National Institute for Public Health
and the Environment
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RIVM Report 2015-0172
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Colophon

Dieneke Schram-Bijkerk (onderzoeker), RIVM
Liesbet Dirven - van Breemen (onderzoeker), RIVM
Piet Otte (Projectleider), RIVM

Contact:
Dieneke Schram- Bijkerk/ Liesbet Dirven-van Breemen
Department for Sustainability, Drinking Water and Soil
Centre for Sustainability, Environment and Health (DMG)
Dieneke.Schram@rivm.nl / Liesbet.Dirven@rivm.nl

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Gezonde stadslandbouw.
Bewoners van steden gebruiken steeds vaker braakliggende grond om met buurtgenoten groenten te verbouwen. Deze niet-commerciële 'buurtmoestuinen' kunnen – evenals de traditionelere volkstuintjes - bijdragen aan de gezondheid en de kwaliteit van de leefomgeving. Door in deze moestuinen te werken bewegen mensen meer en eten ze meer (zelfgekweekte) groenten en fruit. Er zijn ook aanwijzingen dat stress afneemt en (meer) sociale contacten in de buurt ontstaan. Op deze manier kunnen buurtmoestuinen gezondheidsproblemen helpen voorkomen, al is het belangrijk dat de risico's door eventuele bodem- en luchtverontreiniging tot een minimum zijn beperkt.

Buurtmoestuinen sluiten aan bij de trend om in steden meer groen en parken aan te leggen. Ook passen ze in de trend om meer biologische, lokaal geproduceerde producten te eten. Hetzelfde geldt voor de behoefte aan meer betrokkenheid bij de eigen woonomgeving. Via de buurtmoestuinen kan bovendien een verbinding worden gelegd tussen beleid voor gezondheid en beleid voor de leefomgeving. Dit helpt om maatschappelijke vraagstukken aan te pakken, zoals gezond ouder worden.

Deze positieve effecten komen naar voren in een literatuuronderzoek van het RIVM. De bevindingen worden onder andere gebruikt voor onderzoek naar moestuinen in verschillende Europese landen. Het onderzoek geeft ook per gezondheidseffect aan met welke indicatoren deze gemeten kunnen worden. Aanbevolen wordt om dit op consistente wijze te doen om bevindingen internationaal te kunnen vergelijken en duidelijk te krijgen of buurtmoestuinen daadwerkelijk helpen om de leefbaarheid, en daarmee de gezondheid, in de stad te verbeteren.

Kernwoorden: stadslandbouw, bodem, indicator, leefomgeving, gezondheid, overgewicht, stress, cohesie, geweld, ecosysteemdiensten.

Synopsis

Healthy urban gardening
City-dwellers are increasingly using derelict land to cultivate vegetables together with other local residents. Like the more traditional allotments, these non-commercial 'community gardens' can contribute to public health and the quality of the neighbourhood. They provide an opportunity for physical exercise and allow people to consume home-grown fruit and vegetables. There are also indications that community gardens reduce stress while offering opportunities for social contacts. In this way, they can help to prevent health problems, although the risks of possible soil contamination and air pollution must be kept to a minimum.

Urban gardens are part of a general 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. These gardens are therefore relevant to government policy on public health and the human environment, and can help to address societal challenges such as healthy ageing.

These are some of the conclusions of a study of the relevant literature conducted by the Dutch National Institute for Public Health and the Environment (RIVM). The findings will be used for several purposes, including research into the functions of urban gardens in various European countries. The study also lists the indicators which can be used to measure each of the different health impacts. The authors recommend the use of consistent measurement methods to ensure international comparability of findings, and to gain further insight into the possible contributions that urban gardens can make to urban liveability and therefore to public health.

Keywords: urban gardening, soils, indicators, livability, health, obesity, stress, social cohesion, violence, ecosystem services

Contents

Summary

This report describes a framework developed to study the associations between soil ecosystem services, ecosystem health, and human health in urban agriculture. The framework shows that many issues come together in urban agriculture. The presence of ecosystem services and their performance are prerequisites for realization of urban gardening and its potential contribution to individual and community health. Soil quality needs to be assessed to manage the potential risks of soil contamination. Often, a site's history provides a clue to the presence of contaminants in soil such as lead, copper and cadmium. To date, no specific European policy on urban gardening practices has been developed. Risk management policy is usually established by local authorities within a national framework. In cases of contamination, some adaptations to gardening practices (e.g. restriction of cultivation of leafy vegetables) can still enable safe urban gardening.

Although the evidence base is limited, 18 peer-reviewed papers suggest that urban gardening may benefit health because of stress reduction, increased physical activity, increased consumption of vegetables and fruit, and more social contacts, particularly in the elderly. In addition to effects on an individual level, it may also affect neighborhood characteristics favorable to community health, such as social cohesion. Incidentally, effects on violence rates, inclusion of vulnerable or minority groups, and improvement of the physical and ecological quality of the area are described, however these latter effects were not always observed. Urban gardening provides the opportunity to alter and self-manage the environment; central elements in the new definition of human health (Huber et al., 2011). However, the positive effects may have been overestimated: it is likely that urban gardening attracts people selectively. In addition, we have to take into account the possibility that only studies showing positive relationships between urban agriculture and health have been published, in contrast to studies showing negative or no relations.

The use of common, standardized and validated indicators would facilitate an increase in empirical evidence for the relationships between urban gardening and ecosystem and human health. We developed indicators to measure ecosystem services, effects on health of individuals and community health. General indicators for ecosystem services for green space include retention and provisioning of nutrients, soil structure, and pest and disease control. These indicators have to be further developed with regard to the use of urban soils specifically for urban gardening. Urban gardens may contribute to the consumption of locally produced food which reduces the environmental burden of food distribution. Of course, from an ecological perspective, sustainable gardening practices are preferred. Relevant indicators for use in determining the health of individuals are: perceived stress reduction, perceived health, amount of daily physical activity, social contacts, and frequency of consumption of vegetables and fruit. For community health, many different indicators could be used. The most important effect is probably social cohesion which can be measured by assessment

of the extent to which gardeners form relationships with each other and offer each other mutual help. Many organizational issues are relevant to optimize the benefits of urban gardening. Potential indicators of these issues are the numbers of plots and volunteers, clients and/or visitors, background of the users (age, socio-economic status, medical needs, percentage of local residents) and financial data. Over-arching indicators are the perceived health and the presence and location of unsealed soils (i.e. in use for urban gardening or for distinguishing different types of green infrastructure) in cities.

The results of the literature study suggest that urban gardening can contribute to health and to governmental environmental agendas. It could be used to address a wide range of health policies like healthy aging in the elderly, obesity in children, or reduction of socio-economic health disparities. However, each potential effect has specific demands on the soil quality and management and organizational structures of the gardens. Therefore, health or other targets should be defined at the start and relevant stakeholders should be approached. To maximize health benefits, it is valuable to make urban gardens accessible to many people. To express and maximize the benefits, effects should be measured using indicators (preferably by pre and post-assessment). In addition, it is important to exchange experiences and knowledge across initiatives, nationally and internationally.

1 Introduction

1.1 The SNOWMAN project Urban Soils

This report describes the findings of one of the work packages of the SNOWMAN Urban Soils project, (http://snowmannetwork.com/?page_id=289, visited 25 September, 2015). In Europe and elsewhere, there is a strong growth in the use of urban soil for urban gardening. The potential of urban gardening to contribute to societal challenges is neither fully recognized nor understood. The concept and practice of urban gardening has not yet led to the introduction of large-scale policies in the European Union or its Member States. The reason is that urban and peri-urban gardening is a blind spot: it is not acknowledged as a sector of activity and therefore is not found in statistical data. The aim of the international SNOWMAN Urban Soils project is 'to identify how better use of urban and peri-urban soils may impact three dimensions of the urban challenge: poverty, violence, and major ecological risks'.
The Urban Soils project consists of six work packages (WP):
WP1: Project management and coordination
WP2: Urban gardens and their economic and social perspectives
WP3: Perceptions and practices in urban agriculture
WP4: Urban gardening and health
WP5: Educational policies, children and soils
WP6: Dissemination and exploitation

This report describes the findings concerning Work Package four.

In the context of this study we do not restrict ourselves to a specific type of urban gardening. The characterization 'urban gardening' applies to all non-commercial types of food production in or linked with the urban environment. Urban gardens include allotment gardens, community gardens, and collective gardens, see textbox 1.

Textbox 1. Glossary from the SNOWMAN Urban Soils Project.

Urban gardening. *All non-commercial types of food production in or linked with the urban environment.*

Allotment. *A plot of land rented by an individual for growing vegetables or flowers.*

Allotment garden. *A piece of land subdivided into a few or up to several hundred plots of land that are assigned to individuals or families.*

Community garden. *A plot of land used collectively by a group of residents to develop community ties. Also called shared gardens.*

Collective garden. *Garden subdivided in individual plots and common plots for cultivation or infrastructures.*

1.2 Health effects of urban gardening

In this study, we aimed to develop a framework for the relationships between soil ecosystem services, ecosystem health and human health in urban gardening. The main focus of this report is to describe effects of urban gardening on determinants of human health, i.e. 'The range of personal, social, economic and environmental factors which determine the health status of individuals or populations' (WHO, 1998). The factors which influence health are multiple and interactive. They not only include the actions of individuals (lifestyles), but also the characteristics of the social and physical environments they live in. These, in combination, create different living conditions which impact health. This is acknowledged in the so-called 'Healthy Cities' concept of the World Health Organization (WHO, 2015). A healthy city is 'one that is continually creating and improving those physical and social environments and expanding those community resources which enable people to mutually support each other in performing all the functions of life and in developing to their maximum potential'(WHO, 1998). In this report we review the evidence for urban gardening contributing to human health by modifying its determinants. Some attention is paid to potential negative health impacts by soil pollution. For risks related to air pollution in cities, we refer to another study (Dack, 2015).

The SNOWMAN urban soils project has its roots in the social and ecological domain. To connect the public health approach in this report to the ecological approach in other Work Packages, we consider the impact on human health as an 'ecosystem service', i.e. the contribution of ecosystems to human well-being. In addition, we developed a common, interdisciplinary framework. We mention other ecosystem services that urban soils could provide in Chapter 3. Soils that are sealed, as is often seen in urban environments, ignore the values of these services. Open soils offer the possibility for rainwater run-off, contact with nature, and the practice of urban gardening – these functions are examples of soil ecosystem services. However, this list needs further elaboration to evaluate the use of urban soils specifically for urban gardening.
One of the aims of Work Package 4 is to identify and describe environmental health indicators. An environmental health indicator is a numerical value that provides insights into the state of the environment or human health. A key function of indicators is to summarize the volume and complexity of information (Bank, 1996). Indicators should 1) explicitly relate to the underlying policy question 2) be comprehensible for the specific audiences of the assessment 3) be explicit and 4) be reported with adequate information to allow correct interpretation (Knol, 2010). Indicators are usually developed based on quantitative measurements or statistics of environmental or health conditions that are tracked over time. The indicators are intended to support and monitor policy on urban gardening at all levels - from the local to the international level. Indicators might refer to different elements of the link between environmental quality and health; e.g. environmental indicators, mechanistic indicators and health effect indicators. In this study, we describe indicators relating to soil ecosystem services, characteristics of the urban gardens, and effects on determinants of health.

This work builds on previous work on the relationships between green space and health. We previously defined the following indicators; 'the percentage of unsealed soil' and the 'area of green space within 500 meters of households'. Maps of these indicators in combination with maps using indicators such as age composition and socio-economic status of residents can be used in policy assessments. They can show, which neighborhoods may benefit most from investments in parks and public gardens (Claessens et al., 2014). We also used information from the EU Phenotype project (see text box 2, (Nieuwenhuijsen et al., 2014)).

Textbox 2. Description of the EU PHENOTYPE project

Potential mechanisms of the health benefits in relationship to exposure to the natural (green) outdoor environment have been investigated. They include physical activity, stress reduction, restoration, social contacts, and reduction of exposure to environmental hazards. However, these have not been measured simultaneously, and the studies have mostly been conducted in northwest Europe and the USA. Inconsistency and variation in indicators for green or natural space have often made it difficult to compare results from different studies. The EU PHENOTYPE project was set up to provide a better understanding of the potential mechanisms, and better integration of human health needs into land use planning and green space management (Nieuwenhuijsen et al., 2014).

1.3 Approach and guide to the reader

Chapter 2 describes existing frameworks with regard to green space and health. Based on these models and consultation with the SNOWMAN partners, we present a model linking urban gardening to health.

In Chapter 3, we present the concept of ecosystem services and the relationships with determinants of health. Indicators for soil ecosystem services relevant for urban gardening and health are also defined.

Chapter 4 describes the results of a literature search on health effects of urban gardening. It contains factsheets that describe the indicators used to measure determinants of health in relevant scientific papers.

Chapter 5 summarizes and discusses the results of this study and gives recommendations for future work.

2 Framework for relationships between green space and health

A conceptual framework is interpreted as a way of thinking about a subject in order to interpret empirical evidence about that subject and to provide a visual representation of the numerous variables involved with their interrelations. A conceptual model can be used for interdisciplinary research into the multiple relations between urban gardening and human health. To our knowledge, no framework for urban gardening has yet been developed. As we consider urban gardening as a specific kind of urban green space use, we start this chapter by showing a conceptual framework with regard to the relations between urban green space and human health.
The current WHO definition of health, formulated in 1948, describes health as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity." At that time, this formulation was groundbreaking because of its breadth and ambition. However, the WHO definition of health for complete wellbeing may no longer be fit for purpose, given the rise of chronic diseases. Huber and colleagues proposed changing the emphasis from the absence of disease towards the ability to adapt and self-manage in the face of social, physical, and emotional challenges in life. We use Huber's definition in this report (Huber et al., 2011).

Recently, a 'review of reviews' about the relation of nature and health was conducted (Hartig et al., 2014). Pathways that have received relatively large amounts of research attention include air quality, physical activity, social cohesion and stress reduction, see Figure 2.1. They define 'nature' in the broadest sense. In this, 'nature' is not confined to "natural environment", being an environment with little or no apparent evidence of human presence or intervention, but includes all green (natural or built) structures, e.g. urban parks, allotments, gardens, trees, indoor plants and so on. Hartig et al. described each of these pathways and indicated some of the complexities involved in drawing conclusions on the role of the specific pathways, including variation in association across people, activities and characteristics of the nature under study. In the review, Hartig notes that too few primary studies have been carried out in a consistent and rigorous way to establish the causality of relationships between contact with nature and health (Hartig et al., 2014).

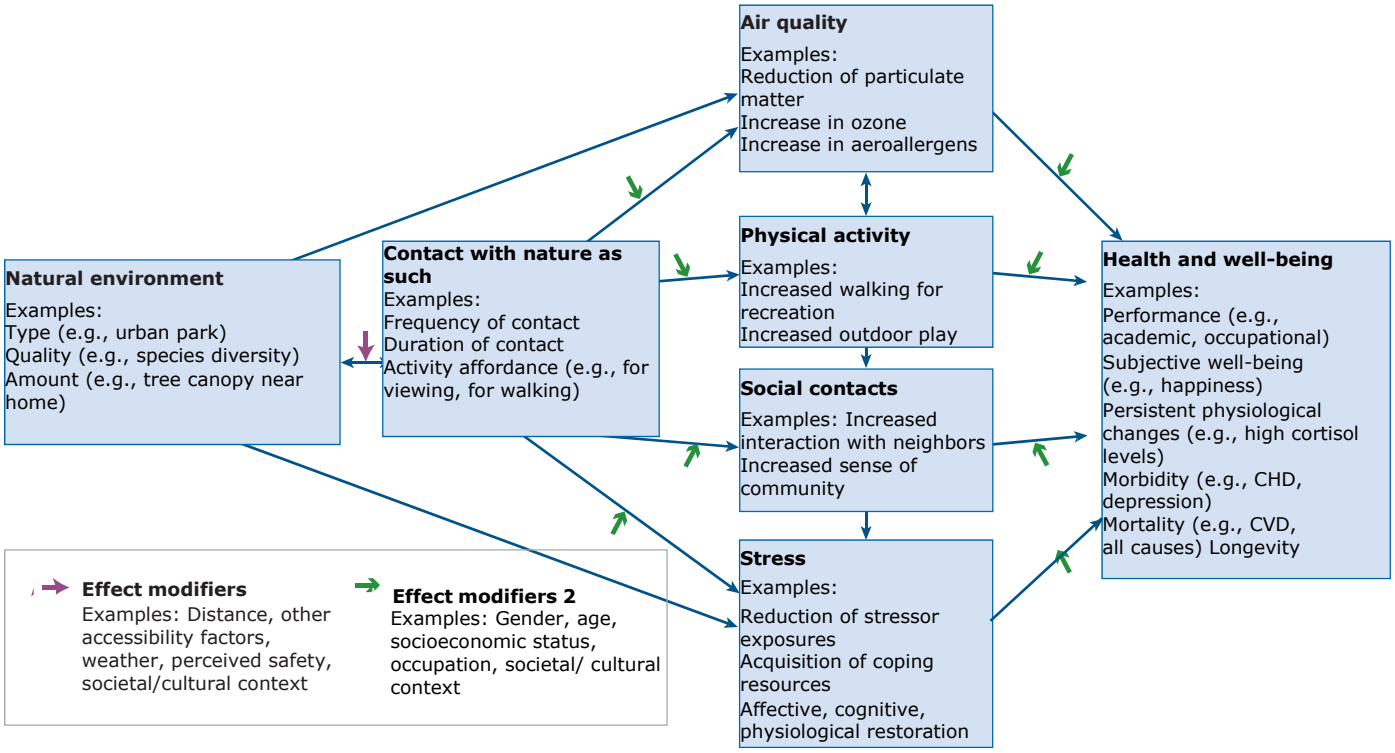

Figure 2.1: Conceptual framework for the relation between nature and health (Hartig et al., 2014).

The framework presented by Hartig et al. does not explicitly mention the role of ecosystems. Within the National Ecosystem Assessment of the United Kingdom, a framework was developed that started with 'ecosystems and habitats' on the left side, affecting health endpoints on the right side (Figure 2.2) (Pretty, 2011). A distinction was made between positive effects on determinants of health on the one hand, and threats to human health on the other: both are relevant for urban gardening. Positive effects relate to the pathways described by Hartig et al. Potential threats are, for example, related to soil pollution.

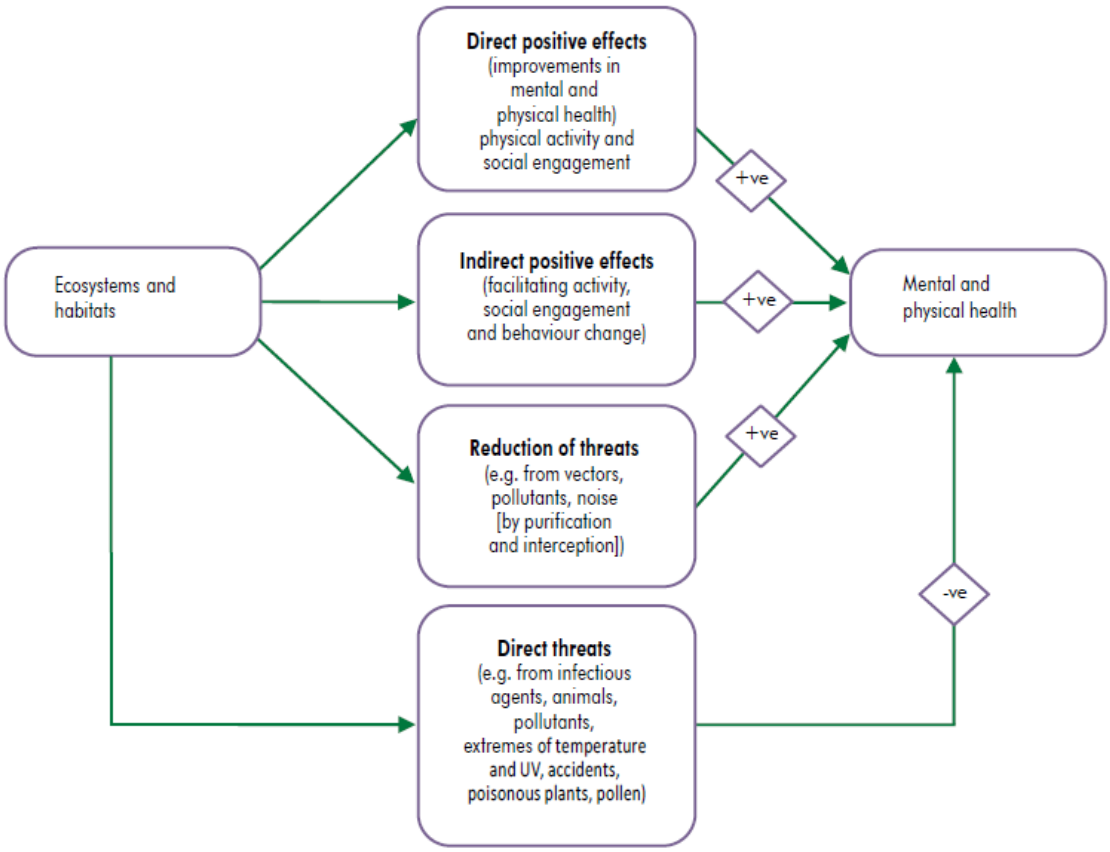

Figure 2.2: Conceptual framework for the relation between ecosystems and health (Pretty, 2011).

Tzoulas et al. developed a comprehensive conceptual framework including green infrastructure, ecosystems, economy and health (Tzoulas et al., 2007). An international study group called 'URBAN NEXUS' combined this with another framework (James et al., 2009) to facilitate the dialogue between urban researchers, professionals and actors, see Figure 2.3 (URBAN-NEXUS, 2012).
The relationships between the many components are indicated with bidirectional arrows to express a two-sided dependence. For example, Tzoulas et al. show that environmental settings contribute to, but are also affected by aspects of public health, which encompass physical, psychological, social and community health. They argue that ecosystem management is inevitably guided by human needs, socio-economic factors, and cultural conditions. For example, the presence of mosquitoes in a place favored by the public may result in a need to use pesticides. Pesticide use may then cause health consequences for the local people (e.g. respiratory irritation) and/or a change in local people's attachment to that place. In turn, this may lead people to select other favorite places. This implies that peoples' health can also be a factor in modifying environments (Tzoulas et al., 2007).
Community health was explicitly included in the framework, as social relationships contribute significantly to the well-being of individuals (Ferlander, 2007). Community satisfaction and involvement, as well as community identity, are fundamental to the social wellbeing of both communities and individuals. The World Health Organization also recognizes culture and lifestyle as determinants of health. Hence lifestyle, community factors and socio-economic factors work synergistically to affect the well-being of individuals (Tzoulas et al., 2007).

Socio-economic health was included in the framework because there is a clear need to evaluate the potential economic implications of green infrastructure, linked to health effects and health service budgets. Estimates of health care savings attributable to increased outdoor physical activity, for instance, make a strong economic case, as well as a strong social case, for enhancing the urban green infrastructure for the purpose of reducing health care expenditure (Tzoulas et al., 2007). All frameworks shown in this chapter describe the mechanisms underlying the relationship of nature or ecosystems with human health. However, the first two schemes include 'health' as the ultimate 'endpoint' or goal, whereas Figure 2.3 focuses on the interplay between physical factors and human health.

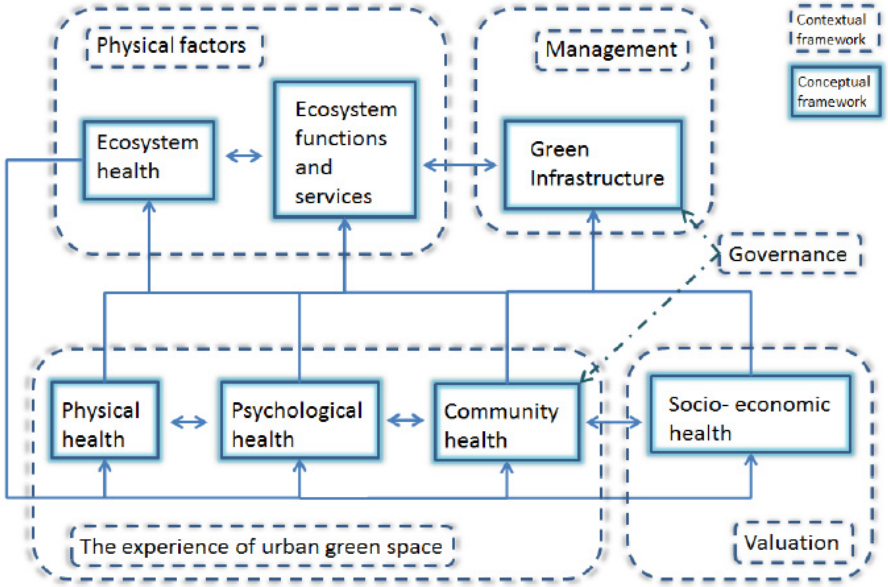

Figure 2.3. Framework linking green infrastructure, ecosystem health and public health. Health was conceptualized by the elements physical health, psychological health, community health and socio-economic health (URBAN-NEXUS, 2012).

2.1 Framework for urban gardening and health

As described in Chapter 1, 'urban gardening' applies to all non-commercial types of food production in or linked with the urban environment. The practice of urban gardening implies contact with green infrastructure and nature. Therefore, we used the framework developed by URBAN NEXUS (URBAN-NEXUS, 2012) and specified 'the contact with urban green space' as the contact with the soil, and 'green infrastructure' as allotments (this term is used interchangeably with urban gardens here). The reason for selecting this framework instead of other frameworks relating green space to health, was that it combines concepts from public health with those from (soil) ecology, and because the central element is the interplay between these concepts. The framework defines four contexts which are our main lines of reasoning to describe potential effects of urban gardening in this report:

1. Physical factors – Ecosystem health and ecosystem services. Ecosystem services include potential health effects in humans (see 3), but also other societal benefits, like the provision of opportunities for education of children.
2. Management – organizational issues of urban gardens that may determine whether gardens have the potential to result in health effects or other societal benefits.
3. The experience of urban gardening – which effects can be observed in humans with regard to physical, psychological and community health. In fact, most studies in this domain do not describe *direct* health effects like a decrease in mortality or the incidence of cardiovascular diseases. We discuss *indirect* health effects, like the potential increase in physical activity, which in turn may reduce the incidence of cardiovascular diseases. These intermediate effects, which we call determinants of health, consist of potential changes in life style (individual level) and in community factors, like the neighborhood infrastructure (community level) – for example, does the neighborhood 'invite' residents to walk or cycle instead of using their cars?
4. Valuation - we discuss the valuation of societal benefits (mainly indirect health effects) of urban gardening by summarizing the results of social cost-benefit analyses on this topic.

The URBAN NEXUS model includes a conceptual and a contextual framework. The concepts define the issues in consideration when evaluating the links between urban gardening and health. The contexts refer to potential driving forces, pressures and policy actions that determine whether people get into contact with urban gardening, and whether that 'exposure' or 'contact' leads to health effects. This is in line with the DPSIR (driving forces-pressures-state-impact-response) framework, used for the formulation of indicators for environmental reporting and assessment in the EU (EEA, 2005). The management or organizational structure of gardens is discussed because it may determine whether it is actually beneficial to (determinants of) health. To increase the social cohesion in a neighborhood, for example, the garden obviously needs to be located in that neighborhood.
Socio-economic health was included as a line of reasoning in this report because there is a clear need to evaluate the potential economic implications of green infrastructure, linked to health effects and health service budgets (Tzoulas et al., 2007).

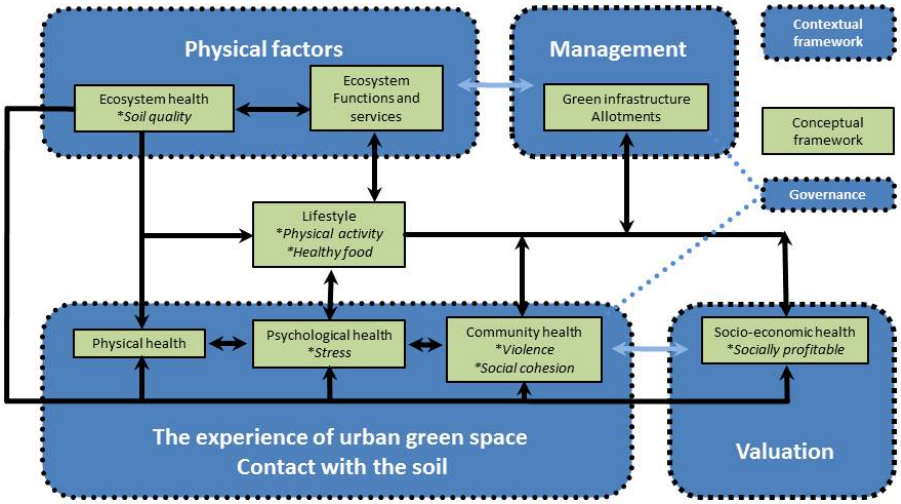

Figure 2.4. Framework illustrating the associations between soil ecosystem services, ecosystem health and human health in urban agriculture. The asterisks in italics show the topics for which we developed factsheets describing potential indicators. Adapted from (URBAN-NEXUS, 2012).

The asterisks of the concepts in Figure 2.4 show the topics for which we will present factsheets and indicators (Chapters 3 and 4). Soil quality is regarded as an element of ecosystem health (left box in upper row). It refers to the ability of soils to deliver ecosystem services like water storage, formation of organic matter, et cetera (see Chapter 3), but also to the potential presence of soil contaminants (see Chapter 4).
We added 'lifestyle' to the framework to illustrate effects related to physical activity and healthy food (vegetable and fruit consumption).We used the same pathways of the relation between green space and health described in the framework developed by Hartig et al. (see Figure 2.1), i.e. physical activity, social contacts (or cohesion) and stress reduction. However, we excluded air quality as the overall impact on air pollutant levels is a function of several processes that operate in opposite directions (Hartig et al., 2014) and because it is not clear whether vegetation (trees and plants) may improve air quality in a city significantly e.g. (Wesseling et al., 2011, Nowak et al., 2006). An additional potential health benefit of urban gardening as opposed to other green infrastructure is linked to healthy food. Urban gardening might invite and enable people to eat more vegetables and fruit than before they started urban gardening. Therefore, we added healthy food to the pathways described by Hartig et al.
Social cohesion refers to solidarity in groups or communities (Berkman and Glass, 2000). As social cohesion is about relations between people, it is a characteristic of a system rather than a personal trait and therefore it is an element of community health.

However, some studies measure social effects at the individual level, which we summarize with the heading 'social contacts' in Chapter 4. The topics 'violence' and 'socially profitable' were added to this report by request of the SNOWMAN consortium at the Utrecht meeting in October 2014. Altogether, we developed indicators for the following elements:

- Soil ecosystem services (see Chapter 3)
- Potential positive effects on determinants of health at the individual level (Chapter 4; factsheets physical activity, vegetable and fruit consumption, social contacts, stress levels)
- Potential positive effects on determinants of health at the community level (Chapter 4; factsheet social cohesion and violence)
- Potential negative effects from soil pollution (Chapter 4; factsheet exposure to soil contaminants)
- Management / organizational issues and valuation (Chapter 4; factsheet socially profitable).

Social profitability refers to the valuation of all potential societal benefits including social cohesion, lifestyle changes, and violence reduction. In case of overlap, we refer to the other factsheets on determinants of health.

3 Soil ecosystem services and ecosystem health in urban areas

In this chapter we address the following questions:

- What are soil ecosystem services and why do we need them?
- What is the importance of urban soil ecosystems as the basis for urban green space?

We present the concept of ecosystem services, the relation with our conceptual model (see chapter 2) and a selection of soil ecosystem services (ESS) relevant for urban green space, and how ESS could be used as indicators for optimizing and assessing the status of urban soil. However, this list needs further elaboration to evaluate the use of urban soils specifically for urban gardening instead of for green infrastructure in general. From an ecological perspective, one of the benefits of urban gardens is that they contribute to the consumption of locally produced food which reduces the environmental burden of food distribution.

For this study about the relationships between urban gardening and human health we have drawn up the following prepositions:

1. Soils are a crucial element for the livability in urban environments. They are the carrier of many functions (EC, 2006).
2. The use (application) of Soil Ecosystem Services and the quality of urban soil (ecosystem health) need to be considered when planning urban functions (Breure et al., 2012). This applies in particular to the so-called 'green' infrastructure.
3. The quality of the urban environment, the quality of urban soils, and the functioning of soil ecosystems is an indispensable element for linking urban gardening and health impacts.
4. The delivery and the value of ecosystem services together with the ecosystem health status can be used as (secondary) indicators for the health impacts of urban gardening.

3.1 Soil ecosystem services

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 that are directly consumed, used, or enjoyed by people. The classification recognizes these outputs to be provisioning, regulating and cultural services (Maes et al., 2013).

Services that are specifically delivered by the soil ecosystem are given in Table 3.1 and vary in importance for society depending on the climate, scale, spatiality, soil type and soil function. The presence of good quality soils and their deliverance of ESS are prerequisites for the realization of urban gardens and whether they have the potential to contribute to health.

Table 3.1: An overview of arrangements for soil ecosystem services.

Ecosystem services (ESS) (Millennium Ecosystem Assessment)	**Ecosystem services in the Netherlands (Oostenbrugge et al., 2010)**	**Soil ecosystem services - attributed to soil (Breure et al., 2012)**	**Ecosystem services according to CICES/SEEA***
Provisioning services	Fresh water Food Wood Fish Genetic sources	Biodiversity pools	Provisioning services
Regulating services	Carbon sequestration Pollination Pest elimination Water regulation Cleansing power	Storage, filtering and transformation	Regulating and maintenance services
Supporting services	Soil formation Primary production Nutrient cycle	Biomass production Carbon Pool	
Cultural services	Cultural history Health Recreation	Archive of geological and archaeological heritage	Cultural services

* CICES=The Common International Classification of Ecosystem Services
SEEA= the System of Environmental-Economic Accounting

The relationship between soils and ESS is stronger or more dominant for so-called sensitive functions, such as urban gardening and urban green space, than for insensitive functions such as parking lots or roads. The interactions are bidirective. To give an example: the functioning of soil ecosystem services depends on soil quality status and use or function of green space. On the other hand, the soil quality can be the result of ecosystem services through the transformation and degradation of nutrients and substances and biomass production.

3.2 Selection of soil ecosystem services relevant for urban gardening

Urban gardening is a way of soil use which has important relationships with the social and environmental quality of the urban area. The green infrastructure of an area contributes to its climate condition by the provision of shade and coolness. Coolness can be provided by evaporation of water from the soil and the plants on the soil. The open, unsealed soil which is necessary for urban gardening adds to the storage of rainwater in the soil and the activity of soil organisms. The first is an important positive contribution to urban water management, and the latter adds to the self-purifying capacity of soil and subsoil, leading to good quality groundwater and a reduction in the exposure of humans to soil pollutants.

Moreover, green areas may reduce noise and temperature in urban areas. Urban gardening stimulates human activity and it may improve the societal coherence in human communities, especially when urban gardening takes place in the public space. Urban gardening is a means to raise the awareness of citizens (especially children), where food comes from and how it is produced. Urban gardening adds to the diversity of urban green, in addition to parks and playgrounds, sport complexes and other green areas such as cemeteries. In this way it adds to the quality of the living environment. Table 3.2 summarizes the ecosystem services that contribute to public health and the livability of a city.

Table 3.2: Ecosystem services (ESS) that contribute to public health and the livability of a city.

ESS (Rutgers and Dirven, 2012)	**Contribution to health of citizens**	**Contribution to the quality of urban infrastructure and functioning of the natural environment**
Retention and provisioning of nutrients	Leads to high quality green areas that may positively influence human activity, quality of urban gardening crops, air quality and noise levels.	Soil quality and quality of urban green space. Less fertilizers needed.
Soil structure	Contributes to good quality green areas and reduction of water nuisance.	Positive contribution to water management and water retention. Positive influence on soil and maintenance needs.
Pest and disease control	Reduces pesticide use, leading to reduced human exposure and better quality of urban gardening crops	Ecological green space management
Resistance and resilience of soil	Recovery of living environment is possible after a negative impact or stress.	Natural purification after soil pollution, recuperation of soil quality after land use changes, or after sealing and compaction of the soil.
Formation and degradation of soil organic matter	Improved soil fertility and a high soil organic matter content leads to higher soil biodiversity and less water nuisance.	Improved water retention and decreased desiccation. High organic matter content of the soil implies carbon sequestration - a positive contribution to climate change mitigation.

ESS (Rutgers and Dirven, 2012)	Contribution to health of citizens	Contribution to the quality of urban infrastructure and functioning of the natural environment
Water management	Flood prevention, insect control	See above
Self-purifying capacity of soil	Contributes to the good quality of the city's environment (water, air and soil)	Maintenance of clean soil and groundwater, capacity to produce healthy crops. Adds to clean ground- and drinking water and reduces soil pollution. Increases water storage capacity and thereby prevents flooding.
Climate function	Better quality of life for citizens. More green space. Reducing heat stress.	Local climate regulation; cooling and potentially reducing noise and air pollution by vegetation. (Temporary) water storage capacity.
Habitat function and biodiversity	Contributes to a living environment that may stimulate physical activity in residents. Leads to less stress and more well-being. Contributes to education and archaeology.	Maintaining biodiversity, education, geological and aesthetic value of the environment.

Different aspects of soil ecosystem function are described below with regard to their potential role in ecosystem services for urban gardening and management. In addition, we we describe methods for measuring soil functions.

Nutrient retention and provision

Organisms in soil play an important role in the biogeochemical nutrient cycles. Nutrients (nitrogen, phosphorus, sulfur) are released from organic (plant and animal) waste, e.g. dead plant material, manure, dead animals. Nitrogen fixing bacteria in the soil capture and converted aerial nitrogen into a form that plants can use. With its capacity to capture, hold and release nutrients, soil is extremely important for the provisioning of nutrients for plant growth. Thus, a well-functioning soil is important for the growth of trees, the maintenance of green areas and the growth of crops and other plants in (urban) gardens. The availability and concentration of nutrients can be measured chemically, the activity of the bacterial biomass responsible for nutrient provision can be measured, and a shortage of nutrients can be deduced from the plant growth and the appearance of the plants. High soil capacities for

nutrient cycling provide the opportunity to obtain high growth yield without the use of fertilizers.

Soil structure
Soil structure is characterized by the granule size distribution, the types of granules and the organic carbon content. Soil structure determines the water holding capacity of the soil, and a good soil structure provides encourages plant root growth. The porosity and organic carbon content of a soil influence the air and water content of soil, and thus are important for the quality of the habitat for soil organisms. Soil biota influence the porosity, e.g. by bioturbation (earthworms), formation of soil organic matter (bacteria and fungi) and the hyphae of the fungi play an important role in granule formation, as do the organic molecules excreted by bacteria and fungi that act like glue.
Soil structure is physically assessed using the Visual Evaluation of Soil Structure and the Visual Evaluation of Soil Structure Score Chart. (see: http://www.sruc.ac.uk/info/120062/crop_and_soils_systems/412/visual_evaluation_of_soil_structure, visited 29 September 2015)
A good soil structure can be maintained in urban areas by preventing soil sealing, e.g. by green space policies that promote urban gardening and open soil car parking spaces and that prevent soil compaction from heavy rolling stock.

Pest and disease control
Pest and disease control in soil is enabled by the presence of organisms that combat pest organisms by predation or competition for a certain habitat. Soil organisms may also excrete toxic compounds. Under natural conditions, soil fungi produce the antibiotic penicillin to combat these bacteria. In general, a high soil biodiversity encourages resistance to disease and pests providing opportunities to obtain good crop yields without the use of pesticides. Therefore an indirect measure is the pesticide use in gardening. Other microbiological methods are also available to determine the presence and activity of specific organisms in soil.

Resistance and resilience
A good-quality soil with a stable community of soil organisms and a good structure is able to recover following natural or man-made stress. Soil quality management is necessary to maintain a good soil quality. Resistance and resilience are also important in case of land use changes, such as the introduction of urban gardening. A resilient soil has the capacity to perform the soil processes under different conditions. In contrast, an intensively managed agricultural cropland only functions under specific conditions. A resilient soil also provides flexibility in the agricultural use of a soil.

Production and degradation of soil organic matter
Soil organic matter (SOM) consists of soil organisms, easily degradable debris of dead plants and animals, and relatively stable organic macromolecules such as humic and fulvic acids, and humine.
Soil organisms together perform the biological processes of the soil. The easily degradable part of soil organic matter forms the food for soil organisms which release nutrients from these compounds to be used for new plant growth. Moreover, soil organisms use the easily degradable

part to produce the stable part of SOM. This in turn determines, to a great extent, the structure and physical properties of the soil. The material is very stable, with a half-life of longer than 100 years. It is important for both the binding and retention of nutrients and pollutants and their buffering capacity. The binding of nutrients by SOM is an important constituent of soil fertility. Soil also provides the micro porosity that is important for the water holding capacity of the soil, the exchange of gases and the provision of a habitat for soil organisms and roots. The formation of stable organic matter is known as carbon sequestration of soils. Therefore, soil organisms may play a role in the mitigation of climate change effects. Oxidizable organic carbon levels can be determined in laboratory. The weight loss on ignition method is based on measuring the weight loss from a dry soil sample when exposed to high temperatures; the resulting weight loss is attributed to oxidizable organic carbon (Hoogsteen et al., 2015).

The role of soil in urban water management

Water may be stored in the soil pores and it is bound by the organic molecules. Therefore, soil structure is important for the water holding capacity of a soil. A well-structured and unsealed soil can provide a high capacity for rainwater storage and can consequently prevent flooding in urban areas. Furthermore, its storage provides water for plants in dry periods, and may lead to evaporation, and hence cooling during warm periods. The soil structure and water holding capacity is determined physically in laboratory tests.

Self-purifying capacity of soil

As mentioned in the SOM section, soil and soil organisms play important roles in geochemical cycles, the cycles of formation of complex molecules from chemical elements and the subsequent degradation of these molecules into elements. This is important for the provision of nutrients for plant growth, degradation of organic material derived from dead plants and animals, and formation of stable SOM. Closely related to this capacity is the self-purifying capacity of soils. Soil organisms may adapt to degrade manmade organic molecules, and can consequently remove polluting compounds from the soils. Adaptation of soil organisms to chemical pollutants is enhanced by a high soil biodiversity. This capacity of soil is important for maintenance of clean groundwater, an important source of drinking water, and for the maintenance of clean soil, capable of producing healthy crops. The self-purifying capacity of soil is applied technologically in biological soil sanitation, where the growth of pollutant degrading organisms in the soil is stimulated in order to clean soil and reduce human exposure to soil pollutants. This self-purifying capacity forms the mechanism behind soils'resilience and resistance to chemical stress. The presence of soil pollutants and the biological activity of soil organisms can be measured.

Climate function

The soil is the carrier of urban green which plays an important role in urban climate regulation, as it influences temperature by providing shade and evaporation. Furthermore, it may also reduce noise levels and urban air pollutant levels. The soil itself also has a role as a reservoir of groundwater and nutrients to enable urban greening. With higher temperatures, water from the soil may evaporate leading to a

decrease in urban temperature. Urban gardening provides green areas and open (non-sealed) soils and can consequently contribute to local urban climate circumstances.
The unsealed soil under urban gardening areas also leads to water-infiltration when it rains and has positive effects on the water content of soil.
As mentioned in the SOM section, the formation of stable SOM in soil (carbon sequestration) which is stimulated by urban gardening, might reduce carbon dioxide concentrations in the air.
In its role in biogeochemical cycles, soil exchanges gaseous compounds with the atmosphere (e.g. CO_2, nitrogen oxides (NO_x) and methane), thus influencing the concentration of greenhouse gases in the atmosphere. Therefore, gardening practices may facilitate the exchange of greenhouse gases.
We defined the following indicators related to the climate function of soils as being 'the presence and location of unsealed soils' and the 'area of green space within 500 meters of households'. Maps of these indicators, in combination with maps of indicators like age composition and socio-economic status of neighborhood residents, can be used in policy assessments. They show which neighborhoods may benefit most from investments in parks and public gardens (Claessens et al., 2014).

Habitat function and biodiversity
Soil is the carrier of the city, its infrastructure, and the habitat of urban organisms, including humans, animals and plants. Furthermore, it is the habitat of soil organisms. The quality of the habitat determines the biodiversity, both above the soil and in the soil. Biodiversity directly and indirectly influences the quality of the living environment, and thus human health and wellbeing. Urban green and urban gardening stimulate physical activity such as hiking, cycling and gardening. Human activity can be measured, and subsequently related to wellbeing and health (see Chapter 4). Biodiversity in and on the soil can also be measured by monitoring activities.

4 Indicators for determinants of health

4.1 Methods

4.1.1 Literature search

We conducted a literature search of electronic databases [Scopus, Medline, Psycinfo and Embase] and Google Scholar in June, 2014. The search included key words related to social cohesion, lifestyle, obesity, stress, general health, perceived health, poverty, physical activity and well-being. The search did not include potential negative effects on health as a result of of soil contamination. The focus was on articles or reports of (potential mechanisms of) health benefits in gardeners working in community gardens. Researchers in this field use a number of different terms for community gardens, for example allotment gardening, or urban agriculture. Because the terms are often interchangeable, all articles regarding gardening, urban agriculture and/or allotments were carefully reviewed.

4.1.2 Selection of literature

The literature search yielded 232 papers on the relationship between community gardening and health. It also included one report of a review of the evidence for the benefits of gardening and growing food for health (Davies et al., 2014).The references of this report were hand-searched but did not yield any additional publications. We added one report in Dutch describing social economic benefit analyses regarding urban agriculture (Abma et al., 2013). 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 as illustrated by the pathways in our framework (Chapter 2.1).
- Described the general population. Papers regarding subgroups, like people with ill health or ethnic minority groups, were not selected.
- Did not evaluate specific workshops or educational programs.
- Were published after 1999.

We focused on the role of urban gardening in health promotion and excluded studies on gardens serving people with ill health or vulnerable groups, like homeless women or drug addicts. Davies et al. summarized the evidence for effects of urban gardening on the mental health of people coping with, for instance, depression, cancer, allergy or HIV/AIDS (Davies et al., 2014). This so-called ‘green care’ might also be useful in the treatment or day-care of older people with dementia (Bruin et al., 2009, Bruin et al., 2010). These health care benefits of urban gardening fell outside the scope of this report.

4.1.3 *Template*

A template was designed to describe the indicators used by the authors to measure the determinants of health, see table 4.1. The template was developed at the SNOWMAN meeting in Utrecht, October 2014. The template is similar to indicator factsheets developed by the European Environment Agency (EEA, see http://www.eea.europa.eu/data-and-maps/indicators/#c5=&c7=all&c0=10&b_start=0). The template includes a summary of the evidence for each health effect based on the results of the literature search. The template also describes measurement units, policy relevance and interpretation of the indicators. This has resulted in the production of factsheets for stress levels, physical activity, violence, social profit, social cohesion, and fruit and vegetable consumption. In addition, a factsheet regarding negative health effects by soil pollution was developed based on expert consultation.

Table 4.1. Common template for the definition of indicators for each determinant of health, developed at the SNOWMAN Utrecht Meeting (2014).

Health determinant	
Description of the health determinant	
Definition	Description of the health determinant and evidence for the association with human health.
Study designs	Description of each study that measured the health determinant in relation to urban gardening retrieved from the literature review.
Findings	The relation between urban gardening and the health determinant under study at different levels, e.g. in individuals, cities, communities. Results of questionnaires, statistics etc.
Indicators used	Which indicator(s) have been used to assess the effect of urban gardening on the health determinant?
Policy relevance	Relevancy for policy-makers/implementation of the indicator.
Interpretation of the indicator(s)	
Means of interpretation	What, precisely, does it measure?
Known limits and bias	State the limits of the indicator and the chance of bias in the measurements.
Quality of the indicator(s)	
Reliability	How consistently and accurately does the indicator measure what it was intended to measure. How can it be interpreted and (regularly) monitored over time?
Availability of data	Availability and accessibility of regularly updated and standardized data in the Netherlands and in Europe that can be used as reference data. For example, which indicators from the European Core Health Indicators might be applied? (http://ec.europa.eu/health/indicators/indicators/index_en.htm, visited July 9)

4.2 Factsheets of determinants of health

The literature search yielded 18 papers that met the selection criteria listed in section 4.2.1. For each health determinant, 2-9 papers were

available. The highest number of papers concerned fruit and vegetable consumption (9) and social cohesion (community level, 7). For violence, only 2 papers were found, which may be explained by the fact that 'violence' was not explicitly included in the search terms. Therefore, the references of these two papers were hand-searched for additional publications. However, no additional papers met the selection criteria. Each factsheet summarizes and discusses the indicators used in the studies to measure the corresponding effects.

4.3 Stress levels

Stress levels	
Description of the determinant of health	
Definition	Reduction of stress levels is one of the pathways in which green space can influence health (see Fig 2.1). Mechanisms might relate to the attention restoration theory (ART) (Kaplan, 1995) or the psychophysiological stress recovery theory (Ulrich et al., 1991). Here, we focus on the physiological and emotional aspects of stress reduction or restoration (terms used interchangeably). The other - cognitional and behaviural-aspects were not specificly assessed in the studies described below. Apart from the restoration effect of contact with nature, there is evidence of the potential stress-relieving effect of the gardening *activity* (Van Den Berg and Custers, 2011). Allotment gardening may have added benefits to stress reduction above those of domestic gardening because of the social context and escape from the home environment (Hawkins et al., 2013).
Study designs	1. (Hawkins et al., 2013): Semi-structured interviews in 14 allotment gardeners, Cardiff, Wales, UK. 2. (Van Den Berg and Custers, 2011): Field experiment with 30 Dutch allotment gardeners. Stress levels (assessed by cortisol levels in saliva) were assessed before and after reading or gardening at the allotment site. 3. (Hawkins et al., 2011): Physiological measurements (weight and height, blood pressure and lung function) and questionniares on self-rated health, perceived stress, physical activity level and perceived social support in 94 over-50 year old adults. People with allotments were compared with members of walking groups, home gardeners, or indoor exercise groups, UK. 4. (van den Berg et al., 2010): Survey among 121 members of 12 allotment sites in the Netherlands divided into a younger and older group. The control group consisted of 63 respondents without an allotment garden living next to the home addresses of allotment gardeners. 5. (Wakefield et al., 2007): Participant observation, focus groups including 55 people and in-depth interviews among 13 gardeners

Stress levels	
Findings	1. (Hawkins et al., 2013) Allotment gardeners appreciate both ' doing' gardening and 'being' at the allotment site as affording a wide range of benefits to their health and wellbeing. 2. (Van Den Berg and Custers, 2011) Cortisol decreased in both groups, but the decrease was strongest following gardening. 3. (Hawkins et al., 2011) Allotment gardeners reported significantly less perceived stress than participants of indoor exercise classes. They also showed lower levels compared to walking group members and home gardeners, but these differences were not significant. 4. (van den Berg et al., 2010) Tendency towards lower perceived stress levels in allotment gardeners compared to controls in the ≥ 62 year age group, but not in the < 62 year age group. 5. (Wakefield et al., 2007) For many participants, being part of a community garden was stress-relieving, as assessed by quotes like 'Sometimes when you are stressed out.. . when you go to the garden, you feel different'.
Indicators used	- Perceived stress (please note: no common definition). - Perceived health/well-being Perceived stress was assessed in all studies except the field experiment, often in combination with the indicator 'perceived health'. However, different standardized stress scales have been used to assess 'perceived stress' – there is no consensus on how to measure this indicator. In contrast, measurements of cortisol and blood pressure are well-standardized. However, because of the large variation in physiological measurements within and between persons, large sample sizes would be required. Therefore, these physiological measurements are more appropriate in experimental settings than in monitoring programs using indicators.
Policy relevance	There is some evidence that urban gardening is associated with reduced self-reported stress levels which is in line with the evidence regarding green space. However, until now, it is not exactly clear what types of green infrastructure provide the greatest benefits and under which circumstances. Urban agriculture might be a valuable resource for preventing stress-related diseases.
Interpretation of the indicator(s)	
Means of interpretation	Perceived stress is often a composite measure of different aspects of stress, e.g. combined amount of stress in the past month and ability to cope with stress in study 4 (van den Berg et al., 2010). However, Hawkins used a one-item measure (Cohen and Williamson, 1988) and sometimes different sets of questions from the Medical Outcomes Study 36-Item Short Form Health Survey (SF-36) are used. Perceived health is more uniformly defined, by asking respondents to rate their general health, for instance on a 7-level scale in the SF-36.

Stress levels	
Known limits and bias	The study by Van den Berg et al. (2011) provides the first experimental evidence of the restorative effects of gardening. The findings are compatible with correlational research on the health benefits of exercise and contact with nature. However, the sample size was small and did not include different subgroups which makes it hard to generalize the findings to other groups of people. The experiment was restricted to a single occasion, therefore it does not show how the psycho-physiological effects of gardening unfold over time (Van Den Berg and Custers, 2011). The other study by Van den Berg et al. (2010) showed that the stress reducing effects were restricted to the ≥ 62 year old group. Both the studies using questionnaires and those using interviews/focus groups suggest that gardening permits (particularly older) people to enjoy the restorative effect of contact with nature on a regular basis (Van Den Berg and Custers, 2011).
Quality of the indicator(s)	
Reliability	Self-perceived health is a European Core Health Indicator from the SF-36, which is used to measure and compare population health across Europe (http://ec.europa.eu/health/indicators/indicators/index_en.htm). It is a summary measure of all aspects of health that are relevant for those filling out the questionnaire. This indicator is a strong predictor of mortality rates (DeSalvo et al., 2006); higher perceived health is associated with lower mortality risk. Self-perceived stress is much more complicated to define. A limitation of both indicators is that perceived benefits explaining better health may differ from person to person. Focus groups/interviews are required to study the underlying mechanisms – which could be related to stress, but also to physical activity, mood or illnesses. Self-perceived health is no specific measure for stress reduction; it is related to all aspects of health, including handicaps, illnesses etc.
Availability of data	International data on perceived health are available from the European Statistics of Income and Living Conditions survey (http://ec.europa.eu/eurostat, visited March 13, 2015). Data for the Netherlands is collected by 'Gezondheidsmonitor GGD'en, CBS en RIVM'.

4.4 Physical activity

Physical activity	
Description of the determinant of health	
Definition	Physical activity is defined as any bodily movement produced by skeletal muscles that results in energy expenditure (Caspersen et al., 1985). To promote and maintain health, adults aged 18–64 years should do at least 150 minutes of moderate-intensity aerobic physical activity throughout the week, or do at least 75 minutes of vigorous-intensity aerobic physical activity throughout the week, or an equivalent combination of moderate- and vigorous-intensity activity. For explanation and full WHO guidelines see (WHO, 2010). National guidelines also exist, e.g. 'at least half an hour moderate physical activity on at least five days a week' in the Netherlands. Most gardening tasks are moderate-intensity forms of physical activity, but some are low-intensity (e.g. watering, planting) and some high intensity (digging, fellling trees) (Ainsworth et al., 2011).
Study designs	1. (van den Berg et al., 2010): Self-reported levels of physical activity in summer among 121 people with and 63 without an allotment garden in the Netherlands. 2. (Wakefield et al., 2007): Participant observation, focus groups including 55 people and in-depth interviews among 13 gardeners. 3. (Quayle, 2008): 22 agricultural projects, including 11 community farms across England using informal interview sessions, participatory appraisal and postal questionnaires. 4. (Hawkins et al., 2011): Physiological measurements (weight and height, blood pressure and lung function) and questionnaires on self-rated health, perceived stress, physical activity level and perceived social support in 94 members of indoor and outdoor activity groups, UK.

Physical activity	
Findings	1. (van den Berg et al., 2010): Both younger and older allotment gardeners reported higher levels of physical activity during the summer than neighbors in corresponding age categories. 2. (Wakefield et al., 2007): A commonly mentioned benefit of the community gardens was increased exercise. Participants, particularly the elderly, said that their gardening helped keep them physically (and mentally) active. 3. (Quayle, 2008): Statements of users included 'I achieved exercise to keep me healthy' and, 'I love the physical work of digging'. Quayle at al. concluded that community farms and gardens offer enjoyable exercise opportunities. 4. (Hawkins et al., 2011): No significant differences in reported levels of physical activity between the groups that performed different types of physical activity.
Indicators used	- Proportion of population reporting practice of daily physical activity - The average number of days a week on which people engage at least half an hour in cycling, household and occupational activities, gardening, sports, and/or other intensive activities *Please note: The new standard indicator will be the proportion of the population that meets the (global and/or national) physical activity guidelines (data are due in 2015, W. Vos, personal communication).*
Policy relevance	Allotment gardens may contribute to achieving recommended levels of physical activity. Physical inactivity is a major preventable health risk affecting a large part of the population that results in chronic diseases. Therefore, correcting this is a public health priority. Physical inactivity is also associated with obesity, another health priority issue.
Interpretation of the indicator(s)	
Means of interpretation	Reported levels of physical activity can be used to measure compliance to guidelines for physical activity. The proportion of population reporting practice of daily physical activity is an European Core Health Indicator, used to measure and compare population health across Europe (see http://ec.europa.eu/health/indicators/echi/list/, visited July 14, 2015), however new data using an indicator that measures compliance to guidelines will be updated soon.

Physical activity	
Known limits and bias	The indicators measure levels of physical activity through self-reporting; this could be measured more objectively using accelerometers. Other objective indicators are heart rate, oxygen uptake or energy expenditure while gardening (Park et al., 2011). However, these physiological measurements are more appropriate in experimental settings than in monitoring programs using indicators.
Quality of the indicator(s)	
Reliability	The findings of Van den Berg et al. may be inaccurate because of the self selection of respondents. It is also possible that older allotment gardeners were self-selected for their fitness to maintain a garden. Gardening has been shown to be related to health benefits, but gardening can also cause bodily pains like lower back pain (Park et al., 2009).
Availability of data	Data for the Netherlands is collected by 'Gezondheidsmonitor GGD'en, CBS en RIVM'. International data is included in the Eurobarometer Sport and Physical Activity of the European Commission, and the WHO European Database on Nutrition, Obesity and Physical Activity (NOPA). The latter will be updated in 2015.
Remarks	For obesity, it has been shown that both male and female community gardeners had significantly lower BMIs than did their neighbors who were not in the community gardening (Zick et al., 2013).

4.5 Violence

Violence	
Description of the determinant of health	
Definition	In many cities, residents have transformed vacant lots into community gardens and other forms of green space. Vacant lots may offer refuge to criminal and other illegal activity and visibly symbolize that a neighborhood has deteriorated, that no one is in control, and that unsafe or criminal behavior is welcome to proceed with little if any supervision (Branas et al., 2011). Therefore, transforming vacant lots into community gardens might reduce violence and influence community health indirecty .
Study design	1. (Gorham et al., 2009): Property crime rates around 11 community gardens and 55 other, random-selected neighbourhoods in Houston, USA. 2. (Quayle, 2008): 22 agricultural projects, including 11 community farms across England using informal interview sessions, participatory appraisal and postal questionnaires.

Violence	
Findings	1. (Gorham et al., 2009) There were no differences in crime numbers between the community garden areas and the randomly selected areas. However, interviews with representatives of 6 of the 11 community gardens showed that residents and/or users of the community gardens perceived a safer neighborhood. 2. None of the projects reported any long-term crime problems
Indicators used	- Property and violent crime rates - Perceived safety
Policy relevance	Community gardening may foster neighborhood improvements. The gardens might attract new residents, restore neighborhood vitality and stability, enhance civic pride, and even reduce local crime (New York Trust for Public Land, 2008).
Interpretation of the indicator(s)	
Means of interpretation	Gorham et al. confined the analyses to property crimes: burglary, theft and auto theft; violent crimes were excluded. Another study evaluating the effect of greening vacant lots in Philadelphia (not restricted to community gardens) included violent crimes. Gun assaults were significantly reduced after greening the vacant lots. Vandalism and criminal mischief were signficantly reduced at some locations (Branas et al., 2011). Quale suggested that the absence of long-term crime problems indicated a sense of ownership generated by community involvement (Quayle, 2008).
Known limits and bias	Currently, there is no evidence on the effects of community gardens on police violence rates. The study by Quayle did not include a comparison group and did not investigate the situation before the introduction of urban gardening. The study by Gorham et al. did not find an association, except for perceived safety. The study was limited to crime rates in 2005 and to property crimes. As it was a study conducted in the United States, it might be quite different from crime figures in Europe. However, it was suggested that community gardens might increase perceived safety, which is a valuable indicator in itself.
Quality of the indicator(s)	
Reliability	Property crime rates as reported by Police Departments are more reliable than self-reported crime rates. They could easily be mapped and monitored over time (regularly).

Violence	
Availability of data	Data can be extracted from existing databases like police records. Mapping techniques can be used to combine these data with neighborhoud characteristics, like population size, age of the population etc. Perceived safety could be measured by questionnaires or interviews. Perceived safety is not a standard European Core Health Indicator.

4.6 Socially profitable

Socially profitable	
Description of the determinant of health	
Definition	This factsheet describes the socio-economic benefits to the community that urban gardening could offer. This topic corresponds to the valuation of health and social effects, see Figure 2.4. It could reduce poverty by improving food security, including vulnerable or minority groups, creating jobs, and by providing educational benefits and opportunities for recreation. The effects on social cohesion and violence are described separately in 4.5 and 4.7. Altogether, these benefits might improve (community) health.
Study designs	1. (Quayle, 2008): 22 agricultural projects, including 11 community farms across England using informal interview sessions, participatory appraisal, and postal questionnaires. 2. (Abma et al., 2013): Socio-economic Cost-Benefit Analysis (SCBA) of Food Garden project in Rotterdam, the Netherlands. Unemployed people grow food that is donated to the Food Bank on a parcel of land that was previously vacant. Data from interviews with 18 volunteers were used. 3. (Wakefield et al., 2007): Participant observation, focus groups including 55 people and in-depth interviews among 13 gardeners, UK.
Findings	(Quayle, 2008) Community farms and gardens encourage local people to become more socially active and develop stronger ties to an area through environmental improvement, which in turn promotes the uptake of eco-friendly practices and benefits local wildlife populations. In deprived areas, gardening raises the aspirations of local people and provides them with the skills to bring about positive changes to both their own lives and their neighborhood. Ten projects can employ 34 people and engage an average of 1200 volunteers, clients and visitors each month. The predominant garden users were white English people, which was in line with the dominant ethnicity of people living in the areas around the gardens/farms. One project worked exclusively with asylum seekers and refugees, another activity engaged Bangladeshi women.The group most worked with were people with learning difficulties.

Socially profitable	
	10 of the 22 projects had been created on derelict sites or on allotment plots in disrepair. People often agreed with the statement 'helping to improve the look of our town'. Six of the 9 food growing projects sold produce which provided 0,004 – 75% of their income Seventeen of the 22 projects had financial concerns; they did not make a substantial profit from their activities. The income from charitable trusts was 15-100%. In addition, regional funding bodies are a key source of income. If succesful in applying for grants, there was a tendency for money to be spent on hiring local contractors and the employment of volunteers. Ten of the 22 projects had established links with local schools. Learning new skills was one of the most important elements mentioned by users. 7 of the 10 projectmanagers agreed that biodiversity at their site had increased. All 10 projectmanagers agreed that their project helped users to reconnect with nature. (Abma et al., 2013) The net socio-economic benefit of the Food Garden is €100,000 cash value, which means that on balance, the welfare of society increases. The greatest benefits have been estimated to be health benefits due to increased physical activity in volunteers. Other important benefits were avoided crime costs as a result of increased social supervision, more possibilities for recreation, and reactivation of the longterm unemployed volunteers (avoided costs of unemployment). However, the financial balance of the Food Garden is negative because it does not generate any financial income. (Wakefield et al., 2007) Community gardens are seen to benefit the community as a whole, by improving relationships among people, increasing community pride, and in some cases by serving as an impetus for broader community improvement and mobilization. In general, gardening was an empowering experience and a way of having something in life 'work out'. This feeling was enhanced by garden-based programming, which occurred in many of the gardens. As one respondent noted, these programs could help to build self-esteem through development of skills: 'the program here, like, helps us all to develop skills that we never thought we had'. The community gardens were also thought to increase attachment to the community and improve the physical features of the community to its broader benefit.

Socially profitable	
Indicators used	- Healthy lifestyle (food consumption and physical activity, see 4.4 and 4.7) - Numbers of volunteers, clients and/or visitors - Background of users; age, ethnicity - Reactivation of unemployed/unskilled people or other target groups: avoided costs of unemployment benefits - Social and physical quality of neighborhood: avoided moving expenses and/or improved property values. - Social supervision: avoided crime costs, see 4.5 - More opportunities for recreation: perception of the environment by visitors and occupants of buildings facing the garden - Climate change: CO_2 reduction - Air quality: health effects of reduced concentrations of air pollution by trees - Finances: food sold, grants, profits - Saving of food costs for gardeners - Profitable property sales - Opportunities for education: links with schools, involvement in school programs
Policy relevance	Quayle et al. conclude that community gardens can make a significant contribution towards social, health, environmental, education and economic government agendas, relating to unemployment and youth disaffection and regeneration, for instance (Quayle, 2008). It is important to define the targets of the gardens from the beginning. For instance, to reduce socio-economic health disparities, it is important to include minority groups from the start of the project. An SCBA enables policy-makers to make a trade-off between different alternatives of a specific area, based on the expected benefits. For example, they can weigh potential benefits of the development of a nature area against the potential benefits of the development of urban community gardens (Abma et al., 2013).
Interpretation of the indicator(s)	
Means of interpretation	An SCBA specifies all pros and cons for stakeholders in the broadest sense, from government, to business and citizens. All benefits and costs are expressed in money. Indicators for the benefits in the study bij Quayle et al. are comparable with the indicators in the SCBA. Costs of the Food Garden included the arrangement and maintenance of the garden, salary for coordinators of the volunteers, and costs of activities, including a website.

Socially profitable	
Known limits and bias	Despite the positive outcomes, Abma et al. conclude that the evidence is too weak to conclude that all urban agriculture initiatives have a positive cost-benefit balance (Abma et al., 2013). An SCBA has many uncertainties and a large number of assumptions have been made. More data is necessary on: - Additional types of urban agriculture, e.g. focusing on social cohesion, health or education; - Demand and supply of locally produced food, care and recreation - the contribution of urban agriculture to pleasurable living and public health. Abma et al. performed sensitivity analyses. The cost-benefit ratio was 1,2 and ranged from 1 to 1,9 under different assumptions.
Quality of the indicator(s)	
Reliability	Many different indicators for a wide range of aspects could be formulated to measure social profits. The relevance of some of these indicators depends on the aim and target group of the garden being studied. In practice, one effect can be quantified or monetized more easily than can other effects. For example, values related to the sustainability of a specific area are difficult to measure. However, if sustainability is linked to climate change adaptation, reduction of stormwater fees could be a measurable benefit. Depending on the underlying assumptions, results of SCBAs could be questionable and uncertain.
Availability of data	Both studies used data from interviews. In the case of Rotterdam, addional data on costs was obtained from the local authority.

4.7 Social contacts and cohesion

Social contacts and cohesion	
Description of the determinant of health	
Definition	Social cohesion refers to solidarity in groups or communities (Berkman and Glass, 2000). Sometimes it is used interchangeably with the terms '(collective) social capital' and 'social networks'. As social cohesion is about relations between people, it is a characteristic of a system rather than a personal trait. However, some studies have measured social effects at the individual level – we summarize these separately. Many research articles have been published reporting positive associations between social cohesion and health (Ferlander, 2007).
Study designs	**Social contacts (individual level)** (van den Berg et al., 2010): Survey among 121 people with and 63 people without an allotment garden in the Netherlands. (Quayle, 2008): 22 agricultural projects, including 11

Social contacts and cohesion	
Study designs	community farms across England using informal interview sessions, participatory appraisal and postal questionnaires. (Hawkins et al., 2011): Questionnaires among 94 members of indoor and outdoor activity groups, UK. **Social cohesion (community level)** (Wakefield et al., 2007): Participant observation, focus groups including 55 people and in-depth interviews among 13 gardeners, UK. (Armstrong, 2000): Telephone interviews among coordinators of 20 community garden programs in upstate New York (representing 63 gardens). (Teig et al., 2009) (Hale et al., 2011) Individual and group interviews with garden leaders and/or community gardeners. Altogether, data were obtained from 67 respondents from 29 garden sites in Denver, US. (Ohmer et al., 2009) Evaluation of a community conservation program in Pennsylvania, US. In-depth interviews with 48 garden volunteers, community partners and funders. Questionnaires returned by 258 volunteers and 201 community partners/funders. (Alaimo et al., 2010) Telephone survey among residents of Flint, Michigan, US (N=1,916) including 563 people with household members who participated in community gardening. (Glover, 2004) Personal narratives from 14 residents: 8 garden leaders and 6 gardening volunteers, US **Both individual and community level** (Walsh, 2011) Interviews with garden leaders (N=23) and gardeners (N=36) in Denver, US.
Findings	**Social contacts (individual level)** 1. (van den Berg et al., 2010): Older (≥ 62 yrs) gardeners reported slightly more contacts with friends, but the difference was not significant. No differences were observed between the younger gardeners versus non-gardeners. 2. (Quayle, 2008): The social element was frequently reported throughout the research. For vulnerable groups, attending the project represented their main point of social contact and provided an important source of support. Social opportunities could lead to the formation of friendships and promoted the development of social skills through meeting people and teamwork. There is also evidence that community-growing projects working with young people can provide an alternative to socialising on the streets. Community farms and gardens provide community spaces and can promote (cross-cultural) integration. 3. (Hawkins et al., 2011): Perceived social support was similar in the 4 activity groups. Social cohesion (community level)

Social contacts and cohesion	
Findings	4. (Wakefield et al., 2007): The gardens were seen by gardeners as a place for positive social interaction. As one gardener noted, the garden is a place where ' people come together. . . it breaks isolation'. Another quote was ' We share ideas, we share . . .tools, vegetables we share, the foods, we share even the knowledge, cultures, through gardening' . For many, the gardens served as meeting places and were seen to benefit the community as a whole, by improving relationships among people, increasing community pride and in some cases by serving as an impetus for broader community improvement and mobilization. 5. (Armstrong, 2000) Gardens in low-income neighborhoods (46%) were four times as likely as non low-income gardens to lead to other issues in the neighborhood being addressed; reportedly due to organizing facilitated through the community gardens. 6. (Teig et al., 2009) Community gardens served as a positive social influence within neighborhoods as well as being a catalyst for other positive place-based social dynamics. Gardeners talked about the process of gaining trust with one another through shared common goals and interests. (Hale et al., 2011) Garden participation awakens the senses and stimulates a range of responses that influence interpersonal processes (learning, affirming, expressive experiences) and social relationships that are supportive of positive health-related behaviors and overall health. 7. (Ohmer et al., 2009) Respondents indicated that the program contributed to revitalizing neighborhoods, as well as their beliefs and behavior regarding conservation issues, sense of community, and volunteerism. 8. (Alaimo et al., 2010) Household involvement in community gardening/beautification activities was associated with residents' perceptions of social capital and neighborhood norms and values. 9. (Glover, 2004) The community gardening project enhanced the level of networking and socializing among residents; this provided them with a sense of community and security. However, garden participants who were not part of the core group felt removed from the decision-making process which weakened their ability to utilize the social capital. **Both individual and community level** 10. (Walsh, 2011) Gardeners commonly emphasized the social aspects of community gardening (meeting and interacting with new people and people from the neighborhoud, learning from others, sharing information) as being important and beneficial to their health. Social networks, trust, and community engagement were shaped by race and class. The social networks of the gardens reflected the racial segregation of the city as a whole (no cross-cultural inclusion).

Social contacts and cohesion	
Indicators used	**Individual level** - Social contacts - Perceived social support - Feelings of belonging - Beliefs and behavior regarding conservation / ecological issues and/or volunteerism **Community level** - Social connections - Community involvement/ political engagement/address issues of public concern (e.g. vandalism, litter issues) - (Cross-cultural) social inclusion - Meeting place / community space / performance area - Common activities (e.g. tree planting, beautification neighborhood) - Social skills and teamwork - Links with community service organizations, e.g. schools, churches - Neighborhood attachment - Collective decision-making (e.g. on watering) - Social norms (e.g. unaccepted behaviors) / common goals and interests - Leadership and recruitment activity (e.g. provide mechanisms for communication) - Mutual trust - Community pride
Policy relevance	Community gardening is always a social activity, even if social contacts are not the (main) motivation of gardeners to start gardening activities (Veen, 2015). This may contribute to individuals, including those from vulnerable groups, having more social contacts and experiencing social support. However, such effects have not been observed in all studies. At the community level, it can improve mutual trust, collective decision-making, civic engagement and community building. Community gardens support collective efficacy, a powerful mechanism for enhancing the role of gardens in promoting health (Teig et al., 2009), particularly in low-income neighborhoods (Armstrong, 2000). Therefore, community gardens may play a vital role in developing active and healthy living policies.

Social contacts and cohesion	
Means of interpretation	Please note that community gardens in which plots are used collectively by a group of residents are a subgroup of urban gardens. Most authors operationalize social cohesion by breaking it into several indicators, but the number and composition of these indicators differ. The indicators often partially overlap, implying that they are strongly related (Veen et al., In Press). Generally, studies were either focused on individuals working in the gardens or neighborhoods in which the garden was located. Sometimes, non-gardeners were included in the study population and they did not always report positive effects – the garden group made them feel excluded (Glover, 2004). The 7 Dutch case-studies performed by Veen et al. were not included in the review, because they were published after the literature search date. She concluded that community gardens do indeed enhance social cohesion. She stated that community gardens do not necessarily foster a more inclusive society; they often attract people with relatively similar socio-economic backgrounds and may support not one, but several communities (Veen, 2015).
Known limits and bias	Comparisons of results of the studies are hampered by differing gardens, differing designs and differing indicators. Some include a small number of people and a wide variety of indicators, whereas others use a few indicators in larger populations. The effects probably depend on local characteristics like ethnic backgrounds and income of residents (Walsh, 2011). Social cohesion is probably also related to the organisational type of garden; presence of communal instead of individual plots, and inclusion of residents of the neighborhood in which the garden is located (Veen et al., In Press). Therefore, caution is warranted regarding the generalization and interpretation of results.
Quality of the indicator(s)	
Reliability	In most studies, the response rate was rather low (<50%). This may have introduced the possibility of response bias; in as far as those gardeners who derived the most benefits from gardening being more likely to respond. Thus, social benefits of allotment gardening in the general population of allotment gardeners may have been overestimated. In addition, effects on the community level might have been overestimated if non-gardening residents (who might even feel excluded) were not included in the sample.
Availability of data	International data at the individual level have been collected by the Eurobarometer, using the 'Oslo 3-item social support scale' http://preview.euphix.org/object_document/o5480n27411.html, visited June 11, 2015). In the Netherlands, social cohesion is regularly measured by the 'WOON' survey (http://www.rijksoverheid.nl/onderwerpen/onderzoeken-over-bouwen-wonen-en-leefomgeving/lopende-onderzoeken/woononderzoek-nederland-woon, visited June 11, 2015) and the 'Veiligheidsmonitor' (http://www.veiligheidsmonitor.nl, visited June 11, 2015).

4.8 Fruit and vegetable consumption

Fruit and vegetable consumption	
Description of the determinant of health	
Definition	Community gardening might improve the access to and consumption of healthy food. 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). These recommendations are based on the evidence of a protective effect of fruit and vegetable consumption against several cancers and cardiovascular diseases (Agudo et al., 2002, Bradbury et al., 2014, WCRF/AICR, 2007, Gezondheidsraad, 2006, Engelfriet et al., 2010). Updated recommendations for the Netherlands, including a review of the evidence of associations between consumption patterns and disease, will be published by The Dutch Health Council by the end of 2015 (http://www.gezondheidsraad.nl/nl/taak-werkwijze/werkterrein/gezonde-voeding/document-werkwijze-van-de-commissie-richtlijnen-goede, visited 14 July, 2015).
Study designs	1. (Wakefield et al., 2007) Participant observation, focus groups including 55 people and in-depth interviews among 13 gardeners. 2. (Quayle, 2008) 22 agricultural projects, including 11 community farms across England using informal interview sessions, participatory appraisal and postal questionnaires. 3. (Alaimo et al., 2008) A telephone interview with 766 people of whom 15% had a member of their household participating in a community gardening project in the last 12 months. The sampling strategy ensured that all census tracts within Flint, Michigan were represented. 4. (Allen et al., 2008) Case studies were conducted with two community gardens with semi-formal youth programs in Flint Michigan, US. Participant observation, photography, and 33 interviews, including 12 youth. 5. (Litt et al., 2011) A population-based survey representing 436 residents across 58 block groups in Denver, Colorado, from 2006 to 2007. 6. (Armstrong, 2000) Telephone interviews among coordinators of 20 community garden programs in upstate New York (representing 63 gardens). 7. (Northrop et al., 2013) Twenty active gardeners participated in four focus groups, Birmingham, Alabama, US. 8. (Twiss et al., 2003) A description of results of community gardens established with grants of the California Healthy Cities and Communities (CCHC), US. 9. (Zoellner et al., 2012) Qualitative key informant surveys and quantitative surveys with low-income youth and their parents involverd in community gardening in the health disparate Dan River Region, US.

Fruit and vegetable consumption	
Findings	1. (Wakefield et al., 2007) Participants spoke of eating more vegetables because of their community garden involvement. Most participants spoke of improved food access and cost-savings in some way. 2. (Quayle, 2008) Four project managers agreed that 'clients and volunteers ate more healthily now than when they started attending the project'. Three project managers were neutral towards this statement. Some statements from volunteers illustrated the potential link with healthy diets, which can spread out to family members not visiting the community garden. 3. (Alaimo et al., 2008) Adults with a household member who participated in a community garden consumed fruitand vegetables 1.4 more times per day than those who did not participate, and they were 3.5 times more likely to consume fruit and vegetables at least 5 times daily. 4. (Allen et al., 2008) Youth mentioned that their involvement in the gardens induced them to eat more fruit and vegetables and less junk food. 5. (Litt et al., 2011) Community gardeners consumed fruit and vegetables 5.7 times per day, compared with home gardeners (4.6 times per day) and non-gardeners (3.9 times per day). Moreover, 56% of community gardeners met national recommendations on the consumption of fruit and vegetables at least 5 times per day, compared with 37% of home gardeners and 25% of non-gardeners. 6. (Armstrong, 2000) One of the most commonly expressed reasons for participating in gardens was access to fresh foods. 7. (Northrop et al., 2013) Provision of fresh and organic food was often mentioned as a reason for participating. Several gardeners reported that participation in the community garden affected the variety of their diets by increasing their exposure to new and different types of vegetables. 8. (Twiss et al., 2003) In Loma Linda, community gardening increased the consumption of fruit and vegetables among 35% of gardeners from 3 to 3.7 servings a day. 9. (Zoellner et al., 2012) Most youth and their parents expressed an interest in eating the produce they harvested. Overall, there was a higher vegetable than fruit availability in the home.

Fruit and vegetable consumption	
Indicator(s) used	- Number of fruit and vegetables servings a day - How many people meet the (inter)national recommendations for fruit and vegetable consumption - [Access to fresh foods - Variety of vegetables consumed / in the home - Variety of fruit consumed / in the home]* Additional suggestions [not included in papers above] - Proportion of people reporting to eat fruit (excluding juice) at least once a day (http://www.healthindicators.eu/healthindicators/object_document/o5991n29137.html, visited 16 July, 2015) - Proportion of people reporting to eat vegetables (excluding potatoes and juice) at least once a day http://www.healthindicators.eu/healthindicators/object_document/o5992n29137.html, visited 16 July, 2015)
Policy relevance	Community gardening is gaining attention as an approach to increase the availability and intake of fruit and vegetables to reduce costs of chronic diseases. It is likely to have greatest success in promoting a lasting change when projects involve schools or other communities (Quayle, 2008). Garden-based youth nutrition intervention programs have not been discussed here. These programs may have the potential to promote increased fruit and vegetable intake among youth (Robinson-O'Brien et al., 2009, Allen et al., 2008, Boyer et al., 2002, Castro et al., 2013, Lautenschlager and Smith, 2007).
Interpretation of the indicator(s)	
Means of interpretation	There are several problems in the assessment of consumption of fruit and vegetables in epidemiological studies, and in the comparison across studies. Major issues when comparing results across different studies are the differing definitions of fruit and vegetables (e.g. potatoes in which category?) and the validity and standardisation of the instrument used to assess dietary intake. Research should pay attention not only to the overall intake, but also to the consumption of individual foods and sub-groups. Inconsistencies in grouping and classifying fruit and vegetables, and in expressing these in raw weights or weights consumed need to be considered (Agudo et al., 2002).
Known limits and bias	A detailed assessment of fruit and vegetable consumption, e.g. by a 24h dietary recall, is time-consuming. Therefore, the response rates and study populations are often small which reduces the representability of the results. Most of the studies included did not measure the consumption before and after the introduction of urban gardening. A randomized intervention study would provide a stronger test of the hypothesis that household participation in an urban garden can lead to an increase in fruit and vegetable consumption. Specifically, it may be that individuals who prefer to eat fruit and vegetables are more likely to seek out community gardens, rather than community gardens having a positive influence on availability and consumption preference.

Fruit and vegetable consumption	
Quality of the indicator(s)	
Reliability	Standardized instruments to assess fruit and vegetable consumption include a 24h dietary recall (Agudo et al., 2002) and food frequency questionnaires (Slimani et al., 2002). The 24h recall provides the best estimate of food consumption.
Availability of data	Eurostat collects data from different countries regularly using the European Health Interview Survey (EHIS) (http://www.healthindicators.eu/healthindicators/object_document/o5991n29137.html, visited 16 July, 2015). Periodic data on food consumption and nutrition status of the Dutch population have been collected by the Dutch National Food Consumption Survey.

* Placed between brackets because there is –to our knowledge- no evidence of an association between 'access to fresh food' or 'variety' and disease prevention.

4.9 Exposure to soil contaminants

Exposure to soil contaminants	
Description of the indicator	
Definition	Contaminants from soil can enter plants through the roots and through the leaf stomata and accumulate in the edible parts of the plant (Elert et al., 2011). Therefore, consuming these vegetables may have negative effects on human health. In addition to exposure through consumption of vegetables, urban gardeners are potentially exposed through the ingestion of soil particles (hand-mouth contact).
Summary	The exposure through vegetable consumption is an important pathway, especially for mobile contaminants (mainly metals and metalloids), but also organic contaminants (Swartjes and Cornelis, 2011). Exposure through vegetable consumption is dependent on the representative concentration in vegetables at the moment of harvesting, the total vegetable consumption rates, and the fraction of vegetables from the contaminated area to total vegetable consumption. Moreover, the relative oral bioavailability in the human body also plays a role for this pathway. A common problem is the presence of cadmium in vegetable gardens (in particular at low pH), since cadmium is easily taken up by vegetables and can induce kidney dysfunction and several types of cancer at relatively low exposures (Swartjes, 2011). Additionally, lead can cause problems in vegetable gardens, in spite of the limited availability in soil, since it is omnipresent in urban areas and is also taken up via the plant stomata. Lead is associated with the impaired neurobehavioral function in children, resulting in a decreased intelligence quotient (Swartjes and Cornelis, 2011). Moreover, inorganic arsenic can cause health problems through vegetable consumption, in particular in flooded paddy cultivations with high-uptake crops such as *Indica* rice (Zhao et al., 2010). After exposure, arsenic leaves essentially no bodily system untouched (Naujokas et al., 2013) and is associated with skin, lung, bladder, kidney, and liver cancer. The second relevant exposure pathway is through direct contact

Exposure to soil contaminants	
	with soil particles and consequently the ingestion by hand to mouth contact, especially for children. Immobile contaminants like lead and PAHs contribute significantly to the total exposure (Bierkens et al., 2011).
Proposed indicator(s)	- Historic use of the site (e.g. parking lots, industrial buildings) - Calculated or measured concentrations of contaminants in the edible parts of the plant - Calculated combined exposure through vegetable consumption and soil ingestion during gardening. - (Soil measurements – but less informative)
Policy relevance	Since the late 1970s, when several notorious cases of soil contamination led to increased awareness among the public, soil contamination became a widely recognized problem in many developed countries (Swartjes, 2011). Today, practically all developed countries have a policy on soil contamination. Moreover, soil contamination is generally recognized as an imposed (non-voluntary) risk wordwide. Most countries have become aware of the great practical, social and financial impact of soil contamination. In the last few years, urban agriculture is considered as a vulnerable activity due to the location of vegetable gardens near historically contaminated areas, the intensive contact with soil during gardening, and the related exposure to contaminants through vegetable consumption. However to date, no European policies specifically on urban gardening practices have been developed. In the Netherlands and in most other countries, the risk management policy concerning urban gardening is determined by local authorities within a national framework.
Interpretation of the indicator	
Means of interpretation	- Often a site's history provides a clue to the contaminants that linger in the soil. Soil measurements might be useful for some contaminants, but generally plant measurements should be preferred. - Calculated combined exposure through vegetable consumption and soil ingestion during gardening is compared with (formalized) tolerable exposure values. - Calculated or measured concentrations in the edible parts of the plant are compared to (EU) food standards.
Known limits and bias	The accumulated concentration in vegetables depends on the contaminant fraction that is available in the pore water, the fraction that is taken up by the roots, and the fraction that is transported within the plant to the edible plant parts. These processes are difficult to quantify. Measuring concentrations in vegetables is hampered by a large spatial variability. Empirical relations between soil and plant concentrations (so-called BCF values) have a limited range of application. Bias: Different vegetables show very different affinities for uptake of contaminants. Moreover, humans are exposed through

Exposure to soil contaminants	
	other sources (backgroud exposure), incuding commercially grown vegetables from the supermarket.
Quality of the indicator	
Reliability	The assessment of the representative concentration in vegetables is related to the limited reliability, in particular regarding calculation procedures.
Availability of data	Many generic bioconcentration factors (BCF) values (linear relation between concentration in the vegetable and the soil) are available for several metals, metalloids, and organic contaminants, both in the scientific literature and in policy documents. However, BCF values for the same contaminant differ strongly between different sources. For a few metals and for organic contaminants, more sophisticated calculation procedures exist, both in the scientific literature and in policy documents. To assess human exposure, a number of exposure models are available (Elert et al., 2011).
Collection of data	The BCF approach and most models use the soil concentration, and in some cases the soil properties, as starting point for the assessment of the accumulated concentration in vegetables. Preferably, the soil concentration is measured in the field.
Own remarks	There is a need for harmonization of the procedure to assess the accumulated concentration in the edible parts of vegetables and the risk of exposure through vegetable consumption (Swartjes, 2011).

5 Conclusions, discussion and recommendations

5.1 Findings

In this study, an existing framework was adapted to illustrate the associations between soil ecosystem services, ecosystem health, and human health in urban gardening. The associations were evaluated using four different perspectives or contexts; 1) physical factors including ecosystem services, 2) management factors, 3) effects of contact with urban gardening on determinants of human health and 4) valuation of societal benefits. A literature review was performed to retrieve indicators from the human health perspective, which was the main topic of this report. In addition, we propose indicator sets for the other perspectives which may facilitate the interdisciplinary dialogue between policy-makers, urban gardeners and other stakeholders.

The framework shows that many issues come together in urban agriculture and that a wide range of indicators has been used to measure these effects. Although the evidence base is limited, 18 peer-reviewed papers suggested that urban agriculture may be beneficial for health because of stress reduction, increased physical activity, more fruit and vegetable consumption and more social contacts, particularly in the elderly. In addition to effects at an individual level, it may also affect neighborhood characteristics that are favorable for community health, like social cohesion. Incidentally, effects on violence rates, inclusion of vulnerable or minority groups and improvement of the physical and ecological quality of the area were described. However, the latter effects were not always observed. Urban gardening provides the opportunity to alter and self-manage peoples' own environment, and are central elements in the new definition of human health (Huber et al., 2011). An evaluation of community farms and gardens in England came to a similar conclusion. They stated that it is not enough to have pleasant surroundings, the ability to alter one's environment is linked to well-being (Quayle, 2008). Gardening raised the aspirations of local people and provided them with the skills to bring about positive changes to both their own lives and their neighborhood (Quayle, 2008).

The quality of urban soils can be assessed by measuring their ability to provide ecosystem services (ESS). Potential indicators of soil ecosystem health include retention and provisioning of nutrients, soil structure and pest and disease control. Others refer to their adaptive potential; unsealed soils can be the basis of climate-proof cities because they increase the water storage capacity and provide cooling services (Claessens et al., 2014). This report lists ESS delivered by unsealed soils in general. A further specification to urban gardening practices is needed. Urban gardens may contribute to the consumption of locally produced food which reduces the environmental burden of food distribution. Of course, from an ecological perspective, sustainable gardening practices should be preferred.

The typical small scale of urban gardening may demarcate the dialog between different stakeholders enabling broad-based solutions. Urban

gardening may support local government agendas like healthy aging or stimulation of healthy food habits in children. Urban gardens have the potential to combine these agendas with ecological agendas like nature conservation and more biodiversity (win-win situations). However, it can be expected that each potential effect has specific demands regarding soil quality and management and organizational structure of the gardens. Therefore, health or other targets should be defined from the beginning and relevant stakeholders should be approached. Potential effects of soil pollution should be managed. To express and maximize the benefits, effects should be measured using indicators, preferably at different moments in time, e.g. before and after the establishment of the garden. In addition, it is important to exchange experiences and knowledge across initiatives, nationally and internationally.

5.2 List of indicators

The factsheets showed that different indicators have been used to measure the effects, just as in correlational research on the associations between green space and health. We recommend using common indicators insofar the interdisciplinary character of the topic allow. The list of indicators below is derived from the factsheets in Chapter 4 and the ESS described in Table 3.2. The ESS indicators for green space in general have to be further developed for urban gardening, including a review of the evidence. The indicators are intended to help support and monitor policy on urban gardening at all levels - from the local to the national to the international level. Obviously, they should be reported with adequate information to allow correct interpretation.

An over-arching indicator, that covers or summarizes several effects on determinants of health is 'perceived (self-reported) health' of gardeners (or residents). This indicator has also frequently been assessed in studies evaluating the health effects of green infrastructure, e.g. (Maas et al., 2006, Mitchell and Popham, 2007).The presence and location of unsealed soils, preferably shown in maps, might be an indicator which measures several potential ESS (like water storage and cooling) in combination (Claessens et al., 2014). Regarding soil ecosystem services, the following indicators have been proposed (Table 3.2);

- Retention and provisioning of nutrients
- Soil structure, e.g. providing possibilities for plant root growth
- Pest and disease control
- Resistance and resilience of soil
- Formation and degradation of soil organic matter
- Water storage
- Self-purifying capacity of soil (e.g. pollutant removal)
- Climate function, e.g. cooling effects
- Habitat function and biodiversity

Of course, soil quality needs to be assessed to manage the potential risks of soil contamination, see section 5.3.

Indicators of potential positive effects on determinants of health –as described in the factsheets- at the individual level could be;

- Number of social contacts of gardeners

- Proportion of population that meets the ((inter)national) physical activity guidelines
- Vegetable and fruit consumption, e.g. number of servings a day or proportion of population that meets the ((inter)national) consumption guidelines

It is difficult to measure stress reduction in gardeners. Currently, there is no consensus on how to measure it, with the exception of some physical measurements. Therefore, we did not include an indicator specifically for stress reduction in this list. However, changes in perceived health might reflect changes in stress levels in gardeners. Indicators of the potential positive effects on determinants of health at the community level could be;

- 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
- Physical quality, e.g. amount of green space within 500 meters of households
- Community involvement/ political engagement/ability to address issues of public concern (e.g. environment, vandalism, litter issues)

Many organizational issues are relevant to optimizing the benefits of urban gardening – see factsheet 4.6. Indicators of management or organizational issues could be;

- Management targets
- Frequency of visits
- Numbers of plots and gardeners (volunteers, clients and/or visitors)
- Background of users; age, ethnicity, income, education, medical needs
- Accessibility, characteristics and presence of allotments (e.g. distances, availability, acreage, surface, communal vs individual plots)
- Neighborhood vs non-neighborhood bound garden (see (Veen et al., 2015))

The evaluation of 22 community farms and garden projects in England showed that the financial structure of gardens might reflect the sustainability of urban gardens (Quayle, 2008), that often had financial concerns. Obviously, social profitability is determined by a range of societal benefits including the determinants of health discussed above. Social inclusion, presence of meeting places, common activities (e.g. tree planting, beautification neighborhood) and neighborhood attachment / pride might be additional indicators. Also, the perception of the environment by visitors and occupants of buildings facing the garden, presence of trees (because of cooling effects) and opportunities for education (links with schools, involvement in school programs etc.) have been assessed in some studies. Social cost – benefit analyses (SCBA), as performed by Abma et al. are useful to valorize the benefits and to find (additional) resources (Abma et al., 2013). Potential financial indicators in SCBA range from number and type of grants to savings of food costs for gardeners. However, it has been argued that the SCBA

are too rough a tool to capture how interventions in the physical environment make a difference to people's lives (Veen, 2015).

5.3 Evaluation of the evidence base for the pathways to health benefits

The literature search yielded 18 papers that met the selection criteria described in 4.2.1. For each health determinant, 2-9 papers were available. The highest number of papers concerned fruit and vegetable consumption (9) and social cohesion (community level, 7). For violence, only 2 papers were retrieved. Inherent to the topic, there was much variation in study designs. Van den Berg et al., for instance, performed an experimental study; they measured stress levels assessed by cortisol levels in saliva before and after reading or gardening at the allotment site (Van Den Berg and Custers, 2011). Others performed field visits, 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. In other words: 'humans are complex, and their lives are ever-changing. The more methods we use to study them, the better our chances will be to gain some understanding of how they construct their lives and the stories they tell us about them' (Fontana and Fray, 2005). Hence, combining different ways of collecting data is a way to increase the validity of the results (Baarda et al., 2005). However, data collected by different methods often do not allow comparison across studies.

The comparison of results across studies is complicated by the fact that different indicators have been used, even if the same issue was studied. The use of common, standardized and validated indicators would facilitate the expansion of empirical evidence for the association between urban gardening and ecosystem and human health. The indicators defined in this report were formulated to provide a basis for formulating common selection criteria and the development of a questionnaire within the SNOWMAN project. This facilitates international comparisons, which in turn will expand the empirical evidence because of the large variety of gardens across Europe, Russia and the United States.

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. 'To some, domestic gardens are an essential element of life providing opportunity for engagement with nature, self-actualization, creativity or well-being; to others, they are at best a parking lot, or worse, represent an additional chore to an already busy lifestyle' (Cameron et al., 2012). This effect may even be stronger for urban gardens. Selection may also take place with regard to the continuation of gardening activities; people who enjoy the benefits concerning determinants of health are more likely to stay in the pool of urban gardeners. Therefore, studies might overestimate the role of urban gardens. For example, one might observe that urban gardeners eat more fruit and vegetables than their non-gardening neighbors. This

might be the result of urban gardening, but it might also reflect selection bias: only people who enjoy healthy eating, start with urban gardening. To reduce selection bias, determinants should 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 example is the field experiment conducted by Van den Berg et al. (Van Den Berg and Custers, 2011). Another tool is to include reference groups, like non-gardening neighbors or people who are involved in domestic gardening or indoor and outdoor activity groups, like in the study by Hawkins et al. (Hawkins et al., 2011). Studies taking selection effects into account make a stronger case for the effects of urban gardening on human health.

Another cause of publication bias that might play a potential role might be that only studies showing positive relations between urban agriculture and health have been published, and no studies showing either negative or no relations.

5.3 Addressing public health from the beginning

These preliminary results suggest that urban gardening can make a contribution towards health and ecological government agendas, despite the fact that some effects might have been overestimated because of selection bias. The results of this study do not provide solid evidence for the relation between urban gardening and health, but they can help to put urban agriculture on governmental agendas and bring health professionals and ecologists together. However, each potential health effect poses specific demands to the management and organizational structure of the gardens. To improve social cohesion, for instance, the extent to which plots are shared is obviously important. Therefore, health or other targets should be defined from the beginning and relevant stakeholders should be approached. To maximize health benefits, it is useful to serve as many people as possible, i.e. to make it accessible for many people. In addition, researchers should partner with local communities to help plan programs and lend expertise when evaluating the impacts of community gardens (Zoellner et al., 2012).

Most studies have only included gardeners or garden leaders. However, urban gardens are likely to have impacts on others as well. Some gardens are used as neighborhood meeting places, attracting not only gardeners but also other local residents. Besides, gardens may beautify an area, which may lead to stronger neighborhood identification, also for people not involved in the gardens themselves. Gardens may therefore also have meaning, for instance, for office workers taking a stroll during their lunch break, or for school children from a nearby school. Conversely, residents may feel that a garden makes the neighborhood look messy, or they may not feel connected to the garden at all. The garden groups might even make people feel excluded (Glover, 2004). Hence, community gardens do not only have an impact on gardeners but also on other residents or family members, and this impact may be both positive and negative; knowing more about these diverse impacts is essential for a full understanding of a garden’s effects. In addition, we recommend measuring the effects of urban agriculture, using common indicators. This kind of information is especially valuable for planners, as

they want to fulfill specific functions effectively and efficiently with their designs of public (green) space.

5.4 Exposure to soil contaminants

Of course, soil quality needs to be assessed to manage the potential risks of soil contamination. Often, a site's history provides a clue to the presence of contaminants like lead, copper and cadmium in the soil. Concentrations of contaminants in the edible parts of the plant can be assessed to evaluate potential exposure. In addition, combined exposure through vegetable consumption and soil ingestion during gardening can be calculated (see factsheet 4.9). These indicators are more informative than concentrations in soils, as they reflect human exposure more explicitly. To date, no European policies specifically on urban gardening practices have been developed. The risk management policy is usually determined by local authorities within a national framework. In case of contamination, some adaptations to gardening practices (e.g. restriction of cultivation of leafy vegetables) can enable safe urban gardening. Risk management guidelines are provided in the Appendix.

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7 Appendix: risk management guidelines

To manage the risk from contaminant uptake in vegetables, and subsequent consumption of polluted vegetables, the following steps have to be followed:

Site investigation: assess the contaminated status of the soil (and in case of high groundwater levels, the groundwater as well) according to national site investigation protocols

1. in case of the presence of contaminants (in particular cadmium, copper, lead, or mobile organic contaminants):

1A. in case appropriate national trigger values for soil quality are exceeded: measure the contaminant concentration in vegetables (including leafy crops such as spinach, endive, broccoli or lettuce)
1Aa. in case appropriate national trigger values for vegetable quality are exceeded: apply box culture with foreign clean soil, only
1Ab. in case appropriate national trigger values for vegetable quality are not exceeded: restrict cultivation of leafy vegetables, increase or maintain high pH (7-8) and high organic matter content of the soil (at least 5%)
1B. in case that appropriate national reference values for soil quality are exceeded: restrict cultivation of leafy vegetables, increase or maintain high pH (7-8) and organic matter content of the soil (at least 5%)
1B'. in case that appropriate national trigger values for soil quality are exceeded, in particular for lead: avoid 'consumption' of soil material by children (hand-mouth contact); wash hands after gardening.

In case of doubt: contact your municipal health council or a specialized commercial consultancy for expert advice.

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