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Eugénie Albert, Anne Roué Le Gall, Philippe Glorennec

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Eugénie Albert [a,*], Anne Roué-Le Gall [b], Philippe Glorennec [c]

[a] EHESP School of Public Health, Irset (Institut de recherche en santé, environnement et travail) - UMR_S 1085, Univ Rennes F-35000 RENNES, French Agency for ecological transition F-49004, Angers, France
[b] EHESP School of Public Health, CNRS, ARENES – UMR 6051, Université de Rennes, 35000 Rennes, France
[c] Univ Rennes, EHESP, Inserm, Irset (Institut de recherche en santé, environnement et travail) - UMR_S 1085, F-35000 Rennes, France

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ABSTRACT

Objective: In the context of growing land pressure, new uses are projected on contaminated soils. In order to inform a comprehensive health assessment of gardening activities on contaminated land, this work aims to synthesise both quantitative and qualitative findings on the links between gardening, health, and well-being, taking gardeners' motivations and practices into account.
Methods: A rapid overview of reviews was conducted following PRISMA guidelines. Both therapeutic and commercial gardening were excluded, as was data from developing countries. Reviews describing at least one link between leisure gardening and health or well-being were included. Pubmed and Web of Science were searched for reviews published up to February 2023. The results were summarised in the form of a conceptual model, to support a comprehensive assessment of the links between health and gardening.
Results: Gardening has been shown to impact i) quality of the environment through supporting and providing ecosystem services and raised ecological awareness, ii) mental well-being through stress relief, positive affect and the provision of meaning and purpose, iii) social capital through increased and stronger relationships, iv) physical activity through enjoyable, low-to- moderate-intensity activities, v) diet through improved food literacy and access to fruit and vegetables, and vi) (potentially) economic status through food savings. Gardening is associated with lower Body Mass Index (BMI) and better self-reported health. Evidence on other health indicators is too scarce for conclusions to be drawn. We propose a framework aggregating these results.
Discussion: As a health-oriented review of reviews, some data may be missing as a result of topic classification or loss from duplicate removal. Some health determinants and contexts are less well documented; caution is needed when addressing these specific issues. Despite these limitations, the evidence gathered is sufficient to support an assessment of the health benefits of leisure gardening.

Introduction

Context and objectives

In recent decades, urban soils have become a coveted resource as cities have experienced increased land pressure as a result of both demographic growth and regulations aimed at limiting urban sprawl (Land use — European Environment Agency February 1, 2024). Meanwhile, there has been fresh interest in leisure gardening, especially among occidental urban-dwellers – whether as individual or collective initiatives (Maćkiewicz et al., 2021). When the topic of health is brought up in public decisions regarding land use, gardening is often considered from the perspective of chemical soil contamination alone. If a health risk assessment raises doubts, gardening may be banned as a precautionary measure, and the land may be 'lost' to other health-detrimental land uses. This precautionary approach is applied because other potential risks and benefits are scarcely, if ever, taken into account when evaluating gardening activities, which begs the question: are health-supporting gardening activities brought to an end because of a biased evaluation? Furthermore, contaminated urban soils often neighbour populations that are at risk for multiple health issues (FAO 2021), creating a paradox: those likely to benefit most from the health benefits of land reuse are denied this opportunity, out of safety concerns. Thus, if these concerns are not addressed within the local context, they

* Corresponding author at: Eugénie ALBERT, IRSET, 9 av. du Pr. Léon Bernard, 35000 Rennes, FRANCE
E-mail address: eme.m.albert@gmail.com (E. Albert).

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may maintain (or even aggravate) health inequities.

Integrated environmental health impact assessments have been conceptualised (Briggs, 2008) to support fairer, more informed decisions regarding policies and interventions that modify the living environment (natural, built, social, economic, etc.). This type of assessment is defined as "a means of assessing health-related problems deriving from the environment, and health-related impacts of policies and other interventions that affect the environment, in ways that take account of the complexities, interdependencies and uncertainties of the real world" (Briggs, 2008). Such an approach is in line with recommendations on new ways to protect public health in the face of today's "wicked problems" (Burke et al., 2017, Keshavarz Mohammadi, 2019).

Any attempt at conducting such an assessment for leisure gardening practices should begin by gathering existing knowledge. Since chemical contamination risks are already addressed in standard health risk assessments, we focused on other health impacts: benefits and other risks. To this end, integrated environmental health impact assessments consider health as a positive concept, as defined by the World Health Organisation (Constitution of the World Health Organization January 23, 2024). It draws on the health promotion approach, incorporating health determinants across the social, economic and physical environments, and the person's individual characteristics and behaviours. Finally, in line with environmental health concepts and the "One Health" approach (Ecosystems Division of the UN environment programme August 24, 2023), environmental quality is considered as a relevant health determinant.

Under the term leisure gardening, we considered all forms of active involvement in taking care of plants in an outdoor setting having no therapeutic or commercial purpose. Since this definition can accommodate many different forms of gardening, we also considered gardens and gardener characteristics to be of interest.

Because previous reviews on the topic have emphasised particular gardening contexts, populations, type of data (quantitative or qualitative) or health dimensions (physical, mental or social), they have painted part of the picture of the impacts of gardening on health. However, for the process of health assessment of gardening activities, all types of garden or populations might present themselves and thus the health dynamics at work will differ each time. This means that the health assessment framework must encompass as many situations as possible: to our knowledge, no such broad review exists. Hence, a rapid review of reviews was chosen, so as to exploit already existing summaries and provide an overarching picture of the links between gardening and health.

The aim of this work, then, is to summarise quantitative and qualitative findings on the links between gardening participation and health, taking gardener motivations and practices into account, across all types of leisure gardening. We propose a framework to consolidate existing research and highlight health-related pathways for integrated environmental health impact assessments and illustrate it with a logical diagram (Fig. 3).

Methods

Search strategy

The search strategy design was based on PRISMA guidelines (Page et al., 2021). The review was conducted on records from Pubmed and Web of Science using the keywords *garden, health* and *well*being* to identify records published up to February 2023. Articles were filtered by publication language (English, French or Spanish) and article type (review).

Eligibility criteria

Because the population of interest was any group practicing leisure gardening, no restrictions based on population characteristics were applied. The exclusion criteria were type of article (*i.e.* not a review), language (*i.e.* not French, Spanish or English), place (*i.e.* not developed countries) and gardening with a therapeutic or commercial aim (*i.e.*, not horticultural therapy or commercial farming). Reviews regarding details of chemical risk assessment such as bioaccessibility or contamination levels were excluded because these aspects are already taken into account in health risk assessments.

The first inclusion criterion was a description of at least one link between leisure gardening and a health determinant, a health outcome or well-being. A second inclusion criterion was a description of gardener motivations or practices (variables such as intensity, setting, growing methods, etc). These variables are essential both to the interpretation of findings and to addressing transferability between contexts. We put no restrictions on gardeners' age, gender, or other sociodemographic characteristics.

Selection process

The web app Rayyan, available at https://www.rayyan.ai, was used both to perform duplicate removal and to track decisions throughout the screening stage: title, title and abstract, plus a third round based on full text screening. Reports for which the full text could not be retrieved even after contacting the corresponding author were excluded. To check screening accuracy, 5% of included and 5% of excluded records were randomly selected for blind screening by a co-author. Discrepancies were resolved through discussion: this process led to clarification of the eligibility criteria regarding green space and urban agriculture reviews. Such reviews were included when they reported results specific to gardening, excluded when gardening was mentioned without being addressed independently. Several existing reviews were identified at that point, and citation searching was performed to identify records of other potentially interesting reviews.

Data extraction

Data extraction was performed using a template based on the PRISMA recommendations for reporting findings. We retrieved information about each review: name of the first author, date of publication, title, review objective, population of interest, type of gardening studied and definition according to authors as well as information about the type of corpus: quantitative, qualitative or mixed, date and location of the search, and identification of included studies. When the scope of the review was broader than leisure gardening, only information pertinent to our aim was retrieved. The extraction table is available in Supplementary Material 2. Overlap of primary studies was assessed based on the Corrected Covered Area. We calculated the CCA using $CCA = (N - r)/(rc - r)$, where N is the number of cited publications including double counting, r is the number of index publications and c is the number of reviews. The CCA was computed only for reviews specific to gardening, and the citation matrix is available in Supplementary Material 3.

Finally, we extracted studied outcomes and associated conclusions. When risk of bias and/or quality appraisal was conducted in a review, the methodology and results were retrieved.

Data synthesis

Health outcomes were classified according to various categories of health determinants (themes and subthemes). First, the most common outcomes were used to form the categories, then less-mentioned outcomes were linked to each category. Based on these themes, a narrative summary was performed as this was deemed the best way of translating the diversity of findings. Quantitative data was presented when possible.

Results

Selected reviews

Fig. 1 shows the results of the selection process. The search yielded 266 results from Pubmed and 364 results from Web of Science. After duplicate removal, 476 records were screened (first by title, then by title and abstract) and 143 potential reports were selected.

Of these 143 reports, 14 proved irretrievable despite contacting the authors, leaving 129 reports to be assessed for eligibility. The main reasons for exclusion were: no results specific to gardening (Carinanos and Casares-Porcel, 2011, Wolf and Robbins, 2015) (n = 31) or topic not gardening and health (Leavell et al., 2019) (n = 18). 47 reviews were included as a result.

Descriptive analysis

Nineteen reviews encompassed gardening as part of a larger topic (i.e., urban green space, nature-based solutions...). Of the 28 reviews focused on gardening, 17 integrated both qualitative and quantitative findings. A single review focused on qualitative findings, exploring the meanings and experiences of gardening. Of the more recent reviews, seven focused on quantitative findings, and three meta-analyses had been performed on the literature up to 2015 (Soga et al., 2017), 2017 (Kunpeuk et al., 2020) and 2019 (Spano et al., 2020) respectively on health in general, nutrition and physical health and psychosocial wellbeing.

The geographical scope of the studies was not always clearly indicated: 14 reviews applied no geographical limitations (only data from developed countries was extracted), 6 focused on developed countries (Berezowitz et al., 2015, Davis et al., 2015, Ohly et al., 2016, Lampert et al., 2021, Tharrey and Darmon, 2021, Savoie-Roskos et al., 2017, Schram-Bijkerk et al., 2018), of which three looked only at Western cultures (Berezowitz et al., 2015, Davis et al., 2015, Schram-Bijkerk et al., 2018). Three reviews did not present the method(s) used (Cameron et al., 2012, Alaimo et al., 2016, Tournier and Postal, 2014) and five others did not indicate whether there were geographical restrictions or not (Genter et al., 2015, Garcia et al., 2018, Howarth et al., 2020, Gregis et al., 2021, Semeraro et al., 2021). Most of the studies captured only English language publications, with just one integrating Portuguese and Spanish publications on community and domestic gardens up to February, 2016 (Garcia et al., 2018).

Garden type

Our search found one review focused on domestic gardens (Cameron et al., 2012) and one on allotment gardens (Genter et al., 2015). Domestic gardens were defined as follows: "*(...) the area adjacent to a domestic dwelling, which itself is either privately owned or rented. A key element*

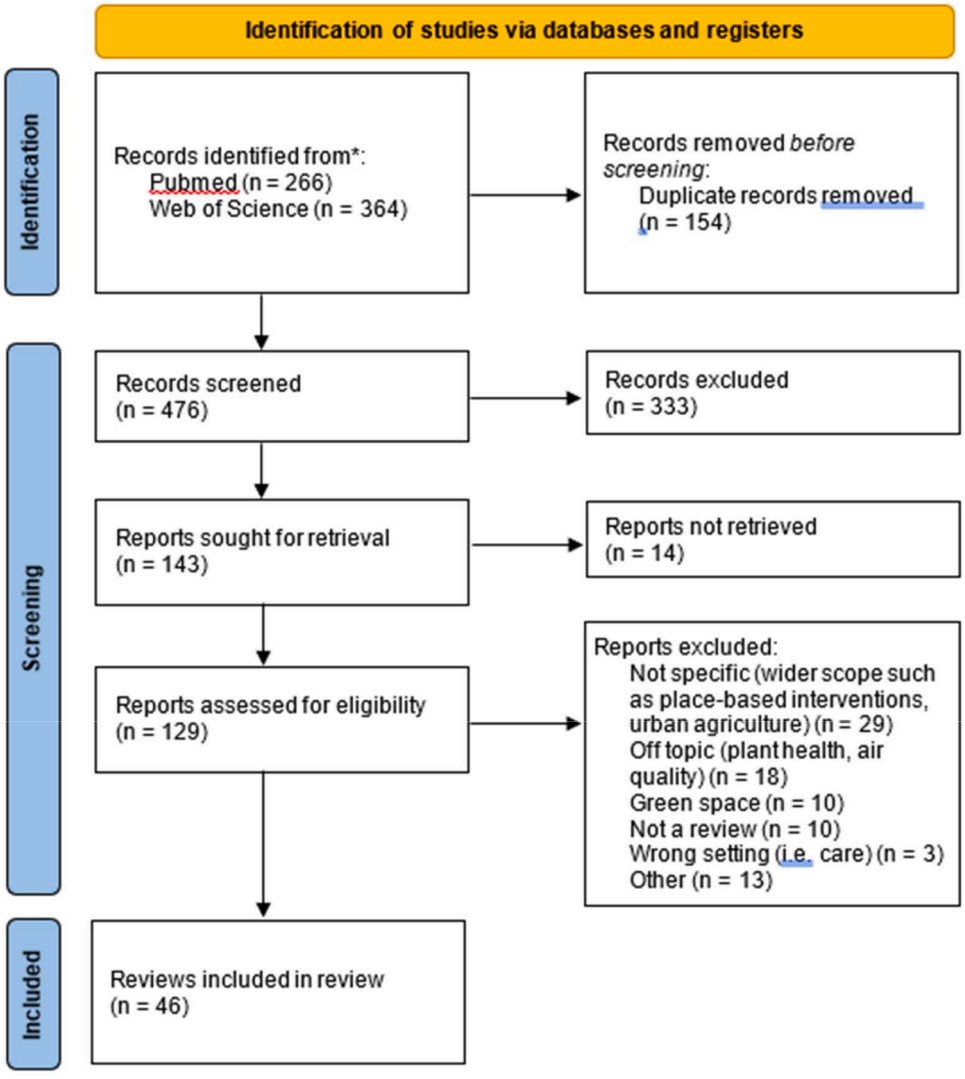

Fig. 1. Health and leisure gardening: selection of reviews.

is that the resident/s have autonomy over the garden, albeit they may wish to delegate responsibility to others (professional designer, hired gardener, etc.)." Allotment gardens were described as follows in the specific review, and some subsequent reviews did include allotments in their wider scope:

"(…) an allotment not exceeding 40 rods (approx. 1000 m^2) in extent which is wholly or mainly cultivated by the occupier for the production of vegetable or fruit crops for consumption by himself or his family' (Allotment Act, 1922, cited in Crouch and Ward, 1997: 278). Contemporary UK allotment plots are smaller, typically 10 rods (250 m^2); where demand is high these are halved (Crouch and Ward, 1997). Location is a key characteristic not mentioned in the Act; typically plots are sited collectively and provided by local authorities, although there is also private provision (Allotment Regeneration Initiative, 2007). Vegetable and fruit growing remain the principle reason for allotment gardening, and this is often stipulated in the tenancy agreement (Allotment Regeneration Initiative, 2007)"

Five reviews addressed school gardens (Berezowitz et al., 2015, Davis et al., 2015, Ohly et al., 2016, Ozer, 2007, Chan et al., 2022), with one including after-school activities (Davis et al., 2015). The two most recent of these specified that garden-based programmes with integrated *curriculum* and other activities (such as tasting and cooking) were also included (Ohly et al., 2016, Chan et al., 2022). This is in line with current practices of offering combined interventions (for example, nutrition education and gardening classes) to maximise learning (Ohly et al., 2016).

Twelve reviews studied community gardens, though differing definitions prove it to be an ambiguous term (see Table S1). Some definitions of community gardening specified consumption of the product grown (Egli et al., 2016), while others described food or flowers (Guitart et al., 2012); some focused on purpose (Kunpeuk et al., 2020) and most mentioned shared responsibility for the space, albeit in different ways (Alaimo et al., 2016, Hume et al., 2022). After considering the differences, some of the reviews were relabelled as a way of removing ambiguities for the remainder of this work, as shown in Supplementary Material 1. After reassignment, five of the 11 reviews retained the 'community' label, using the definition provided by Burt et al. (2021), citing Ferris et al. (2001)):

"*A community garden is defined as a public green space with some shared access, ownership, and control. Community gardens differ from other types of urban agriculture (e.g., urban farming) because the purpose of a community garden is not necessarily food production.*"

Four of the 12 reviews were not specifically about a shared space: "community" meant "not in a therapeutic setting". Ultimately these 4 reviews covered the whole range of leisure gardening settings, and were thus labelled "all".

While the definition used by three reviews did fit that of community gardening (as above), it was unclear whether allotment gardens were excluded or not (Lampert et al., 2021, Hume et al., 2022, Al-Delaimy and Webb, 2017), and verification of the bibliography showed at least one study on allotment gardens (van den Berg et al., 2010). This is a recurring imprecision in community gardening definitions, yet the differences in management can strongly impact how gardeners interact with the garden. One review used the term "collective gardening" (Tharrey and Darmon, 2021) to cover both community and allotment gardens. Its definition referred to a collectively managed space, making it more akin to community gardening than allotment gardening. Indeed, in this review (as well as others, and in the definition above) allotment gardens are defined as divided, rented plots, managed each by a gardener in accordance with an imposed bylaw. One review used the expression urban gardens to cover both community and domestic gardens, but did not specify allotment gardens (Garcia et al., 2018).

Lastly, seven reviews looked at a wider range of gardens. Three did not provide a definition of gardens or gardening (Savoie-Roskos et al., 2017, Tournier and Postal, 2014, York and Wiseman, 2012). Of the four that did define gardens, all included the growing of plants in their definitions. One defined the activities performed (i.e. caring for plants, working the soil), but not the setting (Nicklett et al., 2016), and the other three based their definition on use: multifunctional (Howarth et al., 2020, Wright et al., 2014) or non-commercial (Soga et al., 2017). It is of note that the non-commercial definition was used in one of the community gardening reviews that was relabelled as "all" (Kunpeuk et al., 2020). Two of the seven included horticultural therapy in their definition (Soga et al., 2017, Howarth et al., 2020) – we only used data from sections dedicated to leisure gardening.

Population

Thirteen of the included reviews had no restriction on population studied. Depending on the aim pursued, 34 included restrictions based on age, vulnerability or urban location.

Twelve reviews looked at urban-dwellers, five reviews looked at adults, and one targeted adult urban-dwellers (Tharrey and Darmon, 2021). 8 reviews explored gardening for school-aged children, with one specific to children under 6 years of age (Skelton et al., 2020) and another starting at 5 years of age (McCrorie et al., 2014). 4 reviews focused on seniors, one of which stated that the threshold age varied across studies. One review about urbanisation challenges selected children and seniors, both being vulnerable age groups (Kabisch et al., 2017). Finally, one review focused on socially vulnerable populations (Malberg Dyg et al., 2019), one on people living with dementia (Newton et al., 2021), and one was specific to the Japanese population (Machida and Kushida, 2020).

Data for type of garden and population studied is summarised in Fig. 2. Of note, just one of the reviews concerning children was not specific to school gardens (Savoie-Roskos et al., 2017). Recent reviews tend to encompass more types of gardens (Tharrey and Darmon, 2021, Hume et al., 2022) and to focus on quantitative studies.

Year indicated is the year in which the literature was searched (if not specified by the authors: one year before publication). The review by Garcia et al. (2018) is presented twice, since it looked at both domestic and community gardens.

Health outcomes

The different outcomes studied in each of the 47 reviews were grouped as shown in Table 1.

Regarding health determinants, diet has consistently been found to be the most reported outcome (Tharrey and Darmon, 2021, Burt et al., 2021). Twenty reviews reported some information on this theme, sixteen of which looked at fruit and vegetable (F&V) consumption. Social capital was mentioned just as often in our corpus. This may be due to the fact that we chose to classify data from the "social connectedness and social support" subthemes under the "social capital" theme, whereas others have considered it to pertain to psychological health (Spano et al., 2020, Alaimo et al., 2016). Slightly less reported outcomes among health determinants relate to physical activity (15 reviews) and mental well-being (13 reviews), but overall, these 4 themes are well recognised in the existing literature. Environmental quality was rarely mentioned in reviews specific to gardening and health. Ecological awareness was addressed several times (Ohly et al., 2016, Alaimo et al., 2016, Semeraro et al., 2021, York and Wiseman, 2012, Uhlmann et al., 2018) and contact with nature was described (Ohly et al., 2016, Genter et al., 2015, Newton et al., 2021), though mainly in terms of its psychological benefits. Reviews having a different scope (i.e. nature and health, urban ecosystem services, etc.) have allowed us to draw a picture of the potential environmental benefits of gardens (Cameron et al., 2012, Semeraro et al., 2021, Russo et al., 2017, Knight et al., 2021).

General health and well-being indicators have also garnered a lot of attention, with 18 reviews reporting on such outcomes. This is strongly driven by BMI (9 reviews) and self-reported health considerations (8 reviews).

Finally, seven reviews contributed data on the sustainability of gardening. Some discussed gardening's multifunctional potential to address several health determinants at once (Egli et al., 2016, Russo et al., 2017, Hartig et al., 2014), others looked at urban environment

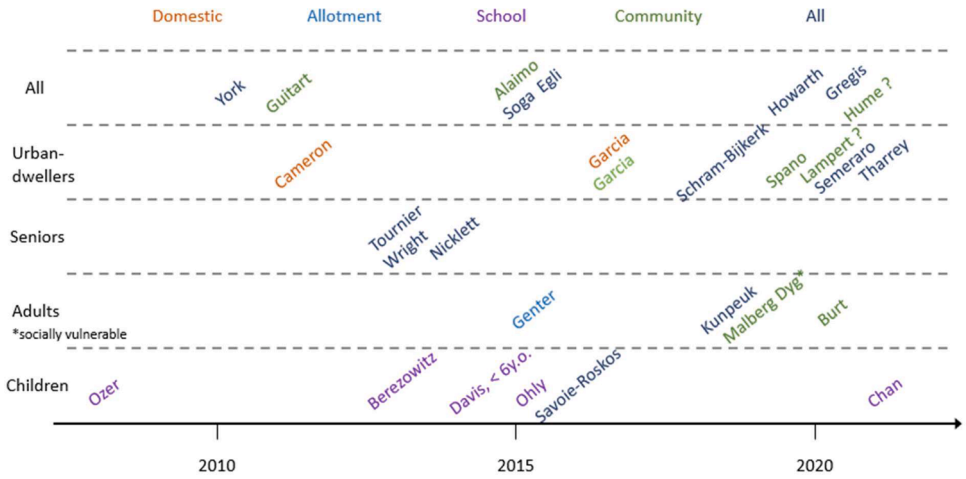

Fig. 2. Timeline for the 27 reviews focusing on gardening, by type of garden and population.

challenges that can be addressed by gardening (Schram-Bijkerk et al., 2018, Semeraro et al., 2021, Evans et al., 2022), and one actively framed gardening activities according to the UN Sustainable Development Goals (Nicholls et al., 2020).

Overlap and quality appraisal

The CCA was estimated at 0.1, indicating very little overlap amongst included reviews (Skelton et al., 2020, Pieper et al., 2014). An excerpt from the citation matrix used for calculating overlap is available in Supplementary Material 3. The article included in the highest number of reviews was Van den Berg *et al.*, 2010 (n =15) (van den Berg et al., 2010).

Since the breadth of the scope and heterogeneity of the methodologies did not allow for a consistent examination of the primary studies, no formal quality appraisal was conducted for this review.

Narrative synthesis

Environmental quality

Gardens are natural features of our physical environment and as such, provide supporting and regulating ecosystem services. Flower or food gardens provide habitats for flora and fauna (Cameron et al., 2012, Russo et al., 2017, Davies et al., 2009); this in turn can foster biodiversity, especially in urban settings where many species can only be found in gardens. A review of comparisons between biotopes showed that gardens play a more modest role than their wilder counterparts, but can act as a complement for some families like arthropods (Filazzola et al., 2019).

Gardens can also play a role in integrated water management, both as infiltrative surfaces for stormwater runoff and as places using water locally for food production (Cameron et al., 2012, Semeraro et al., 2021, Russo et al., 2017, Nicholls et al., 2020). Further, they can mitigate exposure to air pollution and reduce urban temperatures – especially urban heat islands (Cameron et al., 2012, Semeraro et al., 2021, Knight et al., 2021). Lastly, depending on their design (choice of species, cultivation practices), gardens can be places of carbon storage (Cameron et al., 2012, Semeraro et al., 2021, Russo et al., 2017). These different ecosystem services can preserve health and contribute to a healthy environment. For example, limiting urban heat islands avoids deaths during heatwaves, and carbon storage (in soil and plants) mitigates the rise in atmospheric greenhouse gases.

As an activity, gardening involves the senses of smell, taste and touch as well as those of sight and hearing: it is a multisensorial experience. Gardeners also report a sense of connection with nature through observation of the changes that occur over time, such as plant evolution or seasonal rhythms (Ohly et al., 2016, Alaimo et al., 2016, Tournier and Postal, 2014, Wright et al., 2014). Thus, gardens can be places for direct, active involvement with nature, beyond mere passive contemplation (Alaimo et al., 2016). This is a key pathway for several of the benefits of gardening. Where environment is considered, connection with nature leads to caring about it [18,24,40,49]: this translates to heightened ecological awareness among gardeners, as self-reported and as evidenced by declared motivations or observed behaviours such as composting, creating habitat for animals and improving watering techniques (Ohly et al., 2016, Uhlmann et al., 2018). Gardens in which food is grown are also said to reconnect urban-dwellers with the food system, helping citizens to understand and demand environmental accountability (Alaimo et al., 2016, Burt et al., 2021).

Mental well-being

Contact with nature has been shown to provide respite from stress and anxiety. In this respect, gardening is no exception (Cameron et al., 2012, Alaimo et al., 2016, Genter et al., 2015, Hume et al., 2022, Malberg Dyg et al., 2019, Russo et al., 2017), and is identified by gardeners as offering a relaxing break from everyday troubles (Ohly et al., 2016, Schram-Bijkerk et al., 2018). The stress-relieving effects of gardening have been corroborated by biophysical studies of stress markers (Schram-Bijkerk et al., 2018). Two explanations have been investigated: attention restoration theory (Stevenson et al., 2018) and the biophilia hypothesis (Gaekwad et al., 2022). However, as discussed in the environment section above, the physical effort involved in gardening might provide synergistic, amplified stress relief as a result of both contact with nature and physical activity (Genter et al., 2015). Positive feelings and mood improvement are also associated with gardening (Ohly et al., 2016, Alaimo et al., 2016).

In terms of psychological mechanisms, time spent in the garden is identified as grounding, allowing gardeners to experience a sense of place and time (Alaimo et al., 2016, Tournier and Postal, 2014, Genter et al., 2015, York and Wiseman, 2012, Wright et al., 2014, Newton et al., 2021). Gardening also fosters a sense of belonging on several levels: local (neighbourhood), occupational (the community of gardeners), familial and environmental (nature). This in turn supports the continuation or restoration of identity – a benefit already studied in refugee, migrant and marginalised populations and among cancer survivors and seniors (Tournier and Postal, 2014, York and Wiseman, 2012, Malberg Dyg et al., 2019, Bikomeye et al., 2022). One phenomenon suggested is that of a transfer from caring for plants to caring for oneself, in a similar manner to the ecological awareness described above. Lastly, gardening activity is often described as bringing a sense of pride (Ohly et al., 2016, Tournier and Postal, 2014, Malberg Dyg et al., 2019) and can offer an important opportunity to build self-efficacy (Alaimo et al., 2016, York and Wiseman, 2012).

Table 1
Distribution of health themes across reviews

Main outcomes	Outcome subthemes	Reviews included
Environmental quality 12 reviews	Regulating and provisioning ecosystem services	(Cameron et al., 2012, Semeraro et al., 2021, Russo et al., 2017, Knight et al., 2021)
	Ecological awareness	(Ohly et al., 2016, Alaimo et al., 2016, Semeraro et al., 2021, York and Wiseman, 2012, Uhlmann et al., 2018)
	Sensory experience, contact with nature	(Ohly et al., 2016, Alaimo et al., 2016, Tournier and Postal, 2014, Genter et al., 2015, Wright et al., 2014, Newton et al., 2021)
	Environmental adverse effects	(Cameron et al., 2012, Semeraro et al., 2021, Nicholls et al., 2020, Filazzola et al., 2019)
Mental well-being 13 reviews	Stress relief	(Ohly et al., 2016, Schram-Bijkerk et al., 2018, Cameron et al., 2012, Alaimo et al., 2016, Genter et al., 2015, Gregis et al., 2021, Hume et al., 2022, Malberg Dyg et al., 2019, Russo et al., 2017)
	Grounding, sense of place and time	(Alaimo et al., 2016, Tournier and Postal, 2014, Genter et al., 2015, York and Wiseman, 2012, Wright et al., 2014, Newton et al., 2021)
	Meaning, spirituality	(Ohly et al., 2016, Cameron et al., 2012, Alaimo et al., 2016, Wright et al., 2014)
	Sense of pride	(Ohly et al., 2016, Tournier and Postal, 2014, Malberg Dyg et al., 2019)
	Self-efficacy	(Alaimo et al., 2016)
	Artistic expression	(Wright et al., 2014)
	Mental burden	(Wright et al., 2014)
Social capital 20 reviews	Social connectedness	(Spano et al., 2020, Ohly et al., 2016, Lampert et al., 2021, Schram-Bijkerk et al., 2018, Cameron et al., 2012, Alaimo et al., 2016, Tournier and Postal, 2014, Genter et al., 2015, Hume et al., 2022, Malberg Dyg et al., 2019)
	Social cohesion	(Schram-Bijkerk et al., 2018, Semeraro et al., 2021, Hume et al., 2022, Al-Delaimy and Webb, 2017, Hartig et al., 2014)
	Social participation	(Alaimo et al., 2016, Semeraro et al., 2021, Hume et al., 2022, Burt et al., 2021, York and Wiseman, 2012, Malberg Dyg et al., 2019)
	Social inequities	(Schram-Bijkerk et al., 2018, Burt et al., 2021)
	Other information	(Tharrey and Darmon, 2021, Schram-Bijkerk et al., 2018, Ozer, 2007, Burt et al., 2021, Abraham et al., 2010, Hansen-Ketchum et al., 2009)
Physical activity 15 reviews	Increase in physical activity	(Kunpeuk et al., 2020, Ohly et al., 2016, Tharrey and Darmon, 2021, Schram-Bijkerk et al., 2018, Gregis et al., 2021, Ozer, 2007, Al-Delaimy and Webb, 2017)
	Meaningful activity, alternative to sports	(Cameron et al., 2012, Alaimo et al., 2016, York and Wiseman, 2012, Wright et al., 2014, Malberg Dyg et al., 2019)
	Characterisation as a physical activity	(Alaimo et al., 2016, Nicklett et al., 2016, McCrorie et al., 2014, Gagliardi and Piccinini, 2019)
Diet 20 reviews	Fruit & vegetable intake	(Kunpeuk et al., 2020, Berezowitz et al., 2015, Ohly et al., 2016, Lampert et al., 2021, Tharrey and Darmon, 2021, Savoie-Roskos et al., 2017, Schram-Bijkerk et al., 2018, Alaimo et al., 2016, Garcia et al., 2018, Gregis et al., 2021, Ozer, 2007, Chan et al., 2022, Hume et al., 2022, Burt et al., 2021, Al-Delaimy and Webb, 2017, Malberg Dyg et al., 2019, Russo et al., 2017)
	Food acceptability	(Berezowitz et al., 2015, Ohly et al., 2016, Garcia et al., 2018, Ozer, 2007, Chan et al., 2022, Burt et al., 2021, Russo et al., 2017)
	Food accessibility	(Garcia et al., 2018, Semeraro et al., 2021, Burt et al., 2021, Malberg Dyg et al., 2019, Kamphuis et al., 2006)
	Food literacy	(Berezowitz et al., 2015, Ohly et al., 2016, Alaimo et al., 2016, Garcia et al., 2018, Semeraro et al., 2021, Ozer, 2007, Chan et al., 2022, Malberg Dyg et al., 2019, Machida and Kushida, 2020, Russo et al., 2017)
	Changes in diet other than F&V intake	(Ohly et al., 2016, Tharrey and Darmon, 2021, Garcia et al., 2018, Chan et al., 2022, Malberg Dyg et al., 2019)
	Food savings	(Schram-Bijkerk et al., 2018, Garcia et al., 2018, Malberg Dyg et al., 2019)
	Food security	(Alaimo et al., 2016, Burt et al., 2021)
Economic status 6 reviews		(Schram-Bijkerk et al., 2018, Alaimo et al., 2016, Garcia et al., 2018, Burt et al., 2021, Malberg Dyg et al., 2019, Nicholls et al., 2020)
Health and well-being indicators 18 reviews	Anthropometric outcomes	(Kunpeuk et al., 2020, Ohly et al., 2016, Tharrey and Darmon, 2021, Alaimo et al., 2016, Gregis et al., 2021, Hume et al., 2022, Al-Delaimy and Webb, 2017, Malberg Dyg et al., 2019, Hartig et al., 2014)
	Chronic diseases	(Kabisch et al., 2017, Bikomeye et al., 2022)
	Self-perceived health and well-being	(Ohly et al., 2016, Lampert et al., 2021, Tharrey and Darmon, 2021, Alaimo et al., 2016, Gregis et al., 2021, Hume et al., 2022, Al-Delaimy and Webb, 2017, Kabisch et al., 2017, Malberg Dyg et al., 2019)
	Physical risk (injury, pain)	(Lampert et al., 2021, Nicklett et al., 2016)
	Biological risk (pests)	(Russo et al., 2017, Fischhoff et al., 2019)
	Other information	(Soga et al., 2017, Gregis et al., 2021, Skelton et al., 2020, Malberg Dyg et al., 2019, Gagliardi and Piccinini, 2019)
Gardener practices and motivations 21 reviews	Practices	(Davis et al., 2015, Ohly et al., 2016, Tharrey and Darmon, 2021, Schram-Bijkerk et al., 2018, Garcia et al., 2018, Semeraro et al., 2021, Ozer, 2007, Chan et al., 2022, Hume et al., 2022, Al-Delaimy and Webb, 2017, Newton et al., 2021, Russo et al., 2017, Evans et al.,

(*continued on next page*)

Table 1 (*continued*)

Main outcomes	Outcome subthemes	Reviews included
		2022, Gagliardi and Piccinini, 2019)
	Motivations	(Lampert et al., 2021, Schram-Bijkerk et al., 2018, Cameron et al., 2012, Alaimo et al., 2016, Tournier and Postal, 2014, Genter et al., 2015, Guitart et al., 2012, Wright et al., 2014, Uhlmann et al., 2018, Russo et al., 2017)
	Challenges and limits	(Davis et al., 2015, Alaimo et al., 2016, Guitart et al., 2012, York and Wiseman, 2012)
Sustainability 7 reviews		(Schram-Bijkerk et al., 2018, Semeraro et al., 2021, Egli et al., 2016, Russo et al., 2017, Hartig et al., 2014, Evans et al., 2022, Nicholls et al., 2020)

The meaning of gardening has also been evidenced from a cultural and spiritual point of view. This often relates to a sense of belonging to something bigger (Ohly et al., 2016, Alaimo et al., 2016, Wright et al., 2014). Some of the motivations for gardening support this view: partaking in a familiar activity, preserving knowledge and experience, or getting access to culturally meaningful food items (Uhlmann et al., 2018). Lastly, one review suggests that gardening can be a form of artistic expression (Wright et al., 2014). All of these phenomena combine to give gardening a unique meaning in the eyes of gardeners – for them, it is more than a mere hobby.

In terms of risk to mental well-being, only one review (Wright et al., 2014) reported data from a single study (Fänge and Ivanoff, 2009) of Swedish people aged 80-89 years. Those scholars pointed out that at this age, taking care of a garden could become a burden.

Social capital

Social capital refers to all the resources an individual is able to mobilise through his/her social networks. Examples relating to health include information about screening programmes, encouragement to quit smoking, money to cover medical expenses, physical and mental support during difficult times, etc. Although the exact pathways linking social capital to health are unclear, it has been shown to be associated with better health – with some reviews suggesting a protective effect on all-cause mortality (Ehsan et al., 2019). Gardening has been found to foster the various aspects of social capital: support, diversity of relations and social cohesion (the sharing of values that support cooperation).

Community gardens imply the creation and maintenance of social ties as part of their everyday management (Hartig et al., 2014); as such, in this context, the social impacts of gardening have mostly been studied in this context. Indeed, increased social connections have been found across a range of populations including young people, seniors, and migrants to a new country (Lampert et al., 2021, Schram-Bijkerk et al., 2018, Alaimo et al., 2016, Tournier and Postal, 2014, Hume et al., 2022, Malberg Dyg et al., 2019). A meta-analysis of psychosocial well-being also found a positive association between social capital indicators (social cohesion, perceived neighbourhood aesthetics, several forms of social support and social participation) and community gardening (Spano et al., 2020). York reported on a study of children in a school garden project, suggesting that caring for nature led children to caring about their community (York and Wiseman, 2012, Bowker and Tearle, 2007). Allotments have been described by the elderly as privileged places of interaction, both with other gardeners and across generations (Genter et al., 2015, van den Berg et al., 2010). As such, they could be an effective way of tackling loneliness in elderly people. Finally, domestic gardens are also recognised as a forum for interactions within private networks of friends and family. Links to other types of networks (neighbours, other gardeners, etc.) are poorly documented, but the fact that private gardens can be very open to the public space (or, conversely, completely enclosed), undoubtedly has a facilitating effect (or no effect at all, respectively), on the integration of gardeners into non-private networks (Cameron et al., 2012). Thus, all types of gardens can create opportunities for socialising.

Some reviews have looked at the quality and depth of these relations and found that relationships formed in the garden are described as being supportive of trust and reciprocity (Lampert et al., 2021, Schram-Bijkerk et al., 2018, Alaimo et al., 2016, Genter et al., 2015, Burt et al., 2021, Malberg Dyg et al., 2019, Abraham et al., 2010, Hansen-Ketchum et al., 2009). Regardless of garden type, one behaviour consistently reported – whether by researchers or gardeners themselves, is sharing (Tournier and Postal, 2014, Garcia et al., 2018, Burt et al., 2021). Produce is shared with family, friends, other gardeners, and sometimes donated to local non-profits, such as soup kitchens. Gardeners also share knowledge, tools, help with gardening chores or cultural elements such as recipes (Ohly et al., 2016). There is little and conflicting evidence as to whether this behaviour persists beyond the garden.

Although these initial aspects tend to relate to the individual level, social capital can also be assessed at community level. 6 reviews concluded that community gardeners were more likely to participate in neighbourhood initiatives than other people (Schram-Bijkerk et al., 2018, Alaimo et al., 2016, Semeraro et al., 2021, Hume et al., 2022, Burt et al., 2021, York and Wiseman, 2012), which suggests that community gardening could foster informal social control. Four reviews reported on gardens enhancing social cohesion (shared values and codes of behaviour) (Ohly et al., 2016, Semeraro et al., 2021, Hume et al., 2022, Hansen-Ketchum et al., 2009). These tendencies suggest that gardening can impact social capital in terms of both quantity and quality.

A third aspect of the influence of gardening on social capital is in terms of relationship heterogeneity. Three reviews mention that gardening can be an opportunity for cross-cultural communication (Ohly et al., 2016, Semeraro et al., 2021, Burt et al., 2021), though two others identified an account of a garden in which Black gardeners felt excluded, seeing the garden as a "white project" (Schram-Bijkerk et al., 2018). A fourth review (Schram-Bijkerk et al., 2018) reported on a study where a gardening group made non-gardeners feel excluded (Glover et al., 2005).

Physical activity

Gardening has been rated moderate in terms of Metabolic Equivalent of Task (MET). METs are used to grade and compare activity intensity from sleep (0.9 MET) to running > 17.5 km/h (18 MET). The moderate category includes brisk-paced walking or regular cycling (Ainsworth et al., 2011). Of course, METs from gardening depend on the task performed, and movements and constraints also vary accordingly (Alaimo et al., 2016, Nicklett et al., 2016, McCrorie et al., 2014, Gagliardi and Piccinini, 2019). Five reviews also remarked on the fact that gardening is often not thought of as physical activity, and may be a roundabout way of exercising while pursuing a different goal (Cameron et al., 2012, Alaimo et al., 2016, York and Wiseman, 2012, Wright et al., 2014, Malberg Dyg et al., 2019). Although some tasks are low intensity, they still increase non-sedentary time. This makes gardening a promising alternative to sports for people who cannot (or do not wish to) engage in formal physical activities. It is also an interesting way for seniors to maintain or adopt an active lifestyle as they age, since the intensity and diversity of tasks make it possible to adapt the activity to the particular gardener's own needs and ability (Alaimo et al., 2016, Gagliardi and Piccinini, 2019).

Indeed, gardening has proven effective in supporting and restoring such physical functions as mobility, flexibility, gait and balance in seniors (Malberg Dyg et al., 2019, Gagliardi and Piccinini, 2019). In children, physical activity has been studied in relation to school gardening and found to be important in increasing time spent exercising, and decreasing sedentary time (Ohly et al., 2016). We also note that one review reported on a study on domestic gardens that found them to be

conducive to physical activity in children (McCrorie et al., 2014). Gardeners in general report being more physically active than non-gardeners, or as active as other counterparts engaged in outdoor walking (Kunpeuk et al., 2020, Ohly et al., 2016, Tharrey and Darmon, 2021, Schram-Bijkerk et al., 2018, Gregis et al., 2021, Ozer, 2007). One review pointed out the seasonality of garden work, with the spring and summer months being potentially more conducive to physical activity (Alaimo et al., 2016). This same review also cited a study comparing different gardening settings, with community gardening being 33% and 10% more conducive to physical activity than home gardening and no gardening, respectively.

Diet

Pathways. Gardening was found to be a determinant of F&V consumption in the very first review included here (Kamphuis et al., 2006), as well as many times since. Two main mechanisms are described: improved accessibility and improved food literacy.

First, gardening can offer a supply of fresh F&V via direct access and proximity – especially for people living in food deserts or having limited mobility (Garcia et al., 2018, Semeraro et al., 2021, Burt et al., 2021, Malberg Dyg et al., 2019, Kamphuis et al., 2006). Garden produce can also be more affordable, according to both gardeners and a small sample of studies that have sought to objectify savings (see Economical benefits section below). This is obviously dependent on the quantity and type of food grown. A third aspect of access is acceptability: the experience of growing certain food items can broaden the range of fruits or vegetables that people are willing to eat. This has been studied in children, in particular, as a way of addressing neophobia (Berezowitz et al., 2015, Ohly et al., 2016, Ozer, 2007, Chan et al., 2022, Russo et al., 2017). On the other hand, by choosing what is grown in their garden, gardeners can favour food items that fit their personal preferences, and may grow traditional or culturally appropriate produce. This may be particularly relevant to migrant or refugee populations, but is true of every gardener. Indeed, gardeners often confer special value to meals made using garden produce, considering it to be fresher, more natural (or organic), and thus both tastier and healthier (Garcia et al., 2018, Burt et al., 2021).

Second, gardening is associated with improved food literacy (Berezowitz et al., 2015, Ohly et al., 2016, Alaimo et al., 2016, Garcia et al., 2018, Semeraro et al., 2021, Ozer, 2007, Chan et al., 2022, Malberg Dyg et al., 2019, Machida and Kushida, 2020, Russo et al., 2017) – defined as the knowledge and skills needed to navigate one's food environment and make informed, adequate food choices (Truman et al., 2017). Indeed, gardening offers an opportunity to learn about and practice food growing. School gardens have often been studied with a view to this – especially in terms of their effect on knowledge (Berezowitz et al., 2015, Ohly et al., 2016, Ozer, 2007, Chan et al., 2022, Russo et al., 2017). However, food literacy also demands skills such as composing a meal or food preparation. In this regard, gardening is found to be associated with behaviours such as making preserves, sharing recipes, or conferring particular value and meaning to garden products, all of which are indicative of food literacy proficiency. Gardeners confirm that gardening offers an opportunity to learn about new produce or new ways of preparing it, especially through sharing with other gardeners (Alaimo et al., 2016, Semeraro et al., 2021). The most recent review on school gardening found that 14 of the 20 studies included showed improved food literacy among the children involved, especially where curriculum integration and interventions engaged children under 15 years of age (Chan et al., 2022).

Fruit and vegetable consumption. Gardeners' F&V consumption is consistently the most studied outcome across reviews (Gregis et al., 2021). Where school gardens are concerned, a 2007 review found one study showing increased consumption (Ozer, 2007). Since then three reviews on school gardens have yielded mixed results. One review including seven studies showed an overall increase in vegetable consumption (Berezowitz et al., 2015), and suggested that fruit consumption should be treated separately, since children are less prone to refusing fruit, and fruit is less likely to be found in school gardens. A subsequent review of 13 studies found just two studies based on self-report to be statistically significant (Ohly et al., 2016). Of note, one review (focused on children, but not school-garden-specific) found increased F&V consumption in ten out of 14 included studies, also pointing out that long-term data was lacking, for information as to whether these changes were sustained over time (Savoie-Roskos et al., 2017). Finally, a review of programme characteristics associated with increased F&V consumption in schoolchildren showed stronger improvement where the children were younger, the interventions were shorter, the sample sizes were smaller and parental involvement was absent (Chan et al., 2022).

For community gardens, one review presented six studies in which a significant increase in F&V was shown - two of which presented quantitative data (Alaimo et al., 2016). Three recent quantitative reviews having slightly different scopes also concluded that gardening had a significant effect, with two of these finding 4 out of 4 (Lampert et al., 2021) and 5 out of 5 (Tharrey and Darmon, 2021) studies, respectively, showing a significant increase in F&V consumption. The third review did not detail its results, simply concluding that there was a slight increase in F&V consumption due to community gardening (Hume et al., 2022).

A study of allotment gardening reported in one quantitative review (Tharrey and Darmon, 2021) recorded household food supplies and showed an increase in F&V consumption, mainly due to the quantities purchased, rather than grown (Martin et al., 2017). Another quantitative review that included all types of garden (Kunpeuk et al., 2020) found 8 out of 10 studies showing a significant increase in F&V consumption also noted an increased variety of F&V consumed.

Lastly, a similar pattern was found in two mixed studies reviews, finding 7 out of 7 (Garcia et al., 2018) and 12 out 12 studies (Burt et al., 2021) respectively reporting positive findings on variety and quantity of F&V consumed. Wider benefits in the household and the community are also possible, since sharing is widespread among gardeners (see Social Capital and Diet/Pathways sections).

Other changes to dietary practices. Some evidence has also been gathered regarding other changes in diet that may be associated with gardening. Evidence on this topic is inconsistent, with changes probably dependent on which household member does the gardening (Garcia et al., 2018). For school gardens, results are deemed slightly positive in one review of six studies (Ohly et al., 2016). The most recent review on school gardens (Chan et al., 2022) noted four studies with positive results on fibre intake, and one with increased vitamin A and C intake. 1 reported study of an aromatic gardening programme aimed at reducing salt intake met its outcome. 3 other reported studies showed no post-intervention improvement on reducing sugar-sweetened beverages and ultra-processed food consumption. In adult community gardeners, one review cited a study that found no change in consumption of fast food and soda (Tharrey and Darmon, 2021).

Economic status

Evidence on the economic impact of gardening at an individual level is mixed, and has seldom been reported on in our corpus.

Four reviews in our corpus mentioned food savings (Schram-Bijkerk et al., 2018, Alaimo et al., 2016, Garcia et al., 2018, Malberg Dyg et al., 2019). Two of these identified a total of three studies having reported food savings as a motivating factor for gardeners, though no self-reported or objective measure was implemented (Wakefield et al., 2007, Scott et al., August 27, 2014, Freeman et al., 2012). The third review focused on socially vulnerable populations and found 5 studies reporting some savings as a result of community gardening (Malberg

Dyg et al., 2019). The fourth review (Alaimo et al., 2016) was the only one to report on two quantitative estimates of crop value in community gardens (Blair et al., 1991, Algert et al., 2014). Yet little is known about the investment necessary to starting a garden: the data cited above seems to look at value without factoring in costs. Since cost is said to be a deterrent for would-be gardeners, some gardening programmes have provided starter kits – but the necessary composition of such kits is unclear (Alaimo et al., 2016), and actual garden startup cost is unknown.

All four of the reviews reporting on food savings (Schram-Bijkerk et al., 2018, Alaimo et al., 2016, Garcia et al., 2018, Malberg Dyg et al., 2019), plus two of those reporting on accessibility (Alaimo et al., 2016, Burt et al., 2021) (see Diet section above), have suggested that gardening could be an effective way of tackling food security, as household food provision can be facilitated by the combination of low cost and easy access. Indeed, one review found a majority of positive findings across 12 selected studies reporting on food security related outcomes (Blair et al., 2021). One review (Tharrey and Darmon, 2021) mentioned a study that examined overall food purchases for a sample of low-income gardeners (Martin et al., 2017); they found that budget was increased rather than decreased. Two explanations are offered for this: first, that the harvest was too modest (quantity not being an aim for most of these gardeners), and second that they bought better quality items in other food categories (such as dry and processed food), resulting in higher spending on household food supplies. This illustrates that if significant food savings are expected, crop yield should be considered. Different shopping practices could be an effect of higher food literacy, with gardening modifying the way food choices are made.

On a local level, one review cited a study mentioning that gardening as a neighbourhood embellishment could raise property taxes, resulting in increased revenue for the city (Evans et al., 2022). At a larger scale, one review raised the question of monetary valuation of ecosystem services rendered by gardening. Such valuations have been conducted for urban agriculture in general, but no examples of results specific to gardening were reported (Nicholls et al., 2020).

Health and well-being outcomes

While we have described links between gardening and health determinants above, some studies have also directly linked gardening to several specific health outcomes: 17 reviews reported on such outcomes (see Table 1).

Only one review looked at morbi-mortality indicators. It concluded that, in elderly gardeners, the activity improved overall health, preventing falls through improved balance and gait, both inducing lower mortality and increasing longevity for those suffering from mobility impairments (Gagliardi and Piccinini, 2019).

Anthropometric outcomes. Six reviews (Kunpeuk et al., 2020, Tharrey and Darmon, 2021, Alaimo et al., 2016, Hume et al., 2022, Malberg Dyg et al., 2019, Hartig et al., 2014) reported on a selection of 12 studies on the association between gardening and BMI. Conclusions varied, depending on the studies selected for each review. One review (Malberg Dyg et al., 2019) selected just four studies on ethnic minorities (Zick et al., 2013, Barnidge et al., 2015, Baker et al., 2016) – one of which was in children (Castro et al., 2013), and noted that all four had positive results, i.e. they concluded that there was a decrease in BMI associated with community gardening. One meta-analysis (Kunpeuk et al., 2020) pooled nine groups of gardeners from five of the studies (Zick et al., 2013, Park et al., 2009, Hawkins et al., 2011, Etheredge et al., 2016, Wood et al., 2016) and found a non-significant decrease in BMI of 0.14 kg/m^2 (95% CI: -0.06; 0.34). However, there was a high level of heterogeneity, and all significant results showed a decrease in BMI. Targeted analysis of non-cross sectional studies found a similar 0.14 kg/m^2 and did reach significance (95% CI: 0.08; 0.53). Several reviews included one study showing no significant decrease in BMI among allotment or home gardeners, but comparators where individuals engaged in other active hobbies (such as walking or indoor exercise).

One review specific to quality of life among cancer survivors found some positive results in one study on stress, one on total cholesterol, HDL, and BP, and three on dietary habits (Bikomeye et al., 2022). Two reviews (Alaimo et al., 2016, Hume et al., 2022) found one study with positive results on Hg1Ac management in community gardeners having diabetes (Weltin and Lavin, 2012). Other anthropometric outcomes such as lung function (Hawkins et al., 2011), hand grip force (Park et al., 2009) or cholesterol levels (Park et al., 2017) have been investigated by various studies. However, because no outcome was repeated from one study to another, no conclusions can be drawn (Kunpeuk et al., 2020, Tharrey and Darmon, 2021, Hume et al., 2022).

Self-perceived health and well-being. Eight reviews commented on self-perceived health or other well-being indicators. One study (Litt et al., 2015), reported in two reviews (Alaimo et al., 2016, Malberg Dyg et al., 2019) conducted a path analysis and found that urban gardening was associated with better self-rated health through social involvement, aesthetics, and collective efficacy. Four other reviews (Lampert et al., 2021, Tharrey and Darmon, 2021, Hume et al., 2022, Kabisch et al., 2017) reported on seven studies (van den Berg et al., 2010, Blair et al., 1991, Hawkins et al., 2011, Mourão et al., 2019, Porter, 2018, Soga et al., 2017, Booth et al., 2018) that found positive associations between gardening and self-perceived health. One review on school gardens found no conclusive data in four quantitative studies, though qualitative data showed that children found enjoyment and satisfaction in the garden, and supervisors thought that gardening helped children manage their emotions more positively (Ohly et al., 2016).

One meta-analysis was conducted in 2017 [13]: the overall result covered all types of leisure gardening and horticultural therapy, providing 76 measurements across all three dimensions of health (physical, mental, and social). Targeted analysis for leisure gardening also found a positive association (43 measurements, 0.31 95% CI: 0.26 – 0.37).

Adverse health events. Our search yielded two reviews reporting on negative biological consequences of gardening. One showed gardening to be a risk factor for tick-borne diseases, especially for under-fives and, to a lesser extent, for adults aged 50 to 70 years. The other noted the potential of classic vegetable garden plants to induce contact dermatitis (Russo et al., 2017, Fischhoff et al., 2019). No further elements were reported on the frequency or severity of those risks. One review noted that some practices might be associated with biological contamination, such as the use of wastewater and organic waste (Nicholls et al., 2020).

Two other reviews looked at the potentially negative effects of gardening on physical health. One 2013 review on the physical health of gardeners aged over 65 found one (of eight included studies) that reported lower back pain during activities involving bending (Nicklett et al., 2016). The other, conducted in 2020, had "*any discomfort in terms of physical health*" in its outcomes of interest, and found no pertinent information in any of the eight quantitative studies included (Lampert et al., 2021).

One review involving children aged under six (Skelton et al., 2020) explicitly included adverse or unintended consequences of gardening in their scope: none were reported in the 20 studies they included.

Health effects depending on gardens and gardeners' characteristics

Gardeners' motivations & practices

Depending on their aims, different reviews have extracted different motivations from primary data. One review conducted in 2012 included motivations in its aims, finding that gardeners listed numerous reasons for gardening: "*to consume fresh foods, social development or cohesion such as community building and culture exchange, to improve health among members and to make or save money by eating from the garden or selling the*

produce. Other less common, but still important motivations, included: to educate, to enhance cultural practices, to access land, to enjoy nature, environmental sustainability and to enhance spiritual practice" (Guitart et al., 2012). Subsequent reviews relayed some or all of those motivations (Lampert et al., 2021, Schram-Bijkerk et al., 2018, Alaimo et al., 2016, Tournier and Postal, 2014, Genter et al., 2015, Wright et al., 2014, Uhlmann et al., 2018). Three of these (Lampert et al., 2021, Genter et al., 2015, Uhlmann et al., 2018) added "stress relief" to the list, each citing a study taken from a different context (van den Berg et al., 2010, Soga et al., 2017, Northrop et al., 2013).

One of the more recent reviews on community gardening found that only 24 of 53 included studies described the users of investigated gardens (Hume et al., 2022). Eight of those studies featured a comparison with another community group. Gardeners tended to be older or retirees, and educational attainment and income was inconsistent across studies. No comparison was found for urbanisation status or socioeconomic position.

One other review conducted in 2022 included 15 quantitative studies of community and allotment gardening in developed countries, and looked at time spent gardening (Tharrey and Darmon, 2021). Only four studies indicated length of time gardening prior to the study (ranging from $<$ 1 month to $>$ 20 years) and none evaluated its effect on outcomes. Five studies specified frequency of gardening, ranging from daily to less than once a month, with varied results depending on outcomes studied. Of note, one of the reported studies noted different effects depending on time spent actually gardening vs. time spent relaxing in the garden (van den Berg et al., 2010). Another review on the impact of domestic and community gardens on food provision (Garcia et al., 2018) noted that studied outcomes differed according to the gardens or gardeners studied, but no inferences were made. However, the critical appraisal of quantitative studies revealed that level of exposure to gardens was one of the weak points of the included studies.

Garden characteristics. One review suggested a seasonal benefit: higher physical activity in the spring and summer months (Alaimo et al., 2016), an aspect not raised in other reviews. Two reviews proposed different effects depending on type of garden (Schram-Bijkerk et al., 2018, Garcia et al., 2018). One such claim was unverified, while the other cited a single study (Veen et al., 2016) that found community gardens to be conducive to social cohesion, though no comparison with other types was provided.

Reviews on school gardens emphasised programme characteristics as a way of identifying which interventions were most effective (Davis et al., 2015, Ohly et al., 2016, Ozer, 2007, Chan et al., 2022). Overall, they found that outcomes were improved by hands-on experience and integration with the curriculum. The most recent review on school gardens (Chan et al., 2022) found that shorter, earlier age, smaller-sampled interventions had better results. Possible explanations for this are that when gardening ceases to be a novel experience and becomes a mainstream activity, its efficacy may be weakened, and that smaller samples provided more interactions between children, supervisors and the garden. An earlier age might be a more suitable period to address food neophobia. Parental involvement was associated with less effective interventions, but the actual involvement of parents was in fact low, despite various strategies designed to include them. Lastly, improvements were shown in developed countries but not in low- and middle-income countries – so school gardens might be effective in tackling issues related to developed countries.

Three reviews offered insight into the impact of planning and management decisions to draw environmental benefits from gardens (Cameron et al., 2012, Semeraro et al., 2021, Evans et al., 2022). This was true in terms of both choice of vegetation in the garden (i.e., cooling effect is stronger from shading trees, maintenance of genetic diversity can be enhanced if edible and non-edible vegetation is combined) (Cameron et al., 2012, Evans et al., 2022), and integration with other urban infrastructures (ideally, urban gardens could be used to recycle waste, wastewater, and waste heat). As for social capital aspects, garden access management was also important, where the garden was experienced as inclusive or exclusive depending on the sense and expression of ownership of the gardeners on the garden (Schram-Bijkerk et al., 2018, Burt et al., 2021, Al-Delaimy and Webb, 2017). Lastly, two reviews noted that both seniors and people living with dementia were able to benefit from gardening experiences where adaptation of practice allowed them to do so (Newton et al., 2021, Gagliardi and Piccinini, 2019).

Limiting factors. Some reviews mentioned challenges or limitations to the practice. One review found that the implantation or continuation of gardening activities could be limited by: access to (and durability of) land tenure, lack of water, safety issues (including soil contamination), and volunteer input stability (Guitart et al., 2012). The review on vulnerable populations (Malberg Dyg et al., 2019) included one study showing that food-insecure households rarely participate in community gardening, two other reviews identified one study showing that the time investment required might not be suited to families in difficulty, owing to lack of time, interest, space, skills or funding (Alaimo et al., 2016, Al-Delaimy and Webb, 2017).

Discussion

Main findings

This overview of 47 reviews found that gardening has been shown to affect six different types of health determinants, at both personal and community levels, through various pathways. Mental well-being, social capital, physical activity, and diet have been studied in a variety of settings and populations. Environmental and economic benefits are mentioned in the health-associated literature less often, but the evidence we have gathered here is promising.

In terms of mental well-being, gardening has shown stress-relieving properties and is associated with positive affect across all ages and settings. Input from qualitative studies found gardening to be embedded into gardener identities and views of the world. In terms of social capital, gardens are conducive to socialising, both through meeting new people and through strengthening existing relationships. However, evidence on the social support between gardeners on topics beyond gardening is scarce. Moreover, participation in community gardening is associated with civic involvement. In terms of physical activity, gardening implies the varied, low-to-moderate-intensity activities that can suit different gardeners according to age and ability. It can be an effective source of physical activity in highly sedentary or elderly gardeners. In terms of diet, increased consumption of vegetables in particular (and more modestly fruits) has been found in the existing literature. Evidence points to two pathways: enhanced accessibility and food literacy. The first has been emphasised in studies among vulnerable populations, while the latter has mainly garnered attention in school gardens – although evidence in adults also points to food literacy improvements. Other dietary changes have been reported as finding some success, but the evidence is too scant to draw conclusions.

Certain overarching phenomena underlie the impact on health determinants, such as: sharing behaviours in the garden, a caring attitude towards the self, community, and the environment grown as a result of taking care of plants.

Lower BMI and improved self-reported health have been found to be associated with gardening. Several other indicators of health and well-being have been used across studies, though these have not been repeated enough for conclusions to be drawn. In terms of risk, little was found on topics other than ingestion from soil contamination. Some elements were briefly described in specific contexts, such as: lower back pain during certain tasks; mental burden in seniors $>$ 80 years of age;

social exclusion in a garden where access to plots was not equal. Allergenic plants and tick-borne diseases were occasionally mentioned in passing. Care should be taken in the design and management of gardens, so as to minimise risk and maximise benefits.

Building on previous frameworks (Davis et al., 2015, Schram-Bijkerk et al., 2018, Howarth et al., 2020, Egli et al., 2016, Cruz-Piedrahita et al., 2020), a conceptual model is proposed in Fig. 3 to summarise findings. It integrates knowledge on the many pathways along which gardening can impact health, and highlights the influence of context in activating these pathways, so as to support a reliable, locally relevant environmental health impact assessment.

Strengths and limitations

This is the first overview of gardening and health ever to span such a large body of evidence. Following an integrative approach, we have summarised the positive and negative impacts of leisure gardening on health. We have reviewed the benefits and risks across a varied set of health determinants and gardening situations.

Some of the main limitations of this work are inherent to the methods used. Indeed, the overview of reviews was based on already-synthesised data: some elements that were either scarcely mentioned, or beyond the scope of the first level reviews, might not appear in this overview because they have been lost as a result of weak signals. Also, because our search string was based on health or well-being, some data from disciplines not traditionally related to health and well-being may not be visible in this overview. However, inclusion criteria were deliberately lax in an attempt to counterbalance this, and the included reviews did cover a wide range of disciplines. Other limitations are linked to the existing data. The geographic origin of the primary data is predominantly north American (Tharrey and Darmon, 2021, Gregis et al., 2021); some elements may not be pertinent to other developed countries. And because community and allotment gardens have garnered most attention, in home gardens, some mechanisms might differ in nature and intensity.

Moreover, definitions of gardens and gardening are somewhat variable across reviews. In particular, what is meant by the term “community” is not always the same. In this current review, we have used the term “leisure gardening” to clarify our scope. However, because it was the main source of data in children, we decided to include school gardens: this is open to criticism as being “formal” rather than “leisure” gardening. Other contextual information on gardens and gardeners is rarely presented in the reviews. This is especially important since researchers consistently note great heterogeneity between studies, and this is statistically confirmed in all three meta-analyses included here. Information on variables such as frequency and duration of gardening, activities performed in the garden, and crop yield might have explained some of those heterogenous results; such information is essential to any quantitative health assessment of gardening practices.

Despite the diversity of settings studied and results reported, similar mechanisms did however emerge across reviews. Furthermore, this overview spans a large body of evidence, since 471 primary studies formed the basis of the 47 included reviews. This allowed us to build the framework proposed in Fig. 3 as a common basis for integrated environmental health impact assessments, despite the potential differences in situations to be assessed.

Assessments should either observe or estimate modifying variables and proximal phenomena for the situation under consideration to infer probable impacts (risks and benefits) on health determinants and health indicators.Relation to existing knowledge & perspectives

In terms of psychosocial well-being, physical activity, environmental benefits, and cardiovascular health, the benefits of gardening are consistent with findings concerning green spaces (Hunter et al., 2019, Rojas-Rueda et al., 2019, Song et al., 2022). But gardens can also yield food growing benefits, dietary and economic; this is consistent with the urban agriculture literature (Evans et al., 2022). Gardens and gardening can in fact play many roles; they are at once outdoor green spaces (Bikomeye et al., 2022), urban food provision schemes (Garcia et al., 2018), natural landscapes (Abraham et al., 2010), and can provide opportunities for experiential learning (Ohly et al., 2016), nature-based solutions (Kabisch et al., 2017), and health-promoting activity (Hume et al., 2022). Each of these approaches showcases at least one benefit of gardening.

Where only a single health determinant is taken into account, gardening might not be the most effective intervention. In terms of diet, for example, the core components of any health intervention are accessibility, affordability, and acceptability. Gardening is therefore a viable entry point from which to tackle food insecurity or achieve nutritional targets. Yet intensive commercial agriculture (such as indoor aquaponics) might be more effective, since it offers high yields and low resource consumption. On the other hand, in terms of other aspects such as stress relief as a result of combining contact with nature with physical activity, or weight management via both physical activity and F&V consumption, synergistic effects could lead to amplified benefits in comparison with an intervention based on physical activity alone.

The integrated approach we use here highlights the fact that leisure gardening can support health in all its dimensions (physical, mental and social), and via several of its determinants. This sets “leisure gardening”

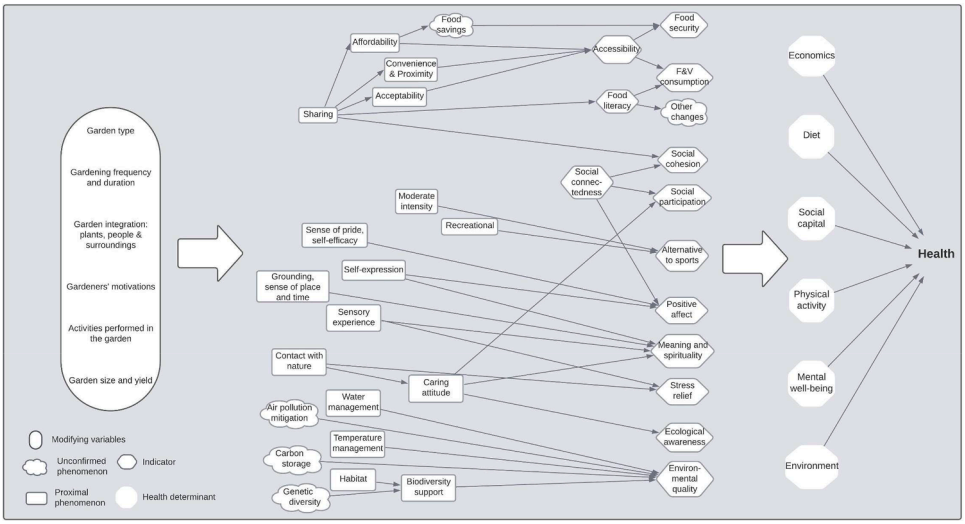

Fig. 3. Proposed logic framework for future environmental health impact assessments of gardening.

apart as a public health tool. Indeed, in a world in which resources are scarcer each day, high multifunctionality is essential to an activity's sustainability. Gardens provide such multifunctionality, on an individual, community and wider level. One review even argues that gardens in developed countries can play a part in meeting seven of the 17 United Nations Sustainable Development Goals (Nicholls et al., 2020). Environmental sustainability aside, gardens have also shown some of their most promising health effects in seniors (Wright et al., 2014). Consequently, they are also well placed to address another major public health challenge in developed countries, namely an ageing population.

In line with our overarching objective of improving gardening health assessment, this overview of reviews shows that gardening health impacts are not limited to soil contamination. On the contrary, other risks and many benefits also exist, and should be taken into account in the design, management and evaluation of gardening.

Conclusion

To gardeners, gardening is more than just a hobby; it is a meaningful, physical and sensory engagement with nature and the food system. Gardeners reap the benefits of their activity across various dimensions of health and its determinants, at both individual and community level, deriving satisfaction and feelings of well-being. For those who are capable of, and interested in, the practice, the many reasons for gardening are an argument for the uptake and continuity of gardening activities throughout life. Perhaps the strongest argument in favour of the health-promoting potential of gardening is its capacity to activate multiple levers of healthy behaviours and environments. This high multifunctionality is a valuable asset in addressing health challenges.

However, if we are to harness the full potential of leisure gardening, more information on context and gardening activities is needed to help us recognise which practices provide the best positive effects on health. This would also assist us in better integrating gardens to urban planning, and offering management recommendations. Complementary research would further consolidate the transdisciplinary perspective proposed here. Although economic benefits have been theorised and observed in some cases, the feasibility and efficiency of gardening to lower food spending, especially for food-insecure households, needs to be further investigated. This is crucial to effectively alleviate health inequities (Al-Delaimy and Webb, 2017). Overall, because consensus on definitions is lacking, authors should systematically describe the type of gardens they are talking about explicitly, including details of purpose and motivation. Activities performed in the garden and their intensity, frequency and duration should also be investigated and reported, then taken into account in subsequent reviews. Such information is essential to optimising the risk-benefit balance.

CRediT authorship contribution statement

Eugénie Albert: Writing – original draft, Visualization, Validation, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Anne Roué-Le Gall:** Writing – review & editing, Validation, Supervision, Conceptualization. **Philippe Glorennec:** Writing – review & editing, Validation, Supervision, Project administration, Funding acquisition, Conceptualization.

Declaration of competing interest

None of the authors declare a conflict of interest.

Data availability

Data will be made available on request.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.envadv.2024.100538.

References

Abraham, A., Sommerhalder, K., Abel, T., 2010. Landscape and well-being: a scoping study on the health-promoting impact of outdoor environments. Int. J. Public Health 55 (1), 59–69. https://doi.org/10.1007/s00038-009-0069-z.

Ainsworth, B.E., Haskell, W.L., Herrmann, S.D., et al., 2011. 2011 compendium of physical activities: a second update of codes and MET values. Med. Sci. Sport. Exerc. 43 (8), 1575–1581. https://doi.org/10.1249/MSS.0b013e31821ece12.

Alaimo, K., Beavers, A., Crawford, C., Snyder, E., Litt, J., 2016. Amplifying health through community gardens: a framework for advancing multicomponent, behaviorally based neighborhood interventions. Curr. Environ. Health Rep. 3 https://doi.org/10.1007/s40572-016-0105-0.

Al-Delaimy, W.K., Webb, M., 2017. Community gardens as environmental health interventions: benefits versus potential risks. Curr. Environ. Health Rep. 4 (2), 252–265. https://doi.org/10.1007/s40572-017-0133-4.

Algert, S.J., Baameur, A., Renvall, M.J., 2014. Vegetable output and cost savings of community gardens in San Jose, California. J. Acad. Nutrit. Dietet. 114 (7), 1072–1076. https://doi.org/10.1016/j.jand.2014.02.030.

Baker, E.A., Barnidge, E.K., Schootman, M., Sawicki, M., Motton-Kershaw, F.L., 2016. Adaptation of a modified DASH diet to a rural African American community setting. Am. J. Prev. Med. 51 (6), 967–974. https://doi.org/10.1016/j.amepre.2016.07.014.

Barnidge, E.K., Baker, E.A., Schootman, M., Motton, F., Sawicki, M., Rose, F., 2015. The effect of education plus access on perceived fruit and vegetable consumption in a rural African American community intervention. Health Educ. Res. 30 (5), 773–785. https://doi.org/10.1093/her/cyv041.

Berezowitz, C.K., Bontrager Yoder, A.B., Schoeller, D.A., 2015. School gardens enhance academic performance and dietary outcomes in children. J. Sch. Health 85 (8), 508–518. https://doi.org/10.1111/josh.12278.

Bikomeye, J.C., Balza, J.S., Kwarteng, J.L., Beyer, A.M., Beyer, K.M.M., 2022. The impact of greenspace or nature-based interventions on cardiovascular health or cancer-related outcomes: A systematic review of experimental studies. PLoS One 17 (11), e0276517. https://doi.org/10.1371/journal.pone.0276517.

Blair, C.K., Harding, E.M., Adsul, P., et al., 2021. Southwest Harvest for health: adapting a mentored vegetable gardening intervention for cancer survivors in the southwest. Contemp. Clin. Trial. Commun. 21, 100741 https://doi.org/10.1016/j.conctc.2021.100741.

Blair, D., Giesecke, C.C., Sherman, S., 1991. A dietary, social and economic evaluation of the Philadelphia urban gardening project. J. Nutrit. Educ. 23 (4), 161–167. https://doi.org/10.1016/S0022-3182(12)81191-5.

Booth, J.M., Chapman, D., Ohmer, M.L., Wei, K., 2018. Examining the relationship between level of participation in community gardens and their multiple functions. J. Commun. Pract. 26 (1), 5–22. https://doi.org/10.1080/10705422.2017.1413024.

Bowker, R., Tearle, P., 2007. Gardening as a learning environment: a study of children's perceptions and understanding of school gardens as part of an international project. Learn. Environ. Res. 10 (2), 83–100. https://doi.org/10.1007/s10984-007-9025-0.

Briggs, D.J., 2008. A framework for integrated environmental health impact assessment of systemic risks. Environ. Health 7 (1), 61. https://doi.org/10.1186/1476-069X-7-61.

Burke, T.A., Cascio, W.E., Costa, D.L., et al., 2017. Rethinking environmental protection: meeting the challenges of a changing world. Environ. Health Perspect. 125 (3), A43–A49. https://doi.org/10.1289/EHP1465.

Burt, K.G., Mayer, G., Paul, R., 2021. A systematic, mixed studies review of the outcomes of community garden participation related to food justice. Local Environ. 26 (1), 17–42. https://doi.org/10.1080/13549839.2020.1861589.

Cameron, R.W.F., Blanusa, T., Taylor, J.E., et al., 2012. The domestic garden - its contribution to urban green infrastructure. Urban Forest. Urban Green. 11 (2), 129–137. https://doi.org/10.1016/j.ufug.2012.01.002.

Carinanos, P., Casares-Porcel, M., 2011. Urban green zones and related pollen allergy: a review. Some guidelines for designing spaces with low allergy impact. Landsc. Urban Plann. 101 (3), 205–214. https://doi.org/10.1016/j.landurbplan.2011.03.006.

Castro, D.C., Samuels, M., Harman, A.E., 2013. Growing healthy kids: a community garden–based obesity prevention program. Am. J. Prevent. Med. 44 (3), S193–S199. https://doi.org/10.1016/j.amepre.2012.11.024.

Chan, C.L., Tan, P.Y., Gong, Y.Y., 2022. Evaluating the impacts of school garden-based programmes on diet and nutrition-related knowledge, attitudes and practices among the school children: a systematic review. BMC Public Health 22 (1), 1251. https://doi.org/10.1186/s12889-022-13587-x.

Constitution of the World Health Organization. Accessed January 23, 2024. https://www.who.int/about/accountability/governance/constitution.

Cruz-Piedrahita, C., Howe, C., Nazelle, A., 2020. Public health benefits from urban horticulture in the global north: A scoping review and framework. Glob. Transit. 2, 246–256. https://doi.org/10.1016/j.glt.2020.10.001.

Davies, Z.G., Fuller, R.A., Loram, A., Irvine, K.N., Sims, V., Gaston, K.J., 2009. A national scale inventory of resource provision for biodiversity within domestic gardens. Biolog. Conservat. 142 (4), 761–771. https://doi.org/10.1016/j.biocon.2008.12.016.

Davis, J.N., Spaniol, M.R., Somerset, S., 2015. Sustenance and sustainability: maximizing the impact of school gardens on health outcomes. Public Health Nutr. 18 (13), 2358–2367. https://doi.org/10.1017/S1368980015000221.

Ecosystems Division of the UN environment programme. Joint Tripartite (FAO, OIE, WHO) and UNEP Statement Tripartite and UNEP support OHHLEP's definition of "One Health". Published online 2021. Accessed August 24, 2023. https://wedocs.unep.org/xmlui/handle/20.500.11822/37600.

Egli, V., Smith, M., Tautolo, E.S., 2016. The development of a model of community garden benefits to wellbeing. Prevent. Med. Rep. 3, 348–352. https://doi.org/10.1016/j.pmedr.2016.04.005.

Ehsan, A., Klaas, H.S., Bastianen, A., Spini, D., 2019. Social capital and health: A systematic review of systematic reviews. SSM Popul. Health 8, 100425. https://doi.org/10.1016/j.ssmph.2019.100425.

Etheredge, C.L., Waliczek, T.M., Zajicek, J.M., 2016. The influence of gardening activities on self-reported health problems, allergies, and body mass index. HortTechnology 26 (6), 776–782. https://doi.org/10.21273/HORTTECH03546-16.

Evans, D.L., Falagan, N., Hardman, C.A., et al., 2022. Ecosystem service delivery by urban agriculture and green infrastructure-a systematic review. Ecosyst. Serv. 54 https://doi.org/10.1016/j.ecoser.2022.101405.

Fänge, A., Ivanoff, S.D., 2009. The home is the hub of health in very old age: findings from the ENABLE-AGE Project. Arch. Gerontol. Geriatr. 48 (3), 340–345. https://doi.org/10.1016/j.archger.2008.02.015.

FAO, 2021. UNEP. chapter 4. environmental, health and socio-economic impacts of soil pollution. Global Assessment of Soil Pollution: Report. https://doi.org/10.4060/cb4894en.

Ferris, J., Norman, C., Sempik, J., 2001. People, Land and Sustainability: community Gardens and the social dimension of sustainable development. Soc. Pol. Administr. 35 (5), 559–568. https://doi.org/10.1111/1467-9515.t01-1-00253.

ro Filazzola, A., Shrestha, N., MacIvor, J.S., 2019. The contribution of constructed green infrastructure to urban biodiversity: a synthesis and meta-analysis. J. Appl. Ecol. 56 (9), 2131–2143. https://doi.org/10.1111/1365-2664.13475.

Fischhoff, I.R., Keesing, F., Ostfeld, R.S., 2019. Risk factors for bites and diseases associated with black-legged ticks: a meta-analysis. Am. J. Epidemiol. 188 (9), 1742–1750. https://doi.org/10.1093/aje/kwz130.

Freeman, C., Dickinson, K.J.M., Porter, S., van Heezik, Y., 2012. My garden is an expression of me": Exploring householders' relationships with their gardens. J. Environ. Psychol. 32 (2), 135–143. https://doi.org/10.1016/j.jenvp.2012.01.005.

Gaekwad, J.S., Sal Moslehian, A., Roös, P.B., Walker, A., 2022. A meta-analysis of emotional evidence for the biophilia hypothesis and implications for biophilic design. Front Psychol. 13, 750245 https://doi.org/10.3389/fpsyg.2022.750245.

Gagliardi, C., Piccinini, F., 2019. The use of nature - based activities for the well-being of older people: An integrative literature review. Arch. Gerontol. Geriatr. 83, 315–327. https://doi.org/10.1016/j.archger.2019.05.012.

Garcia, M.T., Ribeiro, S.M., Germani, A.C.C.G., Bógus, C.M., 2018. The impact of urban gardens on adequate and healthy food: a systematic review. Public Health Nutr. 21 (2), 416–425. https://doi.org/10.1017/S1368980017002944.

Genter, C., Roberts, A., Richardson, J., Sheaff, M., 2015. The contribution of allotment gardening to health and wellbeing: A systematic review of the literature. Brit. J. Occupat. Ther. 78, 593–605. https://doi.org/10.1177/0308022615599408.

Glover, T., SHINEW, K., Parry, D., 2005. Association, sociability, and civic culture: the democratic effect of community gardening. Leisur. Sci. 27, 75–92. https://doi.org/10.1080/01490400590886060.

Gregis, A., Ghisalberti, C., Sciascia, S., Sottile, F., Cristiana, P., 2021. Community garden initiatives addressing health and well-being outcomes: a systematic review of infodemiology aspects, outcomes, and target populations. Int. J. Environ. Res. Public Health 18, 1943. https://doi.org/10.3390/ijerph18041943.

Guitart, D., Pickering, C., Byrne, J., 2012. Past results and future directions in urban community gardens research. Urban Forest. Urban Green. 11 (4), 364–373. https://doi.org/10.1016/j.ufug.2012.06.007.

Hansen-Ketchum, P., Marck, P., Reutter, L., 2009. Engaging with nature to promote health: new directions for nursing research. J. Adv. Nurs. 65 (7), 1527–1538. https://doi.org/10.1111/j.1365-2648.2009.04989.x.

Hartig, T., Mitchell, R., de Vries, S., Frumkin, H., 2014. Nature and health - annual review of public health. Ann. Rev. 35 https://doi.org/10.1146/annurev-publhealth-032013-182443.

Hawkins, J.L., Thirlaway, K.J., Backx, K., Clayton, D.A., 2011. Allotment gardening and other leisure activities for stress reduction and healthy aging. HortTechnology 21 (5), 577–585. https://doi.org/10.21273/HORTTECH.21.5.577.

Howarth, M., Brettle, A., Hardman, M., Maden, M., 2020. What is the evidence for the impact of gardens and gardening on health and well-being: a scoping review and evidence-based logic model to guide healthcare strategy decision making on the use of gardening approaches as a social prescription. BMJ Open 10 (7), e036923. https://doi.org/10.1136/bmjopen-2020-036923.

Hume, C., Grieger, J.A., Kalamkarian, A., D'Onise, K., Smithers, L.G., 2022. Community gardens and their effects on diet, health, psychosocial and community outcomes: a systematic review. BMC Public Health 22 (1), 1247. https://doi.org/10.1186/s12889-022-13591-1.

Hunter, R.F., Cleland, C., Cleary, A., et al., 2019. Environmental, health, wellbeing, social and equity effects of urban green space interventions: A meta-narrative evidence synthesis. Environ. Int. 130, 104923 https://doi.org/10.1016/j.envint.2019.104923.

Kabisch, N., van den Bosch, M., Lafortezza, R., 2017. The health benefits of nature-based solutions to urbanization challenges for children and the elderly – a systematic review. Environ. Res. 159, 362–373. https://doi.org/10.1016/j.envres.2017.08.004.

Kamphuis, C.B.M., Giskes, K., de Bruijn, G.J., et al., 2006. Environmental determinants of fruit and vegetable consumption among adults: a systematic review. Brit. J. Nutrit. 96 (4), 620–635. https://doi.org/10.1079/BJN20061896.

Keshavarz Mohammadi, N., 2019. One step back toward the future of health promotion: complexity-informed health promotion. Health Promot. Int. 34 (4), 635–639. https://doi.org/10.1093/heapro/daz084.

Knight, T., Price, S., Bowler, D., et al., 2021. How effective is `greening' of urban areas in reducing human exposure to ground-level ozone concentrations, UV exposure and the `urban heat island effect'? An updated systematic review. Environ. Evid. 10 (1) https://doi.org/10.1186/s13750-021-00226-y.

Kunpeuk, W., Spence, W., Phulkerd, S., Suphanchaimat, R., Pitayarangsarit, S., 2020. The impact of gardening on nutrition and physical health outcomes: a systematic review and meta-analysis. Health Promot. Int. 35 (2), 397–408. https://doi.org/10.1093/heapro/daz027.

Lampert, T., Costa, J., Santos, O., Sousa, J., Ribeiro, T., Freire, E., 2021. Evidence on the contribution of community gardens to promote physical and mental health and well-being of non-institutionalized individuals: a systematic review. PLoS One 16 (8), e0255621. https://doi.org/10.1371/journal.pone.0255621.

Land use — European Environment Agency. Accessed February 1, 2024. https://www.eea.europa.eu/themes/landuse/intro.

Leavell, M.A., Leiferman, J.A., Gascon, M., Braddick, F., Gonzalez, J.C., Litt, J.S., 2019. Nature-based social prescribing in urban settings to improve social connectedness and mental well-being: a review. Curr. Environ. Health Rep. 6 (4), 297–308. https://doi.org/10.1007/s40572-019-00251-7.

Litt, J.S., Schmiege, S.J., Hale, J.W., Buchenau, M., Sancar, F., 2015. Exploring ecological, emotional and social levers of self-rated health for urban gardeners and non-gardeners: a path analysis. Soc. Sci. Med. 144, 1–8. https://doi.org/10.1016/j.socscimed.2015.09.004.

Machida, D., Kushida, O., 2020. The influence of food production experience on dietary knowledge, awareness, behaviors, and health among Japanese: a systematic review. Int. J. Environ. Res. Public Health 17 (3). https://doi.org/10.3390/ijerph17030924.

Maćkiewicz, B., Szczepańska, M., Kacprzak, E., Fox-Kämper, R., 2021. Between food growing and leisure: contemporary allotment gardeners in Western Germany and Poland. DIE ERDE – J. Geograph. Soc. Berlin. 152 (1), 33–50. https://doi.org/10.12854/erde-2021-502.

Malberg Dyg, P., Christensen, S., Peterson, C., 2019. Community gardens and wellbeing amongst vulnerable populations: a thematic review. Health Promot. Int. 35, 1–14. https://doi.org/10.1093/heapro/daz067.

Martin, P., Consalès, J.N., Scheromm, P., Marchand, P., Ghestem, F., Darmon, N., 2017. Community gardening in poor neighborhoods in France: a way to re-think food practices? Appetite 116, 589–598. https://doi.org/10.1016/j.appet.2017.05.023.

McCrorie, P.R.W., Fenton, C., ida Ellaway, A., 2014. Combining GPS, GIS, and accelerometry to explore the physical activity and environment relationship in children and young people - a review. Int. J. Behav. Nutrit. Phys. Activ. 11. https://doi.org/10.1186/s12966-014-0093-0.

Mourão, I., Moreira, M.C., Almeida, T.C., Brito, L.M., 2019. Perceived changes in well-being and happiness with gardening in urban organic allotments in Portugal. Int. J. Sustain. Develop. World Ecol. 26 (1), 79–89. https://doi.org/10.1080/13504509.2018.1469550.

Newton R., Keady J., Tsekleves E., Adams S. `My father is a gardener ... `: a systematic narrative review on access and use of the garden by people living with dementia ... Health Place. 2021;68. doi:10.1016/j.healthplace.2021.102516.

Nicholls, E., Ely, A., Birkin, L., Basu, P., Goulson, D., 2020. The contribution of small-scale food production in urban areas to the sustainable development goals: a review and case study. Sustain. Sci. 15 (6), 1585–1599. https://doi.org/10.1007/s11625-020-00792-z.

Nicklett, E.J., Anderson, L.A., Yen, I.H., 2016. Gardening activities and physical health among older adults: a review of the evidence. J. Appl. Gerontol. 35 (6), 678–690. https://doi.org/10.1177/0733464814563608.

Northrop, M.D., Wingo, B., Ard, J., 2013. The perceptions of community gardeners at Jones Valley urban farm and the implications for dietary interventions. Qualit. Rep. 18 https://doi.org/10.46743/2160-3715/2013.1495.

Ohly, H., Gentry, S., Wigglesworth, R., Bethel, A., Lovell, R., Garside, R., 2016. A systematic review of the health and well-being impacts of school gardening: synthesis of quantitative and qualitative evidence. BMC Public Health 16, 286. https://doi.org/10.1186/s12889-016-2941-0.

Ozer, E.J., 2007. The effects of school gardens on students and schools: conceptualization and considerations for maximizing healthy development. Health Educ. Behav. 34 (6), 846–863. https://doi.org/10.1177/1090198106289002.

Page, M.J., McKenzie, J.E., Bossuyt, P.M., et al., 2021. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 372, n71. https://doi.org/10.1136/bmj.n71.

Park, S.A., Lee, A.Y., Park, H.G., Son, K.C., Kim, D.S., Lee, W.L., 2017. Gardening intervention as a low- to moderate-intensity physical activity for improving blood lipid profiles, blood pressure, inflammation, and oxidative stress in women over the age of 70: a pilot study. HortScience 52, 200–205. https://doi.org/10.21273/HORTSCI11232-16.

Park, S.A., Shoemaker, C.A., Haub, M.D., 2009. Physical and psychological health conditions of older adults classified as gardeners or nongardeners. HortScience 44 (1), 206–210. https://doi.org/10.21273/HORTSCI.44.1.206.

Pieper, D., Antoine, S.L., Mathes, T., Neugebauer, E.A.M., Eikermann, M., 2014. Systematic review finds overlapping reviews were not mentioned in every other

overview. J. Clin. Epidemiol. 67 (4), 368–375. https://doi.org/10.1016/j.jclinepi.2013.11.007.
Porter, C.M., 2018. What gardens grow: outcomes from home and community gardens supported by community-based food justice organizations. J. Agric. Food Syst. Commun. Dev. 8 (Suppl 1), 187–205. https://doi.org/10.5304/jafscd.2018.08A.002.
Rojas-Rueda, D., Nieuwenhuijsen, M.J., Gascon, M., Perez-Leon, D., Mudu, P., 2019. Green spaces and mortality: a systematic review and meta-analysis of cohort studies. Lancet Planet. Health 3 (11), e469–e477. https://doi.org/10.1016/S2542-5196(19)30215-3.
Russo, A., Escobedo, F.J., Cirella, G.T., Zerbe, S., 2017. Edible green infrastructure: an approach and review of provisioning ecosystem services and disservices in urban environments. Agricult. Ecosyst. Environ. 242, 53–66. https://doi.org/10.1016/j.agee.2017.03.026.
Savoie-Roskos, M.R., Wengreen, H., Durward, C., 2017. Increasing fruit and vegetable intake among children and youth through gardening-based interventions: a systematic review. J. Acad. Nutr. Diet. 117 (2), 240–250. https://doi.org/10.1016/j.jand.2016.10.014.
Schram-Bijkerk, D., Otte, P., Dirven, L., Breure, A.M., 2018. Indicators to support healthy urban gardening in urban management. Sci. Total Environ. 621, 863–871. https://doi.org/10.1016/j.scitotenv.2017.11.160.
Scott, T., Masser, B., Pachana, N., August 27, 2014. Exploring the health and wellbeing benefits of gardening for older adults. Age. Soc. https://doi.org/10.1017/S0144686X14000865. Published online.
Semeraro, T., Scarano, A., Buccolieri, R., Santino, A., Aarrevaara, E., 2021. Planning of urban green spaces: an ecological perspective on human benefits. Land 10 (2), 105. https://doi.org/10.3390/land10020105.
Skelton, K.R., Lowe, C., Zaltz, D.A., Benjamin-Neelon, S.E., 2020. Garden-based interventions and early childhood health: an umbrella review. Int. J. Behav. Nutr. Phys. Act. 17 (1), 121. https://doi.org/10.1186/s12966-020-01023-5.
Soga, M., Cox, D.T.C., Yamaura, Y., Gaston, K.J., Kurisu, K., Hanaki, K., 2017. Health benefits of urban allotment gardening: improved physical and psychological well-being and social integration. Int. J. Environ. Res. Public Health 14 (1). https://doi.org/10.3390/ijerph14010071.
Soga, M., Gaston, K.J., Yamaura, Y., 2017. Gardening is beneficial for health: a meta-analysis. Prev. Med. Rep. 5, 92–99. https://doi.org/10.1016/j.pmedr.2016.11.007.
Song, S., Tu, R., Lu, Y., Yin, S., Lin, H., Xiao, Y., 2022. Restorative effects from green exposure: a systematic review and meta-analysis of randomized control trials. Int. J. Environ. Res. Public Health 19 (21), 14506. https://doi.org/10.3390/ijerph192114506.
Spano, G., D'Este, M., Giannico, V., et al., 2020. Are community gardening and horticultural interventions beneficial for psychosocial well-being? A meta-analysis. Int. J. Environ. Res. Public Health 17 (10). https://doi.org/10.3390/ijerph17103584.
Stevenson, M.P., Schilhab, T., Bentsen, P., 2018. Attention restoration theory II: a systematic review to clarify attention processes affected by exposure to natural environments. J. Toxicol. Environ. Health, Part B 21 (4), 227–268. https://doi.org/10.1080/10937404.2018.1505571.
Tharrey, M., Darmon, N., 2021. Urban collective garden participation and health: a systematic literature review of potential benefits for free-living adults. Nutrit. Rev. (nuaa147) https://doi.org/10.1093/nutrit/nuaa147.
Tournier, I., Postal, V., 2014. [An integrative model of the psychological benefits of gardening in older adults]. Geriatr. Psychol. Neuropsychiatr. Vieil. 12 (4), 424–431. https://doi.org/10.1684/pnv.2014.0498.
Truman, E., Lane, D., Elliott, C., 2017. Defining food literacy: a scoping review. Appetite 116, 365–371. https://doi.org/10.1016/j.appet.2017.05.007.
Uhlmann, K., Lin, B.B., Ross, H., 2018. Who cares? The importance of emotional connections with nature to ensure food security and wellbeing in cities. Sustainability 10 (6). https://doi.org/10.3390/su10061844.
van den Berg, A.E., van Winsum-Westra, M., de Vries, S., van Dillen, S.M.E., 2010. Allotment gardening and health: a comparative survey among allotment gardeners and their neighbors without an allotment. Environ. Health: Glob Access Sci. Sourc. 9, 74–85. https://doi.org/10.1186/1476-069X-9-74.
Veen, E.J., Bock, B.B., Berg, W.V.d., Visser, A.J., Wiskerke, J.S.C., 2016. Community gardening and social cohesion: different designs, different motivations. Loc. Environ. 21 (10), 1271–1287. https://doi.org/10.1080/13549839.2015.1101433.
Wakefield, S., Yeudall, F., Taron, C., Reynolds, J., Skinner, A., 2007. Growing urban health: community gardening in South-East Toronto. Health Promot. Int. 22 (2), 92–101. https://doi.org/10.1093/heapro/dam001.
Weltin, A.M., Lavin, R.P., 2012. The effect of a community garden on HgA1c in diabetics of Marshallese descent. J. Commun. Health Nurs. 29 (1), 12–24. https://doi.org/10.1080/07370016.2012.645724.
Wolf, K.L., Robbins, A.S.T., 2015. Metro nature, environmental health, and economic value. Environ. Health Perspect. 123 (5), 390–398. https://doi.org/10.1289/ehp.1408216.
Wood, C.J., Pretty, J., Griffin, M., 2016. A case–control study of the health and well-being benefits of allotment gardening. J. Public Health 38 (3), e336–e344. https://doi.org/10.1093/pubmed/fdv146.
Wright, S., Wadsworth, A., 2014. Gray and green revisited: a multidisciplinary perspective of gardens, gardening, and the aging process. J. Aging Res., 283682 https://doi.org/10.1155/2014/283682, 2014.
York, M., Wiseman, T., 2012. Gardening as an occupation: a critical review. Brit. J. Occupat. Ther. 75 (2), 76–84. https://doi.org/10.4276/030802212X13286281651072.
Zick, C.D., Smith, K.R., Kowaleski-Jones, L., Uno, C., Merrill, B.J., 2013. Harvesting more than vegetables: the potential weight control benefits of community gardening. Am. J. Public Health 103 (6), 1110–1115. https://doi.org/10.2105/AJPH.2012.301009.