications. However, no additional papers met the selection criteria.

3.1. Framework for urban gardening and health

Fig. 1 shows the adapted URBAN-NEXUS framework (URBAN-NEXUS, 2012). The framework defines four contexts, which have been used to structure our results;

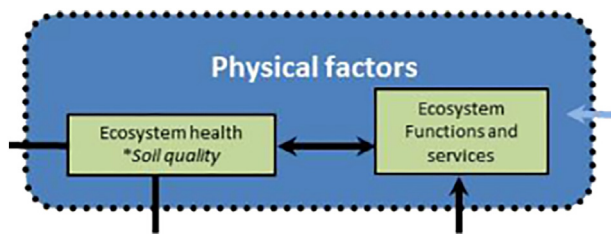
1. Physical factors – Ecosystem health and ecosystem services (see 3.2). These are considered as the 'source' of positive health effects. We focused on soil ecosystem services, as described in previous work (Claessens et al., 2014).
2. Management – Refers to urban planning and development (see 3.4). We focused on organizational issues of urban gardens that may determine whether gardens have the potential to result in positive health effects or other societal benefits.
3. 'The experience of urban gardening', including contact with the soil (see 3.3). This experience (in environmental health often called 'exposure') may lead to positive health effects. Health was categorized in physical, psychological and community health (see Definitions). In fact, most studies in this domain do not describe physical health

in terms of the absence of disease. We discuss *indirect* health effects, like the potential increase in physical activity, which in turn may reduce the incidence of diseases. These intermediate or indirect effects consist of potential changes in lifestyle (individual level), psychological health (stress) and community factors, like the social relationships in a neighborhood that significantly contribute to the well-being of individuals (Ferlander, 2007; Tzoulas et al., 2007). To emphasize the intermediate character of some of the effects (i.e. physical activity and healthy food), we added a box called 'Lifestyle' to the framework.

4. Valuation. Valuation was beyond the scope of this study, however we discuss it in the Discussion section under 4.4 'future directions'.

Definitions	
Urban gardening	All noncommercial types of food production in or linked with the urban environment. The term 'allotments' is used in the framework to refer to it being a specific type of land use.
Health	The ability to adapt and self manage in the face of social, physical, and emotional challenges (Huber et al., 2011).
(Environmental Health) Indicator	An expression of the link between (living) environment and health, targeted at an issue of specific policy or management concerns and presented in a form which facilitates interpretation for effective decision-making (Briggs et al., 1996).
Lifestyle	The way in which people live, particularly with respect to health-related behaviors.
Psychological health	Emotional and cognitive elements of health (Tzoulas et al., 2007). A synonym of mental health. It includes stress in our framework.
Physical health	Health related to the body as opposed to the mind.
Community health	Health of people living in a neighborhood considered collectively, especially in the context of social relationships, values and responsibilities.
Soil ecosystem health	The extent to which the soil ecosystem is able to deliver sufficient ecosystem services and meets soil quality standards.
Soil ecosystem services	Contributions of soil ecosystems to human well-being.
Urban gardening	All noncommercial types of food production in or linked with the urban environment. The term 'allotments' is used in the framework to refer to it being a specific type of land use.

3.2. Soil ecosystem health and services in the physical environment



In our framework, the physical environment includes soil ecosystem health and ecosystem services. The functioning of ecosystems is an important factor for an optimal functioning of urban gardens and determines whether they provide potentials to contribute to human health. Ecosystem services (ESS) are the contributions of ecosystems to human well-being. They arise from living organisms (biota) or from the interactions of biotic and abiotic processes. They refer especially to the 'final' outputs or products from ecosystems. That is, the things, which are directly consumed, used, or enjoyed by people. Different classification systems for ESS exist. Following the classification of CICES (Common International Classification of Ecosystem Services) (Haines-Young and Potschin, 2013) three types are recognized: provisioning, regulating and cultural services (Haines-Young and Potschin, 2013; Maes et al., 2014).

A principle element of ecosystem health in urban gardening is the chemical quality of the soils being used. Exposure to soil contaminants, through vegetable consumption and/or the ingestion of soil particles

(hand-mouth contact) may have negative effects on human health. Therefore an assessment of the chemical quality of the soil prior to the start of urban gardening activities is necessary – it should at least meet standards for safe use for food production. A common problem is the presence of cadmium (in particular at low pH), since cadmium is easily taken up by vegetables (Swartjes, 2011). Additionally, lead can cause problems since it is omnipresent in urban areas (Swartjes and Cornelis, 2011). Often, a site's history provides a clue to the potential presence of contaminants in the soil. In case of contamination, some adaptations to gardening practices (e.g. restriction of cultivation of leafy vegetables) can enable safe urban gardening. In terms of indicators, concentrations of contaminants in soils could be measured, but estimates of the actual exposure to these contaminants are more informative. Concentrations in the edible parts of the plant may be determined to evaluate exposure when consumed. In addition, combined exposure through vegetable consumption and soil ingestion during gardening can be assessed (Swartjes and Cornelis, 2011; Swartjes, 2015).

Urban gardening is a way of 'sensitive land use', meaning that there is an obvious interaction between land use, soil quality and soil ESS. This is in contrast to so-called hard (sealed) infrastructure such as roads and parking lots. The most prominent interactions include the relation between soil quality and the potential contamination of crops and between soil fertility and the ESS food production. Services delivered by the soil ecosystem can be attributed and arranged in different ways. We previously distinguished 1) provisioning of nutrients and 2) soil structure, both classified as provisioning services. Regulating services include 3) natural disease suppressiveness, 4) resistance to stress and resilience and 5) formation and degradation of soil organic matter (Breure et al., 2012). Obviously, soils deliver additional services when used for urban gardening, see Table 1 and the graphical abstract. Like green spaces on unsealed soils, urban gardening adds to water storage and regulating cooling services, and thereby, to climate-proof cities (Claessens et al., 2014). Another soil ecosystem service is the self-purifying capacity of soil that may reduce concentrations of contaminants (Schram-Bijkerk et al., 2015). On neighborhood level, green areas may buffer traffic noise and reduce the exposure to air pollution (WHO, 2016). Cultural services include nature education and recreation. In summary, urban gardening contributes to the quality of the physical environment by a range of ecosystem services and thereby to the health and well-being of citizens.

Table 1 shows how each soil ecosystem service contributes to the quality of the physical environment and thereby, to the health and well-being of citizens. It refers to more detailed descriptions of the most prominent health effects in paragraph 3.3. The soil ecosystem services (ESS) from Table 1, delivery and value of such, are proposed as indicators for optimizing and assessing the status of urban garden soils and their potential to deliver societal profits. Rutgers et al. (2012) previously explained the selection and use of indicators to quantify the performance of soil ecosystem services. The selection and application of indicators for urban gardening land use needs further elaboration, but could include measurements of the presence and activity of organisms (e.g. earth worms and bacteria), the amount of organic matter and an assessment of the soil structure.

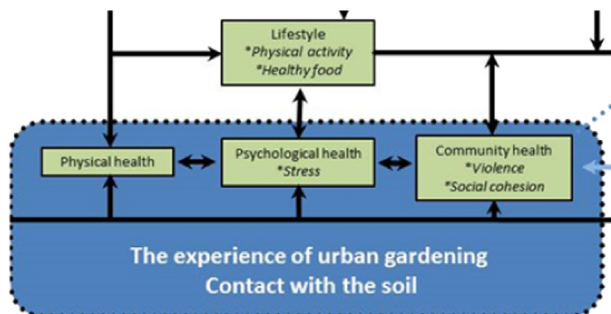
As shown in our framework, interactions between soil ESS, soil quality and urban gardening are two-sided. To give an example: crop growth, and thereby the production of food, depends on the presence of organisms and the amount of organic matter in the soil. On the other hand, some crops, like green peas, and garden waste add to the amount of organic matter in the soil – therefore it is good to have compost heaves in the gardens. The soil organisms take care of the degradation of garden waste, and thereby add to the amount of soil organic matter. Pesticide use may increase the amount of food produced in the short term, but may also decrease the presence of organisms, the natural disease suppressiveness and thereby reduce the food production in the long term. Urban gardening can make people aware of the importance of good quality soils and how we depend on its functioning.

Table 1

Physical factors; indicators of soil ecosystem services (ESS) and how they may contribute to the urban environment and citizen health.

Indicators of soil ESS, adapted from Rutgers et al. (2012)	Contribution to physical factors in the urban environment	Pathways to a better health of citizens
Provisioning services		
Nutrient retention and release	Soil quality and quality of urban gardens. Less fertilizers needed.	Quality, variation and amount of crops – healthy food (see 3.3.2).
Soil structure, stable aggregates	Positive contribution to water management and water retention.	Reduction of water nuisance, quality, variation and amount of crops.
Food production	Positive influence on soil and maintenance needs. Local food infrastructure – less (inner city) traffic.	Contributes to public health by provisioning of healthy food (see 3.3.2). Potentially less exposure to traffic noise and air pollution.
Natural disease suppressiveness (pest control)	Fits in ecological green space management. If less pesticides are used, it adds to habitat functions and biodiversity.	Amount and quality of urban gardening crops – healthy food. If less pesticides are used, it may decrease human exposure to pesticides and associated negative health effects.
Regulation and supporting services		
Resistance and resilience to stress - adaptation and flexibility towards land use	Natural purification after soil pollution, recuperation of soil quality after land use changes, or after sealing and compaction of the soil.	Less exposure to soil contaminants. Recovery of living environment after a negative impact or stress like climate change.
Fragmentation, mineralization and storage organic matter	High organic matter content of the soil implies carbon sequestration - a positive contribution to climate change mitigation.	Improved soil fertility and a high soil organic matter content leads to better crops, higher soil biodiversity and less water nuisance.
Water storage and retention	Improved water retention and decreased desiccation	Quality, variation and amount of crops
Natural attenuation, self-purifying capacity of soil	Maintenance of clean soil and groundwater. Adds to clean ground- and drinking water and reduces soil pollution. Increases water storage capacity and thereby prevents flooding.	Better crops. Less exposure to soil contaminants. Contributes to the quality of the urban environment (water, air and soil)
Climate function	Local climate regulation; cooling and potentially reducing noise and air pollution by vegetation. (Temporary) water storage capacity.	Quality, variation and amount of crops. More well-being for citizens because of reduced heat stress.
Others, cultural and ethical		
Habitat function and biodiversity	Maintaining biodiversity, education, geological and aesthetic value of the environment.	Contributes to a living environment that stimulates physical activity (see 3.3.1) in residents. Leads to less stress and more well-being (3.3.3). Contributes to education and archaeology.
Culture and nature education	Provision of opportunities for education and cultural heritage.	Providing opportunities for education, recreation, social contacts (see 3.3.4) and social cohesion (see 3.3.5) and cultural attachment
Recreation	Provision of accessible public space, cultural facilities	Contributes to a living environment that stimulates physical activity in residents. Potentially leads to less stress (3.3.3) and more well-being, social contacts and cohesion (see 3.3.4 and 3.3.5) cultural attachment and community pride.

3.3. Effects of the experience of urban gardening on lifestyle and health



In our earlier report (Schram-Bijkerk et al., 2015), factsheets were compiled to describe the results of the literature study on lifestyle and health effects. These factsheets contain a description of study designs, results and indicators of all papers. An explanation of that information is provided in the text below and summarized in Table 2.

3.3.1. Physical activity

Physical activity is defined as any bodily movement produced by skeletal muscles that results in energy expenditure (Caspersen et al., 1985) and is a fundamental means of improving people's physical and psychological health. It reduces the risks of many chronic diseases (WHO, 2010). Physical activity includes playing, working, active transportation, house chores and recreational activities. Gardening and associated activities such as walking or cycling to the gardening plot, may add to the overall physical activity levels of people (Ainsworth et al., 2011).

Four studies described the association between urban gardening and physical activity levels. Two studies used questionnaires to collect quantitative data (Van den Berg et al., 2010; Hawkins et al., 2011). The other two had a more qualitative design, using interviews and/or group

discussions (Wakefield et al., 2007; Quayle, 2008). Indicators were 'the proportion of population reporting practice of daily physical activity' and 'the average number of days a week on which people are at least half an hour physically active'. Another -internationally standardized- indicator is the proportion of the population that meets physical activity guidelines (see Table 2). Urban gardeners often mentioned increased physical activity as a major benefit of urban gardening, e.g. 'I love the physical work of digging' and 'I achieved exercise to keep me healthy' (Quayle, 2008). The questionnaire studies showed that gardeners reported higher levels of physical activity than their neighbors without urban gardens (Van den Berg et al., 2010), but not if compared to people engaged in other active groups, like outdoor walking groups (Hawkins et al., 2011).

3.3.2. Healthy food; Fruit and vegetable consumption

Fruit and vegetables are important components of a healthy diet, and their sufficient daily consumption could help prevent major diseases, such as cardiovascular diseases and certain cancers (Agudo et al., 2002; Gezondheidsraad, 2006; WCRF/AICR, 2007; Engelfriet et al., 2010; Bradbury et al., 2014). Urban gardening might improve the access to fruit and vegetables and increase the consumption. Most people do not meet dietary recommendations that promote the daily consumption of at least five portions (400 g) of fruit and vegetables (<http://www.who.int/dietphysicalactivity/fruit/en/>, visited 16 July 2015, Five a day). Nine studies described the association between urban gardening and fruit and vegetable consumption. Five had a qualitative design, using (in-depth) interviews and/or group discussions. Three had a quantitative design, including two that performed telephone interviews among all residents of neighborhoods in the United States. One study used both qualitative and quantitative data (Zoellner et al., 2012). One of the telephone interview studies included 766 people in Michigan, of whom 15% turned out to have a member of their household participating in urban gardening (Alaimo et al., 2010). Indicators in that study were the

Table 2
Indicators of the experience of urban gardening and related health effects as derived from the literature review and internationally standardized indicator sets. For more detailed information see (Schram-Bijkerk et al., 2015).

Individual positive health indicators	Community health indicators	Health-relevant management indicators
Amount of social contacts of gardeners	<ul style="list-style-type: none"> - Social cohesion, e.g. the extent to which gardeners form relations with each other and offer each other mutual help - Perceived safety, property and violent crime rates 	<ul style="list-style-type: none"> - Neighborhood vs non-neighborhood bound garden - Numbers of plots and gardeners (volunteers, clients and/or visitors) - Frequency of visits - Background of users; age, ethnicity, income, education, medical needs - Presence of common shop, sitting area etc.
The proportion of the population that meets physical activity guidelines	Physical quality, e.g. amount of green space within 500 m of households, cycle and walking paths	Accessibility of allotments (e.g. connection to cycle or walking paths, distances to homes, availability, acreage, surface)
Fruits and vegetables consumption, e.g. number of servings a day or proportion of population that meets the ((inter)national) consumption guidelines	Community involvement/political engagement/capability to address issues of public concern	Stakeholder involvement (e.g. school programs on healthy food)
Perceived stress (not standardized, differing sub items are used) Perceived general health/well-being (e.g. how would you rate your general health on a scale of 1 (poor) to 5 (excellent))	Local demographics; ethnic background, income and age distribution of residents	

number of fruit and vegetable servings a day, and whether people met the dietary recommendations for fruit and vegetable intake. Adults with a household member who participated in an urban garden consumed fruit and vegetables 1.4 more times per day than those who did not have a gardening family member. They were also 3.5 times more likely to meet the dietary recommendations. Access to fresh foods was one of the most commonly expressed reasons for participating in gardening in the interview studies. Also cost-savings (Wakefield et al., 2007) and an increased vegetable variety in their diets (Northrop et al., 2013) were mentioned. Most youth and their parents expressed an interest in eating the produce they harvested (Zoellner et al., 2012).

3.3.3. Psychological health; Improved relaxation and restoration

It has been recognized for centuries that contact with nature can be restorative and beneficial for psychological health (Hartig et al., 2014; WHO, 2016). Two different mechanisms seem to play a role here. Contact with nature (e.g. views of natural settings) can have a positive effect for those with high levels of stress, by shifting them to a more relaxed, positive emotional state (e.g. a decrease of fatigue and anxiety) (Ulrich et al., 1991; Hartig et al., 2014). The other mechanism suggests that attention given to nature helps to restore; the performance in cognitively demanding tasks improves thereafter (Kaplan, 1995). The latter effect is referred to as restoration. Five studies described the effect of urban gardening on relaxation and/or restoration. Two had a qualitative and three a quantitative design. One Dutch study measured stress hormones in 30 people before and after reading or gardening at the allotment site. Stress hormones decreased in both groups, but the decrease was strongest following gardening. This suggests that the activity of gardening in green space may be restorative (Van Den Berg and Custers, 2011). The other studies also showed that urban gardening permits (particularly the elderly) people to enjoy the relaxation and restorative effect of contact with nature on a regular basis. For example, one of the gardeners' quotes was; 'Sometimes when you are stressed out when you go to the garden, you feel different' (Wakefield et al., 2007). All studies used different questions to assess 'perceived stress', which makes it difficult to compare the results. There are no standard, often-used indicators for stress levels, except for standardized body measurements like in the experimental study of Van Den Berg and Custers (2011).

3.3.4. Psychological health; Social contacts

Urban gardening is often a social activity, even if social contacts are not the (main) motivation of gardeners to start gardening activities (Veen, 2016). Social effects of urban gardening have been measured at

either an individual level (summarized in this paragraph) or on a group level (3.3.5). Five studies have measured social effects at the individual level. Gardeners commonly emphasized the social aspects of urban gardening (Walsh, 2011), but none of the studies found significant increases in their number of social contacts or social support. The only exception was the study by Litt et al. (2015). It showed a positive relation between garden participation and social involvement, that was a construct of 4 indicators in the interviews that were held; 1) participation in local activities 2) neighborhood meetings 3) public education meetings and 4) contacts with central people in the neighborhood such as religious leaders or a minister (Litt et al., 2015).

3.3.5. Community health; Social cohesion

Social cohesion refers to solidarity in groups or communities (Berkman and Glass, 2000). It is a characteristic of a system rather than a personal trait. Sometimes it is being used interchangeably with the terms '(collective) social capital' and 'social networks'. Many research articles with positive associations between social cohesion and health have been published (Ferlander, 2007), although there is debate on the mechanisms involved. It has been suggested that high levels of social capital in local communities can influence health through the spread of healthy norms and/or a faster and wider diffusion of (health) information and knowledge (Eriksson, 2011). It can make people aware of the influence they have on their health and stimulate healthy behavior. It may also lead to trust, participation, mutual support and collective action (Eriksson, 2011). Thus, urban gardening might support health-enabling, cohesive communities. There were large differences in the indicators used to measure social cohesion. Seven, mostly qualitative studies described the effects of urban gardening on a group level, e.g. by interviewing coordinators of urban gardens, like in a study in New York (Armstrong, 2000). The studies showed that in general urban gardens are seen as meeting places that benefit the community as a whole, by improving relationships among people and increasing community pride. In some cases gardens served as an impetus for broader community improvement and mobilization, like in the low-income neighborhoods of New York (Armstrong, 2000). Community garden coordinators mentioned, for instance, that a community fought to keep a local supermarket in the area. Another community took care of the development of a new sidewalk close to the garden and others managed that a park and playground were developed in their community. Because of the network developed by the gardens, people knew who to call to initiate other initiatives beside the gardens. Some gardeners became more active in local politics, (Armstrong, 2000). This kind of 'community

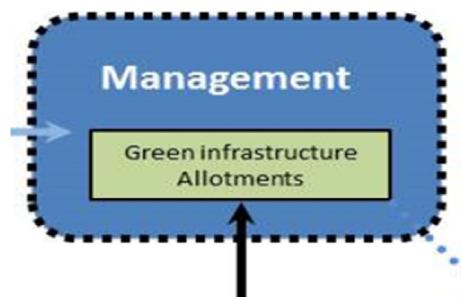
involvement', was also mentioned in other studies. Teig et al. (2009) described that community gardens served as a positive social influence within neighborhoods as well as being a catalyst for other positive place-based social dynamics. This is in line with the study of Wakefield et al. (2007), who described that gardens were to increase attachment to the community and improve the physical features of the community to its broader benefit. Quayle (2008) concluded that community farms and gardens encourage local people to become more socially active and develop stronger ties to an area. Therefore, we added the indicator 'community involvement' to the indicator list in Table 2.

Different types of urban gardens seem to have different effects (Veen et al., 2016). Logically, stronger cohesive effects are expected when plots are used collectively by a group of residents – a recent Dutch study was restricted to these so-called 'community gardens' (Veen et al., 2016). The 7 case-studies in this publication indeed showed that these gardens contributed to the development of social cohesion. However, urban gardens do not necessarily foster a more inclusive society; gardens often attract people with relatively similar socio-economic backgrounds and although people from different cultures may work in the same garden, it does not necessarily lead to cross-cultural contacts (Veen, 2016). Another study also noted that the social effects are not always beneficial for all; one garden group made non-gardeners in the neighborhood feel excluded (Glover, 2004).

3.3.6. Community health; Violence reduction

Urban gardening may foster neighborhood improvements and reduce violence (e.g. auto theft, gun assaults), especially if the site, taken for urban gardening, lay fallow. The gardens might attract new residents, restore neighborhood vitality and stability and enhance civic pride. Two studies addressed this issue; one used Police Records of property crimes in Houston as an indicator (Gorham et al., 2009), and the other evaluated safety in several English agricultural projects (Quayle, 2008). Overall, there were no differences in crime numbers between urban garden areas and randomly selected areas. However, interviews showed that residents and/or users of the urban gardens perceived a safer neighborhood (Gorham et al., 2009), which is a valuable indicator in itself. The English evaluation did not observe any long-term crime problems in the projects. It was suggested that these problems were prevented by a sense of ownership generated by community involvement (Quayle, 2008).

3.4. Health-relevant management aspects of urban gardening



The last column of Table 2 lists potential indicators of health-relevant management factors that were used in some of the studies, like the one by Quayle (2008). This evaluation of subsidized agricultural projects, including 11 urban gardens, is worth reading because of the broad assessment that was performed by order of a charity organization. One of their suggestions was to include schools or other communities as stakeholders, because that was a success factor in the evaluated projects; they promoted a lasting change in healthy behavior. Garden-based youth nutrition intervention programs have not been discussed here. Such programs may have the potential to promote increased fruit and vegetable intake among youth (Boyer et al., 2002; Lautenschlager and Smith, 2007; Allen et al., 2008; Robinson-O'Brien et al., 2009; Castro et

al., 2013). Thus, a description of the connections with urban garden stakeholders can provide a clue of the potential health effects. Other health-relevant management factors include local characteristics like ethnic backgrounds and income of residents (Walsh, 2011). The presence of communal instead of individual plots, and inclusion of residents of the neighborhood in which the garden is located may provide clues to estimate the effects on social cohesion (Veen et al., 2016).

4. Discussion

We developed a framework and derived indicators based on empirical evidence for different beneficial effects of urban gardening on health and well-being. We presented indicators for both physical and social (experience) factors, which may both lead to health benefits of urban gardening. Like green space in general, urban gardening provides opportunities for physical exercise, stress reduction and social cohesion. Additionally, it allows people to consume homegrown fruit and vegetables. In this way, it can help to prevent health problems. Some studies showed that the grassroots development of urban gardening provides a promising way of sustainable urban management as it may create health-enabling, cohesive communities involved with their living environment. It fits in the trend towards more green space in cities, consumption of organic, locally grown products, civilian participation and a closer relationship with one's own living environment. The results of this study do not provide solid evidence for the relation between urban gardening and health, but they illustrate how to motivate investments in urban gardening. The combination of physical, health and management indicators present a broad picture of the potential use of urban gardens in sustainable urban management. The indicators could be used to inform the evolving dialogue in decision-making processes and partnership activities in cities and to monitor progress on relevant policy goals.

4.1. Chance of bias

A major issue in the studies on urban gardening, which is often neglected, is the chance of selection bias. It is likely that urban gardening selectively attracts people who like gardening, healthy food or social contacts et cetera. Selection may also take place with regard to the continuation of gardening activities; people who enjoy health benefits are more likely to stay in the pool of urban gardeners. In addition, the gardeners only represent a small proportion of the total urban population. Therefore, studies might overestimate the role of urban gardens. To maximize the effects, it is important to make the gardens accessible for many people, including non-gardeners. To reduce selection bias, effects could be measured at different moments in time in the same people, e.g. what is the consumption of gardeners before and after they started gardening activities? Another aspect to take into account is that possibly only studies showing a positive influence of urban agriculture on physical activity, stress levels, social cohesion or healthy food consumption have been published. Studies showing no or a negative influence might not have reached the scientific literature. This would create bias in the results. Studies taking selection or publication bias into account, like the one of Hawkins et al. (2011), make a stronger case for the effects of urban gardening on human health.

4.2. Standardized indicators

Inherent to the topic, there was much variation in study designs addressing the lifestyle and health effects. Van Den Berg and Custers (2011), for instance, performed an experimental study with bodily measurements of stress levels. Others performed field visits, applied semi-structured interviews at the individual or group-level, or distributed questionnaires. We aimed to select quantitative data only, but some of the results shown were fairly qualitative, like the quotes from urban gardeners. However, the quotes complemented the quantitative information; they facilitated their interpretation. Combining different ways of

collecting data is a way to increase the validity of the results (Baarda et al., 2005). A disadvantage is that data collected by different methods often do not allow comparison across studies.

The graphical abstract provides an overview of potential indicators for human health and ecosystem health in urban gardens. The use of common, standardized and validated indicators would facilitate the expansion of empirical evidence for the association between urban gardening and human health. It would facilitate the comparison of results across studies, which is difficult at this moment. We propose to focus on physical activity, healthy food, social contacts, social cohesion and stress reduction, which is in line with indicators for green space in general (with the exception of healthy food). An over-arching indicator, that covers or summarizes several effects on determinants of health is 'perceived (self-reported) health' of gardeners (and/or residents). This indicator has been assessed frequently in studies evaluating the health effects of green infrastructure, e.g. (Maas et al., 2006; Mitchell and Popham, 2007). Also for urban gardening, this indicator has been studied and positive effects were shown (Wakefield et al., 2007; Van den Berg et al., 2010; Hawkins et al., 2011; Litt et al., 2015; Wood et al., 2016; Hawkins et al., 2013; Soga et al., 2017).

4.3. Connections between ecosystem health and human health

Quayle (2008), who described the social benefits of urban agriculture theme by theme, suggested that the biggest benefit of all could be the connection between the themes, which allows so many benefits to be delivered by one project. Our conceptual framework and Table 1 show how ecosystem health and human health are connected and reveal potential synergies (win-wins). This is most obvious for the food aspect of urban gardening; healthy soils support healthy crop growth, and the consumption of the crops adds to a healthy lifestyle of citizens. Making use of urban soils for recreation may contribute to stress reduction, social cohesion and physical activity. By the identification of ecosystem services, additional health benefits were revealed. The cooling function of the gardens' open soils with greenery may reduce heat stress of citizens. The gardens increase the water storage capacity of urban areas and can consequently prevent flooding. Like other green spaces, it may also reduce noise and air pollution and related negative health effects (not shown) (WHO, 2016). Last but not least, gardening can raise the aspirations of local people and provide them with the skills to bring about positive changes to both their own lives (i.e. health promoting behavior) and in their neighborhood (Quayle, 2008).

4.4. Future directions

As described in the introduction, this inventory of indicators could be regarded as a first step towards valuation of urban gardening. However, although there is evidence of positive effects of urban gardening on human health, the evidence base is too weak to provide quantifications of the (overall) effects in cost-benefit analyses. Even for green space in general, it is difficult to estimate and compare the effects despite the expanding evidence base. Still, indicators can be tools to express the link between (living) environment and health, targeted at an issue of specific policy or management concerns. They can provide a basis to inform an evolving dialogue in decision-making processes and partnership activities in cities. Recognizing the effects, and discussing what is important to whom, without knowing the exact effect sizes, might be enough to find synergies. Urban gardening initiatives could be used to bring international health and sustainability goals for cities into practice. Linking urban gardens to policy goals would be a kind a valuation in itself. In Manchester, for instance, community gardens are incorporated in a large strategy and program called 'Manchester Food Futures', which aims to provide wide access to healthy, sustainably produced food for all. A partnership of the City council, the National Health Service, community voluntary and private sector groups was established (www.foodfutures.info, visited November 9, 2017). Also in Lyon and Paris,

urban agriculture has been adopted as a component of green policy and as a means of ensuring a constant supply of healthy and sustainable food for everyone (Schram-Bijkerk et al., 2013). These are promising examples of how urban gardens can be advanced from local, isolated, temporary initiatives to a structural element of sustainable urban management.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.scitotenv.2017.11.160>.

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