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Review

Urban Gardening in a Changing Climate: A Review of Effects, Responses and Adaptation Capacities for Cities

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Abstract: Climate change is impacting the ecological, social and technological aspects of urban gardens. Gardens experience threats (e.g., water scarcity) but are also responding through adaptation strategies (e.g., selecting drought-resilient plants). A synthetic overview of how urban gardens are affected by climate change and responding to climate change is unclear. Here, we systematically reviewed articles and book chapters published in the last two decades (2000–2022) to illustrate the relationship between climate change and urban gardening. From 72 documents analyzed with Nvivo Software, we found that there has been an increase in academic publications. Universities from the US (14) and Germany (9) universities are the dominant producers. Evidence shows that climate change can have negative impacts on cities, people and urban food. Suggestions on how to build the adaptation capacity of urban gardens include collecting rainwater, changing plant selection, changing planting times, applying vegetative cover on the soil and other practices. For cities, community and allotment gardens are helpful for adaptation, mitigation and resilience. This includes the capacity to regulate the microclimate, to reduce urban heat island effects and to buffer urban floods, the power to capture carbon, the ability to create social networks and other socio-environmental benefits for urban climate planning.

Keywords: urban gardens; community gardens; allotment gardens; adaptive gardening; climate change; urban mitigation; urban adaptation; urban resilience; urban sustainability

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1. Introduction

Urban gardening is receiving a great deal of academic attention due to popularity in society and city planning [1], as has the impacts of climate change on cities and their adaptation [2]. However, the volume of scientific literature on community gardening per se is small [3]. Most of this literature provides evidence for the benefits of community gardening related to social aspects, such as stress rejuvenation and well-being [4]. Furthermore, little is presently known about the effects of climate change-related events on urban food production or the resilience of urban gardening and urban food supply to extreme climate conditions [5].

Urban gardening is a practice of urban agriculture (UA) that can be defined as the production of crop and livestock goods within a city's boundaries [2,6]. UA can occur in home yards, on rooftops and in public spaces, in settings for private use and for enterprise [7,8]. UA has many diverse initiatives [9] such as urban farms, allotment gardens, community gardens, collective gardens, therapeutic gardens [10], private gardens, easement gardens [11], family gardens, educational and school gardens [12], vertical and hydroponics farming [10], guerrilla gardens [7], indoor farms, windowsill gardens, balcony gardens [13], rooftop gardens, among others [14]. Here, we focus on community gardens and allotment gardens, often considered synonymous, but they differ from each other. In allotment gardens, land is subdivided and parcels are cultivated individually, while in community gardens, an entire area is tended by a collective group [11]. In addition, the concept changes geographically because the term "community gardens" has different meanings [10]. For example, North American community gardens may be considered a hybrid between European allotment gardens and European community gardens [10].

There are limited studies that assess urban and peri-urban gardening's possible benefits to climate change adaptation and food security maintenance [15]. Among these benefits, the following are considered: climate regulation, carbon capture, water retention, food security, educational opportunities on environmental issues, etc. More research is needed to understand how plants in urban agroecosystems will respond to increasing temperatures, drought, changes in precipitation patterns, nutrient deposition, and weather extremes [11].

The current revival of urban gardening and growing impacts of climate change in cities motivates this review. In order to illustrate the main relationships of urban gardens with climate change, in this review, the following questions will be examined and analyzed: (1) what are the effects of climate change on urban gardens, (2) how are urban gardens responding and adapting to climate change and (3) what are the adaptation, mitigation and resilience capacities of urban gardens for cities? To investigate these questions, we reviewed the literature to identify and compile the main climate change threats experienced by urban gardens and the main ways to respond, in addition to the potential that these spaces offer to cities in terms of adaptation, mitigation, and resilience. For this, a systematic review was carried out, following the PRISMA methodology, with the stages of (a) "Searching", (b) "Screening" and (c) "Include to encode". To further contextualize our review, we briefly provide context of the urban environment, urban gardening and its function as an urban agricultural practice in a climate context.

1.1. Cities Need to Address the Challenge of Food Supply and Climate Change

Urban areas are now home to 4.2 billion people [16] and represent about 56 percent of the world's population [13]. The projections indicate that approximately 70 percent will live in cities by 2050 [17,18]. Consequently, cities need increases in food supplies [15], and the people are highly exposed to climate change impacts [16]. Urbanization, food security and climate change are three closely linked issues [15].

- The agri-food sector generates 21–37% global greenhouse gas (GHG) emissions [18], a figure which increased by 16% between 1990 and 2019 [19]. The urban areas generate over 70% of the GHG emissions [15].
- Agriculture is highly dependent on climatic conditions and susceptible to projected climate changes [20]. Climate change impacts are stressing agriculture [16], and highly centralized agriculture is more vulnerable [21]. Stronger and more irregular precipitation or increased temperatures lead to significant declines in crop yields and crop stability [5].
- Climate change reduces the quality of urban life through Urban Heat Islands (UHI), pollutions, storms, and floods and leads to significant impacts on human health and economy [22]. Urban populations are expected to experience longer and more frequent extreme heat, drought and flooding events [23].

In this context, cities are recognized as key actors in supporting systemic change and climate change governance [24]. Cities need to be at the forefront of sustainable development [24] and need to address the triple challenge of climate change mitigation, adaptation and improving urban food security and resilience [2]. We follow the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) [16] in defining these terms:

- Adaptation: In human systems, the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate and its effects [16].

- Mitigation: Human intervention to reduce emissions or enhance the sinks of GHG. Moreover, mitigation potential is the quantity of net GHG reductions that can be achieved by a given mitigation option relative to specific emission baselines [16].
- Resilience: The capacity of interconnected social, economic and ecological systems to cope with a hazardous event, trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure [16].

1.2. Renaissance of Urban Gardens in Climate Crisis

Urban community gardening movements and practices were very important for people and cities throughout history, particularly during periods of social, economic [10] and environmental crisis [25]. Some historical cases of crisis that motivated the implementation of urban gardening were: the Great Depression [26]; the First and Second World Wars [26]; post-war periods [1]; the collapse of the Soviet Union [27]; the socialist bloc in Cuba [28]; the 1970s oil crisis [14,27] and the economic recession of that decade [10]; post-Hurricane Sandy [25]; economic and financial recession in Southern European countries (e.g., in Spain during the 2000s, in Portugal after 2000 and later in Greece in 2010) [14,28]. Currently, we can consider the climate context as a contemporary crisis of the 21st century: The IPCC confirms that the climate extremes have led to irreversible impacts, and the most ambitious GHG mitigation scenarios indicate that climate change will continue for decades to centuries [16]. Climate change intensifies existing vulnerability and inequalities, considering that there are particular regions with more urgent adaptation needs [16].

Urban gardening dates back to the beginning of the urban living [1], and urban food production is currently experiencing a renaissance and becoming a global trend [29]. In the context of climate change, the impacts on food availability and nutritional quality will increase the number of people at risk of hunger, malnutrition and diet-related mortality (vulnerable groups being most at risk) [16]. For these reasons, the climatic crisis can support and motivate the renaissance of urban gardens, as historical moments of crisis did. On the other hand, urban gardens can help cities and people to be more resilient in the context of climate crisis through their adaptation and mitigation opportunities mentioned in the results section.

2. Methods

We used a systematic review in order to collect a range of existing evidence, studies and scientific analyses in published literature on urban gardens, particularly community and allotment gardens, and climate change. We followed the PRISMA methodology and process [30], which is an evidence-based minimum set of elements to report in systematic reviews and meta-analyses.

In the stages of the systematic review, we asked an initial research question, we formulated the eligibility criteria (general and particular), we delimited the terms for the bibliographic search, we searched for the scientific literature in bibliographic databases and we downloaded the results. Then, we refined the captured literature according to the established criteria (Table 1). Finally, we selected the literature for reading, analysis and coding with Nvivo Software Version Release 1.6.1.

Table 1. Eligibility criteria defined for the review.

Criteria	Considerations of Criteria
General (applicable for the "Searching" stage)	- The bibliographic databases were WOS and Scopus; - The publication years were 2000–2022; - The types of documents were articles and book chapters (excluding conference papers, reviews, books, conference reviews, letters, errata, notes, short surveys, meetings and others); - No open-access selections; - No language limitations; - No country/region limitations; - No subject area limitations; - No other general filters.

Table 1. *Cont.*

Criteria	Considerations of Criteria
Particular (applicable for the "Screening" and "Included to encode" stages)	- The publications referred to urban gardens with special interest in community gardens and allotment gardens (excluding other initiatives of UA); - The publications corresponded to gardens located in urban or peri-urban areas (excluding rural areas); - The publications referred, directly or indirectly, to climate threats and the capacities of mitigation, adaptation and resilience.

2.1. Terms and Searching Bibliographic Databases

We conducted an exhaustive search of the literature using bibliographic databases such as Web of Science (WOS) and Scopus, the global bibliographic references managed by the Spanish Foundation for Science and Technology (FECYT). FECYT is a public foundation dependent on the Ministry of Science and Innovation of the Government of Spain. The terms that we used for the bibliographic search were discussed and tested, regarding specificity and sensitivity, using the selected databases.

We linked the searches to the relationship between *Urban Gardens* and *Climate Change*, considered as the central terms to solve our research question. Therefore, to obtain a broader search, we discussed, searched and defined synonyms for the core terms mentioned: For *Urban gardens*, we defined the synonyms of "*Community gardens*", "*Urban community gardens*", "*Urban agriculture*", "*Urban agroecosystems*", "*Urban horticulture*" and "*Allotment gardens*". For *Climate change*, we defined the synonyms of "*Mitigation*", "*Adaptation*", "*Resilience*", "*Heat island*" and "*Urban environment*". In this way, we decided to cross a group of terms that contemplate the concept of *Urban gardens* with another group that represents the concept of *Climate change* (also contemplating these central terms). This initial stage of the bibliographic search was called (a) "Searching" and is explained below:

(a) Searching:

Once the central terms with their respective synonyms were defined, we performed a first search in WOS and Scopus using all the possible combinations between the terms of the two groups. We used simple Boolean operators such as "*AND*" and "*OR*" for the combination of terms.

For the search, we tested all terms in the group corresponding to *Urban gardens* in combination with all terms in the group corresponding to *Climate change* (using only one term for each group). In addition, we performed another search that had all the terms of the group corresponding to *Urban gardens* (separated with "*OR*"), with all the terms of the group corresponding to *Climate change* (also separated from each other with "*OR*"). Both groups of terms were integrated in the same search with the Boolean operator "*AND*".

We found that in these first searches, the terms "*Urban agriculture*" and "*Urban environment*", with their respective combinations, generated too much irrelevant literature. Therefore, we excluded the terms "*Urban agriculture*" and "*Urban Environment*". Also, we excluded the combined search with all the combinations of terms because the results between the WOS search (totaling more than 1,000,000 articles and book chapters) and Scopus (totaling only one result) were not comparable.

Finally, for the definitive searches, we found the following terms valid: For "*Urban gardens*": "*Community gardens*", "*Urban community gardens*", "*Urban agroecosystems*", "*Urban horticulture*" and "*Allotment gardens*". For "*Climate change*": "*Mitigation*", "*Adaptation*", "*Resilience*" and "*Heat island*". The results obtained from the combination of these terms were retrieved for the next stage.

Once the central terms with their respective synonyms were defined, we carried out searches in WOS and Scopus using all the possible combinations between the terms of the two groups. We used simple Boolean operators such as "*AND*" and "*OR*" for the combinations.

For the initial search, we tested all terms in the group corresponding to *Urban gardens* in combination with all terms in the group corresponding to *Climate change* (using only one term for each group). In addition, we carried out another search that had all the terms of the group corresponding to *Urban gardens* (separated with the Boolean operator "*OR*") with all the terms of the group corresponding to *Climate change* (also separated from each other with the Boolean operator "*OR*"). We integrated both groups with the Boolean operator "*AND*".

In these searches, we detected that the terms "*Urban agriculture*" and "*Urban environment*" generated too much irrelevant literature. Therefore, they were removed. Moreover, we removed the combined search with all the combinations of terms because the results between WOS search (totaling more than 1,000,000 articles and book chapters) and Scopus search (totaling only one result) were not comparable.

Finally, for the definitive searches, we found the following terms valid: For *Urban gardens*: "*Urban gardens*", "*Community gardens*", "*Urban community gardens*", "*Urban agroecosystems*", "*Urban horticulture*" and "*Allotment gardens*". For *Climate change*: "*Climate change*", "*Mitigation*", "*Adaptation*", "*Resilience*" and "*Heat island*".

2.2. Selection of Literature Captured for Inclusion in Data Coding and Review

We initially captured a total of 5709 literatures. Then, we excluded duplicate posts (3208) and applied the eligibility criteria in the titles (1888), keywords (537), abstracts and in the full texts (537), respectively. The unavailability of the full texts made it possible to exclude four articles. Finally, we included a total of 72 articles and book chapters to codify and qualitatively analyze using the Nvivo Software (Figure 1). We denominated these stages as (b) "Screening" and (c) "Include to encode".

(b) Screening:

We searched, retrieved and examined the bibliographic results obtained according to the particular eligibility criteria and search terms.

Firstly, we only searched for the types of documents corresponding to articles, and the results obtained were 3736 in WOS and 1642 in Scopus. In total, 5276 articles were captured. Then, we searched the type of documents corresponding to book chapters and their results were 163 in WOS and 157 in Scopus. A total of 320 book chapters were captured. The search dates were 17 February 2022, except the searches that have the term "*Allotment garden*", which were incorporated on 6 July 2022. Adding the total results obtained from the articles (5378) with the book chapters (331), we obtained a total of 5709 literatures (Figure 1).

- Of the total of 5709 literatures identified, many of them have been replicas. Therefore, we excluded the duplicate literatures. A total of 3208 literatures were excluded, leaving a total of 2501 articles and book chapters included.
- By reading and analyzing the titles, 1888 articles and book chapters were excluded, and 613 literatures were included.
- By reading and analyzing the keywords, abstract and full texts, 537 literatures were excluded, and 76 articles and book chapters were included.
- Due to the availability and open access of the articles and book chapters, 4 literatures were excluded because they were not available. Therefore, a total of 72 literatures were included to encode.

(c) Included to encode:

After the stages of (a) "Searching" and (b) "Screening", a total of 72 articles and book chapters were included to codify and qualitatively analyze using the Nvivo Software.

We used Nvivo Software to differentiate the documents according to the type of file, the year of publication, the writing language, the country and continent of the corresponding author's home University and others. In addition, we used the software to conduct a word frequency analysis to list the words or concepts that appear most frequently in bibliographic literature, which is a useful way to identify topics or concepts. The analyses of the nature of the literature and the word frequencies do not directly answer the research question, but provide results to understand and justify the review process. The words found were linked to the topic of the review, providing a context surrounding the data (scope of the research, environments and place of development, related services, actors involved and the topics that are frequently covered in this type of research). Moreover, they allow visualizing the main topics to take into consideration regarding the responses of urban gardens to climate change.

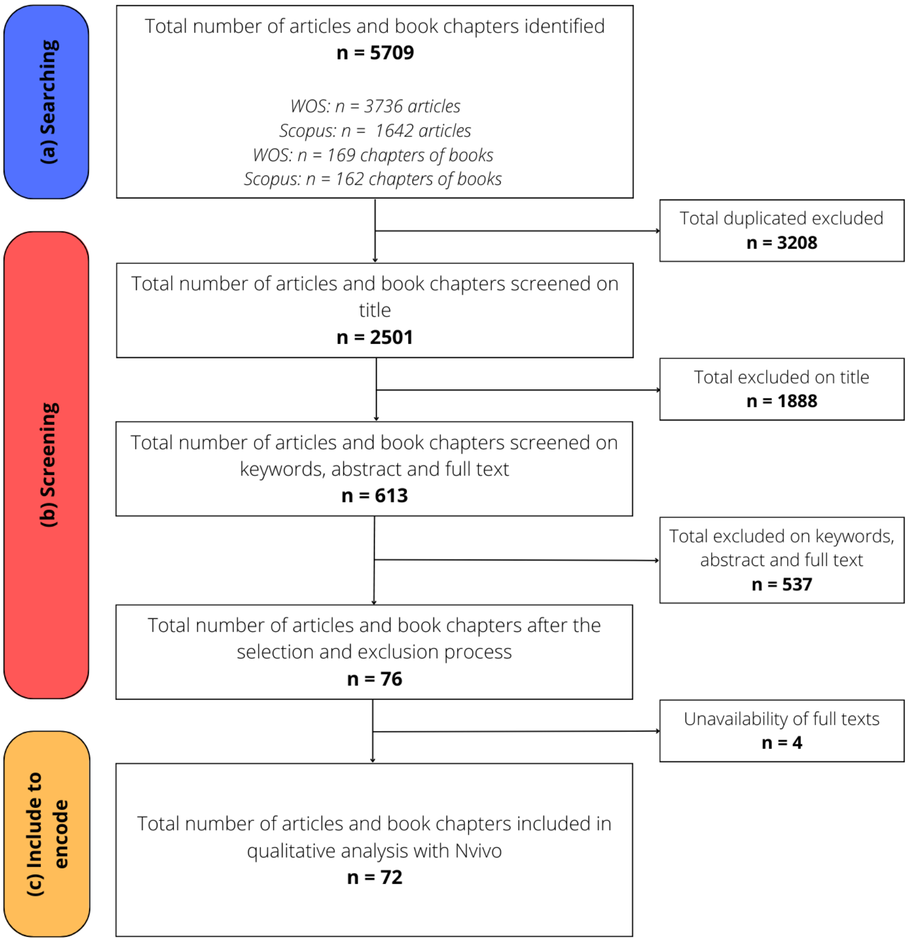

Figure 1. Flow chart illustrating the number of articles and book chapters included in the systematic review according to the PRISMA process.

3. Results

3.1. Literature Analysis

In the 72 items of literature included, 65 of them are articles and seven are book chapters. In addition, two publications are in Spanish while 70 are in English. The highest number of publications on the subject were in the year 2020 (Figure 2).

A high concentration of publications comes from US universities (14). The European universities that have most publications are in Germany (9), followed by the United Kingdom (7), Sweden (7), Spain (5), Italy (2), Poland (1), the Czech Republic (1), Norway (1), the Netherlands (1), France (1) and Greece (1). On the American continent, Canada (4) is the other representative of North American universities, while Latin American universities are represented by Mexico (1), Brazil (1) and Argentina (1). Universities from Oceania are fully represented by Australia (7), and Asian universities are represented by Japan (3), China (2) and Singapore (1). African universities are represented by Egypt (1) and South Africa (1).

In the analysis of the full texts, the 50 most frequently used words are in Figure 3, with the words "*garden*", "*urbans*" and "*community*" being the most counted. Those three words are followed by "*waters*", "*socials*", "*changing*", "*climatically*", "*agriculture*", "*plants*" and "*studying*" to cover the podium of the first ten most frequently found words. In this case, a word frequency search was selected with the following characteristics:

50 most frequent words, with a minimum length of five letters (to avoid years), and grouping "with stemmed words". The resulting key words confirmed that the content of the articles was in line with our research focus.

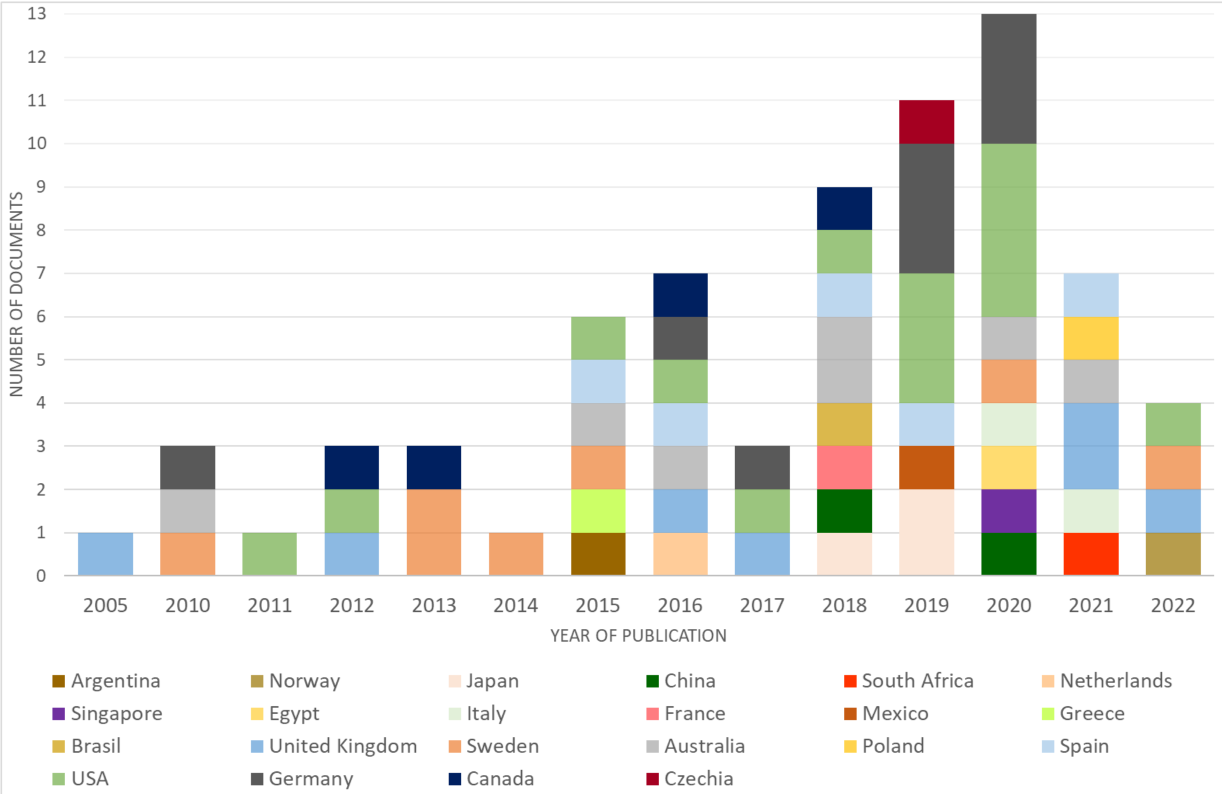

Figure 2. Years of publication and countries of the corresponding author's home University of included literature.

Figure 3. The 50 most frequent words in the full texts of the literature (n = 72) included.

For the abstracts, it was selected to be a search of the 30 most frequent words, with a minimum length of three letters and grouping "with stemmed words". The five most frequent words found in the abstracts are "*urban*", "*gardens*", "*community*", "*food*" and "*city*", respectively. On the other hand, in the analysis of the keywords, we selected: a word frequency search with 30 most frequent words, with a minimum length of three letters and a grouping "exact matches" option. The five most frequent words in the keywords are "*urban*", "*agriculture*", "*climate*", "*food*" and "*community*", respectively.

3.2. Climate Threats to Urban Gardens

3.2.1. Climate Change Threats to Urban Gardens

In general, urban climates can be considered a microclimate [2]. Regional scale studies have shown that urban areas can exacerbate the effect of warming climatic conditions [31,32]. Such behavior is associated with UHI effects [15,33] that can add 2 °C to local warming [16]. According to the IPCC, the main driver for increased heat exposure is the combination of global warming and population growth in already-warm centers [16]. These global change factors can have an effect at multiple scales, impacting environmental and social elements of urban gardens [34].

For the social elements, the risk faced by people from hazards associated with climate change has increased and the climate change will increasingly expose outdoor workers [16].

For the environmental elements, UA is increasingly vulnerable to environmental change impacting cities [35], and urban vegetation is sensitive to high heat and water stress [23], among other threats (Table 2). Mainly the effects of temperature and precipitation variation at a local scale could limit urban gardens [36,37] because species have temperature and moisture thresholds that allow or inhibit their survival [38]. As a result, many plant species may not survive or thrive in the more variable and extreme future climate scenarios of some cities [23].

Changes due to global climate change and intensifying UHI effects are likely to affect the composition and diversity of urban gardens [38]. Extreme climate conditions, extended periods of high heat, drought and limited water can negatively affect the productivity and survivability of food crops [34]. In addition, changes in temperature and water patterns bring other associated consequences such as pests, weeds, disease, invasive species [21] and even the way that people use resources [38].

Extreme and high temperature threats can scorch the leaves, desiccate the crops, affect the timing of flowering, damage pollen, reduce fruit production and increase the likelihood of crop failure [23], especially if plants do not have enough water [39]. On the other hand, water threats can range from urban floods [40] to scarcity in the use of water due to restrictions stemming from city [41].

Table 2. Main climate change threats to urban gardens.

Threats	References
(1) Extreme heat.	[7,31,38,39,42]
(2) High temperatures (extended and more frequent periods).	[23,34,35,38,41,43]
(3) Intensifying UHI effects.	[23,41]
(4) Intraday temperature variability (Day/night).	[23,38,43]
(5) Frost risk.	[21]
(6) Flooding and water runoff.	[21,25,40]
(7) Drought (prolonged, more frequent and more intense).	[7,12,21,23,34,35,41]
(8) Variability in weather patterns and changes in seasonal timing (drying trend and decreasing rainfall in the summer months).	[7,21,34,44]
(9) Water shortage (access and availability) and conservation policies (restrictions and limitations).	[34,41,45]
(10) Diseases, pests, weeds, invasive species.	[21,39]
(11) Effects on soil properties and soil moisture retention.	[34,37,38]
(12) High winds and storms.	[25]

However, effects of temperature change can increase the capacity for food production in Subarctic and Arctic Zones due to more hospitable conditions for growing a greater variety of edible plants [46].

3.2.2. Building Adaptive Strategies in Urban Gardening Practices in Response to Climate Threats

Heat and water availability are essential considerations for urban gardens [39], but the vulnerability and exposure to risk are multi-dimensional [44]. To minimize the vulnerability and climatic exposure of urban gardens, adaptive gardening practices can be incorporated as a response (Table 3).

There are many different and complementary ways for gardeners to [47]: improve water use efficiency, collect and store rainwater [47], reduce water use [35], improve holding capacity of soil water, design the plot and site layout to minimize run-off and improve water infiltration [47] and adopt drought resilient plants [35]. Although gardeners are less likely to change the plants that they grow in response to weather, more extreme heat and projected declines in water availability will call for more proactive adaptation strategies [23].

In water management, adaptive gardening should collect rainwater and minimize water losses by evaporation from the soil surface [47]. To achieve this, the following methods could be incorporated: tanks to store rainwater, drip irrigation and trickle irrigation systems, water timers and even water early (when the ground is cool) or late (after the sun has set) in the day.

Planting decisions and cultivation practices about what to grow, when to grow it and how to manage it before and during the growing season could also represent adaptive practices: changing planting times, replacing crops with more adaptable-resilient ones (to drought conditions, to more heat or plants with lower water needs), diversifying the crop varieties group (provides insurance against variable climate conditions), selecting plants according to water needs (potential to improve water use efficiency and productivity), using cover crops, rotating crops and staking fragile plants are some recommended practices.

Soil management is important because it reduces the loss of water from the soil surface through evaporation, increases the amount of available water held in the soil [47], improves moisture retention and increases water use efficiency [41]. This is possible with mulches, grasses, straw, organic matter, compost, and amendments that could be added. No-till soils generally exhibit higher water-holding capacity than tilled soils [41].

In the design of an urban garden or during its operation, structures could be incorporated to better implement a workspace with all the necessary equipment: well laid-out paths (if possible: made of permeable material), ponds or wildlife areas, different sizes of plot, a communal building, toilets, mains water supply and composting areas are some of the most desirable structures. Providing shade with trees and shrubs or protecting the crops from high temperatures with greenhouses and polytunnels can also turn the urban garden into a garden with a climatic perspective and one that is more futureproof. Shade can also be beneficial for working conditions for gardeners [31].

Community gardens promote environmental education as well as social cohesion, which are important factors for urban adaptation [14]. Community centers have the potential to function as catalysts of mobilization for climate action [48]. It is advisable to involve gardeners in the design and undertaking of research to improve overall sustainability of the food system [37]. Education programs and dialog can also focus on increasing perceived adaptive capacity to overcome socio-cognitive barriers that may hinder adaptation and may even elicit maladaptive responses [23].

Table 3. Adaptive urban gardening practices in responses to climate change.

Adaptive Gardening Practices	References
(1) **Water management:** Collect and store rainwater; improve efficiency and reduce water use.	[23,34,35,37,39,47]
(2) **Planting decisions:** Change planting times; change plant selection; implement structural diversity of crops; diversify crop varieties.	[21,23,34,35,37,39,47,49,50]
(3) **Cultivation practices:** Group plants by water needs; use cover crops; intercropping; rotate crops; supply floral resources; stake fragile plants.	[21,28,39,47,50]
(4) **Soil management:** Apply vegetative cover on the soil (mulches, grasses, straw) and add organic matter, amendments, or compost; no-till soils.	[21,23,34,35,37,39,41,47,49,50]
(5) **Garden's structure:** Necessary equipment; trees and shrubs; greenhouses and polytunnels.	[39,47]
(6) **Rules and policies:** Implement and respect policy measures that consider land security, tenure or access to water and resources; respect the garden's rules for water use.	[34,37]
(7) **Controls:** Visit the gardens more frequently; weed control.	[38,47]
(8) **Education and knowledge:** Environmental knowledge, education and awareness; harnessing the power of diverse socio-ecological memories; involving gardeners in research.	[23,34,35,37,51]

3.3. Opportunities for Adaptation, Mitigation and Urban Resilience That Urban Gardens Provide for Cities

3.3.1. Urban Gardens and Urban Adaptation

Faced with the climatic threats that have been mentioned, urban gardens can help to adapt cities. Urban gardens are nature-based solutions (NbS) that can help mainly due to the power of their vegetation and their soils. Their adaptive capacities are related to temperature regulation, water retention and infiltration, and storm attenuation capacity.

Regarding the temperatures, cities need vegetation that can regulate local microclimate and provide cooling benefits [23,52]. Garden management may be able to combat regional and local warming effects through the careful management of local vegetation and ground cover [41]. Also, vegetation has a key role in reducing solar radiation that is absorbed into building materials (such as pavement) during the day and released at night [31,53]. The cooling potential in gardens will depend on the design and management of the system [41].

The adaptive capacity of urban gardens also allows to reduce the runoff associated with impervious surfaces, resulting in a decrease in urban flooding. In addition, urban gardens help protect urban residents and agricultural production from the damaging effects of storms (e.g., rain and wind damage, flooding).

3.3.2. Urban Gardens and Urban Mitigation

Urban gardens and their plants can support CO_2 sequestration and reduction [15] due to the photosynthesis of the vegetation and the power of the soil. The amount of CO_2 sequestered depends on the typology of plants, the size of the plot, the typology of soils and their processing [15]. Also, urban gardens can contribute to the mitigation of urban GHG emissions indirectly through changes in the behavior of society (food, transportation, among others).

Their various forms of urban mitigation, direct and indirect (Table 4), are useful for the reduction of GHG emitted by the city and for the social change towards attitudes with lower emissions. It should also be considered that urban gardens have the potential to produce food with lower GHG emissions compared to traditional agriculture.

Table 4. Adaptation, mitigation and resilience capacities provided by urban gardens for cities.

	Capacities for Cities	References
Adaptation	(1) Microclimate regulation.	[3,10,23,29,54–59]
	(2) Mitigate extreme temperature.	[2,10,23,41]
	(3) Reduce and control UHI effects.	[3,12,15,40,60,61]
	(4) Retention and water infiltration.	[3,12,14,15,29,40,54,58,62]
	(5) Storm attenuation.	[54]
Mitigation	**Direct urban mitigation by urban gardens:**	
	(1) Carbon capture and sequestration (power of plants and soil).	[3,15,50,63]
	Indirect urban mitigation by urban gardens:	
	(2) Vegetation lowers ambient temperatures, thus reducing cooling demand of houses and buildings.	[3]
	(3) Gardening reduces emissions because an hour spent gardening is an hour not spent driving, not spent using a computer or other appliances and not spent indoors in an environment that uses energy-dependent cooling/heating/lighting.	[3]
	(4) Composting reduces "trash" being sent to landfill. Recycling waste will not only reduce methane emissions from landfills but also improve your garden's soil and help it store carbon.	[3,50]
	(5) Coworking spaces have the potential to reduce CO_2 emissions.	[48]
	(6) Dietary change by urban gardeners.	[18]
	Mitigation compared to traditional agriculture:	
	(7) Less use of fertilizers.	[3]
	(8) Less food transport ("food miles").	[3,12,40]
	(9) Less use of gasoline (powered tools and machines).	[50]

Table 4. *Cont.*

	Capacities for Cities	References
Resilience	(1) Food security and food supply.	[8,38,45,56,62,64–66]
	(2) Diversity of food sources.	[49,67]
	(3) Community building, social network and self-organization at the community level.	[3,4,12,25,27,34,62]
	(4) Educational opportunities in environmental issues.	[3,57]
	(5) Knowledge exchange among people (socio-ecological memories, experience and cultural diversity).	[35,49,51]
	(6) Contact with nature.	[34,68]
	(7) Physical activities.	[54]
	(8) Transformative spaces that can contribute to urban spatial planning and design.	[27,29]
	(9) Evacuating the site during a disaster and post-disaster site recovery (traumatic stress).	[27,58]
	(10) Air quality improvements.	[65]
	(11) Biodiversity enrichment.	[65]

The results presented aim to provide an overview of the main capacities for adaptation, mitigation and resilience that have been found in the reviewed literature.

It should also be considered that urban gardens are also potential sites for GHG emissions since they are sites of agricultural production. But their emissions to produce food are much lower than those of traditional agriculture. One reason for their lower GHG emissions are due to less use of agricultural machines [20]; often, spaces without animals and many urban gardens practice organic agriculture, where the application of synthetic fertilizers is prohibited.

3.3.3. Urban Gardens and Urban Resilience

Urban gardens can help to improve the resilience of cities [7]. Providing available food is the most important thing for society (especially for a vulnerable society). In addition, among other environmental, social, urban, and economic benefits that motivate urban resilience,, the ability to create social networks in cities is very important for urban resilience and for overcoming crisis situations (health, economic, natural catastrophes, among others).

Civic engagement is an important element of building societal consensus and reducing barriers to action on adaptation, mitigation and sustainable development [16]. Networked community actions can go beyond neighborhood-scale improvements to address widespread vulnerability [16]. Drawing upon local knowledge can contribute to overcoming the combined challenges of climate change, food security and biodiversity conservation [16].

4. Discussion

UA is increasingly recognized as a pathway towards urban climate change adaptation, mitigation and for building the resilience of cities [13]. Although there are many types and initiatives of UA, in this review we focus on urban gardens, particularly community gardens and allotment gardens, due to their similar biophysical characteristics and common similarities in their community management. These urban spaces are particularly interesting for research, even though they are traditional and well-known practices in the history of the cities [1,10,12]. In the context of the climate crisis [3,24], a threatening situation in the 21st century, it is interesting to investigate the relationship between urban gardens and climate change to understand if there are practices that can contribute to more resilient cities and people. Based on the results obtained, this review can help to value urban garden spaces, as climate changes are likely to impact more severely on urban environments, with associated negative effects on food security [5].

This review has compiled the main climate threats faced by urban gardens as the main suggestions on how to develop more adaptive gardening. In addition, urban gardens are spaces with different capacities to help adaptation, mitigation and resilience for cities.

Climate change threatens the places where urban gardens are developed (cities), their vegetation and crop production and the people who manage these spaces [16]. In this review, we highlight the effects of increased temperatures and droughts. While the increase in temperature is global, the phenomenon of drought may change depending on the geographical location of each city [16]. Therefore, the incorporation of adaptive practices in the urban gardens is a key to having resilient urban gardens and crops as food. Considering that people in urban gardens work outdoors [64], often in summer, the gardening activity can change from a leisure activity [1,3] to a risky activity for the vulnerable populations, such as the elderly.

The adaptive capacity in cities is limited and adaptation funding continues to target large-scale physical/grey engineering projects [16]. For this, urban gardening could be an NbS alternative for cities. These practices can be very useful in places with high vulnerability and few resources, since they are well-known and inexpensive practices. On the other hand, urban gardens can be useful for cities that want to decrease their carbon footprint because can help to mitigate GHG. The social factor provided by urban gardens is very important for the resilience of the city, providing food and providing real social networks.

This review can provide an overview of the state of knowledge to be used by urban gardeners, urban planners and the scientific community. Adaptive gardening practices can be useful to replicate in urban gardens and disseminate good urban agriculture practices. For urban planners, this review can be the starting point for cities to pay attention and incorporate the capacities provided by urban gardens in their climate action plans. However, for this it must be considered that the net impact of community gardens depends on the scale of the intervention [3]. Regarding the benefit to the international scientific community, this review demonstrates, in a precise and compact way, the main relationships between urban gardens and climate change. This can motivate particular (in urban gardens around the world) and in-depth studies on each of the identified points of threats, adaptive gardening, mitigation capacity, adaptive capacity and resilience capacity.

The review helps to consider that perhaps one of the solutions to the problem of climate change in cities are urban gardens. The garden city concept can potentially be one of the solutions for the climate emergency, balancing community and daily requirements, as well as accommodating a diverse environment that will balance nature with social coherence [24]. Perhaps the threats "of the future" have already arrived and the solution is to rethink cities as capable spaces to grow food and provide multiple socio-environmental benefits.

5. Limitations and Future Directions

The review prioritized the demonstration of the data found in the literature included in the review, but also showed information from additional supporting literature (such as IPCC). Additional literature served to give better context and show accurate information on some topics.

The selection of community gardens and allotment gardens helps to define the scope and the focus of the review. This is important, since there are many other initiatives of urban agriculture and urban gardens.

The searches that were carried out in bibliographic databases such as WOS and Scopus adopted simple Boolean search engines with "*OR*" and "*AND*"; however, the searches could have been more detailed, using more complex search formulas.

The results of the analysis of the included literature have limitations. The year 2022 was not fully analyzed because the review was carried out during this year. The English language as the predominant language of publication is potentially related to publishing journals because many of them require literature in English language. The dominance of publications from the Global North does not exclusively mean that these practices occur mostly in these places, but perhaps it shows that there is a greater interest in their research.

This review motivates future research since each of the points presented in the different tables of results can be investigated in detail from a climate change perspective. Precise data are necessary due to the lack of information related to urban gardens and climate change. This review supports and motivates future research in urban climate action plans.

This same research can be replicated in other countries of the international scientific community, but other bibliographic databases should be considered. This is justified because scientific journals from many countries (for example, Latin American journals) have low indexing in international databases such as WOS or Scopus, limiting the estimation of bibliometric indicators for international comparison.

6. Conclusions

Urban agriculture has gained relevance in urban planning for climate-resilient cities and in urban food systems to enhance food security in cities. This systematic review highlights recent and growing literature that relates urban gardening to climate change. According to WOS and Scopus, the largest number of scientific publications in the years 2000 –2022 are from US and European universities (mainly Germany, the United Kingdom and Sweden). Urban gardens can be an adaptation strategy in urban greening to face climate change threats. Considering community gardens and allotment gardens as urban gardens with very similar characteristics and nature, these spaces are sensitive to the urban and agricultural threats of climate change (especially the increase in temperature and localized droughts). Adaptive gardening practices such as rainwater capture, drought-resilient plant selection and ground cover management can be incorporated as a response, improving the sustainability of the practice, reducing risks and reducing vulnerability. Furthermore, urban gardens are useful to directly or indirectly aid adaptation, mitigation and urban resilience through social networks, education and environmental awareness. Urban gardens can be further studied in their environmental and climate aspects, considering them in the planning of cities and their climate action plans.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/agriculture13020502/s1, Table S1: Search variables: central terms with their respective synonyms; Table S2: General searching; Table S3: Search results included; Table S4: Screening: Result numbers. Combinations of terms; Table S5: Screening: Organization of the results from A–Z. Exclusion of duplicates; Table S6: Screening: Organization of the results from A to Z. Exclusion on titles; Table S7: Screening: Organization of the results from A to Z. Exclusion on keywords, abstracts and full texts; Table S8: Screening: Organization of results from A to Z. Exclusion on unavailability full texts; Table S9: Total of articles and book chapters included in qualitative analysis with Nvivo.

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