Cool Down the Town: Provision of Ecosystem Services in Urban Heat Island Effect Solutions

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Abstract
*In this literature review, 12 publications about the Urban Heat Island (*UHI*) in a moderate maritime (*Cfb*) climate were selected -out of a total 813 publications- to determine which Ecosystem Services (*ESS*) might be underexposed in green UHI solutions. For this, the solutions were categorized based on the type of green or blue infrastructure (*GBI*) mentioned in the respective study. From 42 preselected publications, most were about 'building greens', such as green roofs. Next, the mentioned ESS in 12 publications were classified using the Common International Classification of Ecosystem Services* (CICES). *Further analysis of these publications showed that Regulating & Maintenance services are studied most and that cultural services appear to be the most difficult to quantify. The numerous ways in which green UHI solutions provide ESS are partially known, but not completely quantified in the analyzed studies. In general, most publications quantify the ESS 'Regulation of temperature and humidity', but do not provide a complete quantification of other mentioned ESS. It is recommended that -when implementing green solutions to create a more climate resistant and adaptable city-, all ESS of the solutions are qualified and quantified extensively. This helps to create a comprehensive and specific picture of the benefits provided by nature in the build environment.*

Key words: Urban Heat Island, Ecosystem services, Biobased solutions

Layman's summary
The urban heat island (UHI) effect is the phenomenon that cities are warmer than its surroundings. This occurs because buildings retain more heat than, for instance, green open spaces. This UHI effect has negative consequences for the people living in cities. Not only thermal comfort is decreased, increased air pollution as an effect of the UHI has negative effects on human health. One option to combat the UHI is the addition of more green in cities, for instance through the building of parks or green roofs. Bringing nature in cities also brings ecosystem services. Ecosystem services are the services that nature provides for humans. Not only can urban green reduce the temperature in cities, through for example the provision of shade or increased transpiration, it can also reduce pollution levels in the air or increase the biodiversity in the build environment. Because it remains difficult to determine exactly in what way nature can help us live in a more safe and healthy environment, it is important to think of useful ways to calculate the benefits we get from nature.

Introduction
Climate change will have an ever growing impact on civilization in the coming years. One of the consequences of climate change, is an increase of extreme weather events such as heat waves and flash floods. These events impact people where they live. Already 50% of all people reside in urbanized areas and this number is steadily increasing. It is projected that in 2050, 68% of the world population will live in urbanized areas (UN, 2018). The effects of an

increasing temperature are especially felt in urbanized areas, because of the urban heat island (UHI) effect. This is the phenomenon that the urban center is and stays warmer than the surrounding area. The UHI is mainly caused by heat generated and heat retained from solar radiation by different urban structures (e.g. buildings and roads), and from other anthropogenic heat sources (Rizwan, Dennis et al. 2008). Other causes for the UHI, and determinants of its intensity include the percentage of vegetation cover in cities, air pollution, seasonal changes, population density, and the presence of water bodies in the urban environment (Deilami, Kamruzzaman et al. 2018, Nuruzzaman 2015, Taha 1997). The UHI not only has an impact on the temperature of cities, the UHI also contributes to heat related mortality and morbidity (Heaviside, Vardoulakis et al. 2016, Lay, Sarofim et al. 2021). Although partially caused by air pollution, the UHI can also lead to higher pollution levels, decreased water quality, and increased energy consumption in urbanized areas (U.S. EPA 2014). A study performed in the Netherlands showed that the UHI can lead to an increase of temperature between 3 to 10 K in the city compared to the surrounding area (Van Hove, Steeneveld et al. 2011). Since the number of people living in cities will only increase in the coming years, it is important to create climate-resilient and -adaptable measures in the urban environment. This is linked to sustainable development goal 11 from the United Nations (UN 2016).

Multiple solutions for the UHI effect exist, but an important one that can have additional benefits is the addition of Green and Blue Infrastructure (GBI) in urban areas. GBI are natural elements, which therefore provide ecosystem services (ESS) to the people living in urban areas. ESS are the contributions of ecosystems on human wellbeing and their health (Millennium Ecosystem Assessment 2005). To determine which ecosystem provides what service, multiple classification systems exist. One of these, is the Common International Classification of Ecosystem Services (CICES). Here, ESS are defined as the contributions that ecosystems make to human well-being. The definition of each service subsequently identifies the purposes or uses that people have for the different kind of ESS and the particular ecosystem attributes or behaviors that support them. Contrary to the Millennium Assessment classification, CICES recognizes three main sections of ecosystem outputs: Provisioning, Regulating, and Cultural services (Haines-Young, Potschin 2018). Provisioning services are the products people can receive from ecosystems. This can be: food, fresh water, fuel, but also genetic material. Regulating services are the benefits that arise for people because of the regulation of ecosystem processes, including: air quality maintenance, climate regulation, erosion control, and water purification. Cultural services are the nonmaterial benefits people receive from ecosystems through: recreation, education, entertainment, or spirituality (Alcamo, et al. 2003, Haines-Young, Potschin 2018). These three main sections can be further subdivided (figure 2). An example of a regulating ecosystem service that can be used as a solution for the UHI effect is temperature regulation (CICES code 2.2.6.2). Gill et al. (2007) showed that adding 10% green cover to areas with little green (town centers + high density residential areas) keeps maximum surface T at or below the 1961-1990 baseline up to 2050.

When implementing GBI in the urban environment, it is possible to catch more birds with one stone, so to speak. GBI does not only provide a temperature regulating service, but more often than not, multiple ESS are provided by these solutions (Kumar, Debele et al. 2021, Chen, Wang et al. 2020, Parsa, Salehi et al. 2019). These can include stormwater regulation, air quality improvements, CO_2 sequestration, and cultural services like recreation. However, a clear overview of all possible ESS is still lacking. Solutions are also context specific and it can be difficult to attribute a clear categorization to them. This is the case because services are numerous and interlinked, and there can be many different ways to describe overlapping and intersecting services and benefits (Fisher, Turner et al. 2009). Existing UHI solutions can be more or less effective, depending on the geographical location in which the solution is presented (Susca 2019). One important factor is the climate of the region (Rahman, Mohammad A., Stratopoulos et al. 2020). In this literature review, the climate of the Netherlands was selected. This is a moderate maritime (Cfb) climate according to the climate categorization of Köppen (Rubel, Kottek 2010). The Cfb climate was chosen so that this review can serve as a guide for future policy makers in the Netherlands.

Review articles of ecosystem services in the build environment exist, and these aim to provide an overview of existing (climate mitigating) strategies and the ESS they provide. One of these articles analyzed 850 different publications on the topic until May 2019 and concluded that a systematic quantification of nature in urbanized areas is still lacking (Veerkamp, Schipper et al. 2021). This extensive literature review serves as the basis of this literature research. Although this review focusses specifically on recent strategies to combat the Urban Heat Island effect, the article by Veerkamp et al. (2021) provides a clear description of the strategy to research ESS focused literature. As it appears now, a comprehensive overview of the newest designs and research into nature-based solutions for the UHI effect is still lacking. The intention of this literature review is to create an overview of different existing, state of the art, solutions to reduce the UHI effect and the ESS they provide in a Cfb climate.

Methods

2.1 Selection of research articles

To find research articles related to the UHI effect and ESS in the build environment, a methodology similar to Veerkamp et al. (2021) was used. I searched for articles on the Web of Science (WOS) database using 'Urban Heat Island' as a broad search term. To select for only articles about solutions in areas with a moderate maritime (Cfb) climate, based on the *Köppen* climate categorization (Peel, Finlayson et al. 2007), a list with countries was added to the search query (Appendix, (0)). Countries with a partial Cfb climate were purposefully added to the query, so further selection based on specific geographical location could be done in a next selection step. After searching specifically for articles about the UHI that also mentioned the name of a country with a Cfb climate, 813 articles were identified. To narrow down to only state of the art solutions, some advanced search options of WOS were used. Only research articles and Early Access articles from 2019 onwards were selected. To further screen the publications for solutions that fit within the scope of this review, one of the following terms had to be mentioned in the selected publications: *"Green", "Nature based", "Ecosystem", "Ecosystem based adaptation", "Environmental services", "Natural Capital", "Life Support services", or "Nature Services"*. This search limitation resulted in 114 publications. Of these 114 articles, the abstracts were downloaded (Appendix, (1)) and scanned to remove the publications where no solutions were mentioned and to remove the research outside of areas with a Cfb climate. This was done by manually searching on the website climate-data.org/ for the Köppen climate categorization of each mentioned city in the article. The results were added to the Results table (Appendix, (3)) and only the publications with research done in a Cfb climate were selected (Appendix, (4)). Lastly, of these 56 remaining articles, the UHI solutions were roughly categorized based on the urban Green Blue Infrastructure (GBI) types used by Veerkamp et al. (2021) (*Section 2.2; Appendix, (6))*. Only the publications that fell into one of the categories was selected (Appendix, (5)). If a publication researched more than one GBI, the other solutions were counted as well. Because of time constraints, 12 articles were selected (2 from each mentioned GBI category). If possible, an article containing multiple solutions was selected, otherwise the most recent publication was selected (Appendix, (6); Figure 1). These papers were read completely to determine which ecosystem service(s) each UHI solution provided. A full overview of the search terms and selection criteria can be found in the Supplementary Data (Appendix, (0)).

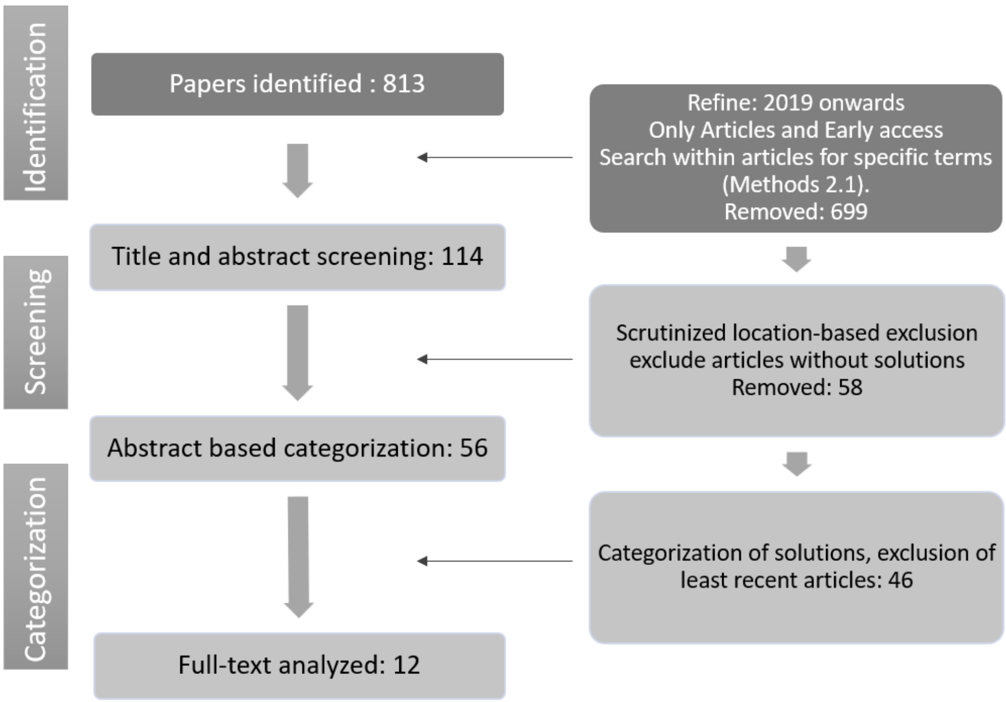

Figure 1. Overview of selection of research articles

2.2 Categorization of UHI solution

The solutions mentioned in the remaining publications, were written in the results table (Appendix, (4)). Clustering of the solutions was done based on the categorization of Veerkamp et al. (2021). Seven different categories were used (Table 1). For a full description of the GBI types, see Appendix A, table A2 from Veerkamp et al. (2021). From each category 2 of the most recent publications, or the publication that fell into more than one category (Appendix (5)), were selected. From these articles, the ecosystem services provided by the mentioned solutions were determined.

Table 1. Selection categories for Urban GBI types. From Veerkamp et al. (2021)

Category	**Examples**
1. Building Greens	Green roofs, Green walls
2. Green and blue connected to grey structures	Street trees, Vegetated swales
3. Parks and (semi-) natural green areas	Forests, Parks
4. Gardens	Allotment and community gardens
5. Water areas	Lakes, Rivers
6. Abandoned land	Vacant land, Brownfield
7. Unspecified GBI	Summarized as ‘green space’, or combination

2.3 Categorization of ESS according to CICES framework

To compare what ecosystem services were provided by the solutions, the ESS were categorized based on the most recent version of the Common International Classification of Ecosystem Services (CICES) (Haines-Young, Potschin 2018). CICES was intended as a reference classification that allows translation between different ESS classification systems. The CICES categorization helps to identify which ESS are already well-covered in green UHI solutions and which ESS might still be underexposed in the existing solutions. CICES works with a hierarchical structure (figure 2). From each solution in the publication, the Section, Division, Group, Class, and Class type were chosen (APPENDIX, (6)).

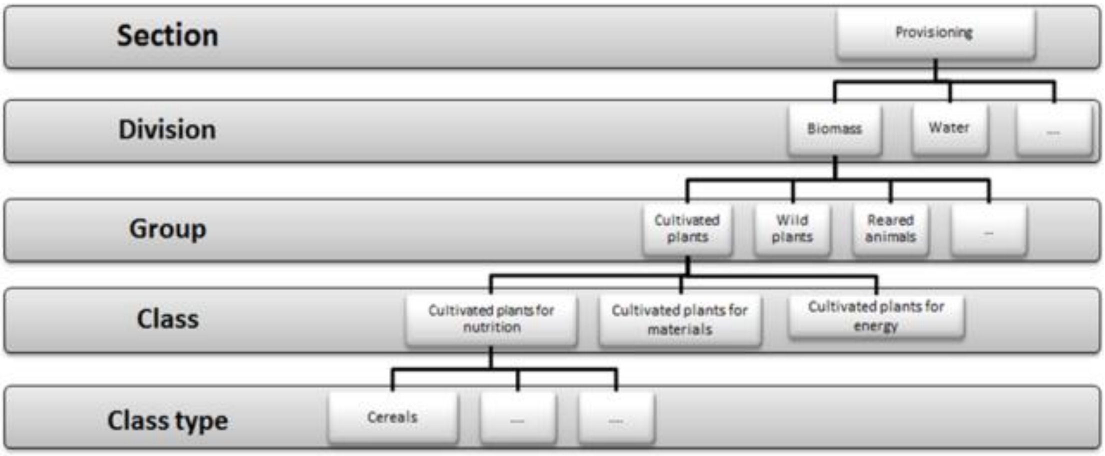

Figure 2. Hierarchical structure of CICES V5.1 (Haines-Young, Potshin 2018). The ESS provided by growing crops for food (Cereals) is used as an example here.

2.4 Quantification of ESS in selected publications

The benefits, or services, that people derive from ecosystems can be quantified. This is often not a straightforward process because of the multitude of different quantification methods (Boerema, Rebelo et al. 2017). For a full analysis of the service it is important that both the ecological and socio-economic aspect, as well as the relation between these two, is considered (de Groot, Alkemade et al. 2010). There are a plethora of methods in use to quantify the provided ESS, including: complex field measurements, *in silico* modeling, or rapid assessment methods (Dunford, Harrison et al. 2018, Gaudio, Louarn et al. 2021, Peh, Balmford et al. 2013). The unit of measurement for this assessment depends on the ESS that is provided. Some ESS can be quantified in terms of monetary value, others in changes in temperature, or for instance the amount of carbon sequestered (table 2). For each publication, it was determined whether and how the ESS was quantified (Appendix (7); table 2).

Results

3.1 Categorization of existing solutions

The articles remaining after selection were categorized based on the urban main GBI types as described by Veerkamp et al. (2021). From the publications, none mentioned category 6, abandoned land, as a solution. De Valck et al. (2019) does mention brownfields, but proceeds to describe the redevelopment of these lands with other GBI types (Appendix (6)). Out of the in total 48 solutions that were mentioned in 40 different publications, most were either unspecified or related to building greens (figure 3). Within that main GBI type, most solutions focused on green roofs. From the 40 publication that were categorized on the main GBI type solutions, 2 of each mentioned category were selected for full reading (Appendix (6)).

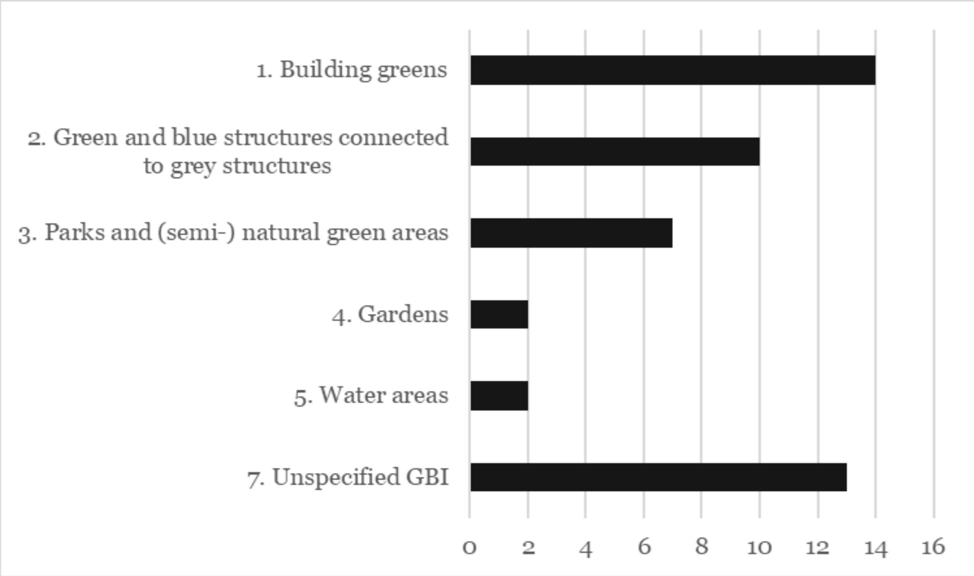

Figure 3. Number of UHI solutions found in the 40 selected publications. In total, 48 different solutions were categorized based on the main GBI types from Veerkamp et al. (2021).

3.2 Provision of ESS by published solutions

To determine what ecosystem services were provided by the selected solutions, and which might still be underexposed, all 12 selected articles were read in full. Table 2 provides an overview of the different ESS provided for each of the analyzed publication. A full overview of the results can be found in Appendix (7). The ESS were categorized based on the CICES method. In total 12 different ESS were mentioned, of which 7 were also quantified in the different publications. In table 2, the first unique mentions of a CICES code linked to an ESS that was quantified are highlighted in light grey. The first mentions of a unique code that was not quantified are highlighted in dark grey.

Since all solutions are focused on mitigation the UHI effect through the cooling of the (local) environment, and since all solutions are nature-based in one way or another, all publications except for Egerer et al. (2021) mentioned the importance of temperature regulation as an ESS provided by the green solutions. Other provided ESS were not mentioned as consistently across the analyzed publications. The sequestration of carbon by the different green solutions was mentioned 4 times in the publications (De Valck, Beames et al. 2019, Roetzer, Moser-Reischl et al. 2021, Hartigan, Fitzsimons et al. 2021, Johnson, See et al. 2021). Pollution removal and stormwater mitigation were mentioned in 3 publications (Hartigan, Fitzsimons et al. 2021, De Valck, Beames et al. 2019, Johnson, See et al. 2021). These 3 ESS were all quantified in the mentioned publications except for Hartigan et al. (2021).

Table 2. ESS mentioned in each article and the corresponding CICES code. A full overview can be found in Appendix B, (7). When the CICES code starts with 1, a provisioning services is provided, 2 is a biotic Regulation & Maintenance service and 3 is a cultural service. 4 is an Abiotic provisioning service. Codes in light grey are the first unique mentions of a quantified ESS, codes in dark grey are the first mentions of an unquantified ESS.

Solution mentioned	GBI type (table 1)	ESS mentioned	CICES code	Quantified in study	Publication
Green roof, Wadi (drainage), Green corridor	1,2,3	Avoided runoff	2.2.1.3	Yes	(De Valck, Beames et al. 2019)
		Air filtration and ventilation	2.1.1.2		
		Local climate regulation	2.2.6.2		
		Carbon sequestration	2.2.6.1		
		Recreation	3.1.2.4		
Green roof, trees, grasslands	1,2,3	Local climate regulation	2.2.6.2	Yes, Temperature	(Tiwari, Kumar et al. 2021)
Urban trees	2,3	Local climate regulation	2.2.6.2	No	(Fuentes, Tongson et al. 2021)
Urban trees	2	CO2 fixation	2.2.6.1	Yes, kg/yr	(Roetzer, Moser-Reischl et al. 2021)
		Transpiration	2.2.6.2	Yes, M3/yr	
Urban forest	3.	Heat reduction	2.2.6.2	Yes, T	(Hartigan, Fitzsimons et al. 2021)
		Improve air quality	2.1.1.2	No	
		Treatment of stormwater	2.2.1.3	No	
		Carbon sequestration	2.2.6.1	No	
		Biodiversity benefits	2.2.2.3	Yes, # birds	
Green roof, vegetation	1,3	Temperature regulation	2.2.6.2	Yes, T	(Herath, Thatcher et al. 2021)
Community gardens	4.	Food production/ products	1.1.1.1/2	No	(Egerer, Lin et al. 2019)
		Beauty/ aesthetics	3.1.2.4		
		Cultural meaning	3.1.2.3		
		Animal habitat	2.2.2.1		
Allotment gardens	4.	Microclimate regulation	2.2.6.2	Yes, T	(Rost, Annemarie Tabea, Liste et al. 2020)
		Provision of food	1.1.1.1	No	
		Recreation	3.1.1.1	No	
		Biodiversity benefits	2.2.2.3	No	
Canals, urban parks/ trees	5, 7	Thermal comfort	4.2.1.2.	Yes, T and perceived T	(Klok, Rood et al. 2019)
			2.2.6.2		
Canals, urban parks/ trees	5,7	Thermal comfort	4.2.1.2	Yes, Temperature	(Lauwaet, Maiheu et al. 2020)
			2.2.6.2		
Green city	7	Human health	-	Yes, value in €	(Johnson, See et al. 2021)
		Runoff reduction	2.2.1.3		
		Cooling/ warming	2.2.6.2		
		Habitat creation	2.2.2.3		
		Pollution removal	2.1.1.2		
		CO2 reduction	2.2.6.1		
Urban Green	7	UHI reduction	2.2.6.2	Yes, temperature	(Rakoto, Deilami et al. 2021)

The focus of the different publications lies mostly on regulation & maintenance services provided by the different urban GBI types (Figure 4). Within this section, the ESS class 'Regulation of temperature and humidity' can be found. Some, but not all publications mention the cultural benefits that these UHI solutions could provide to the public. The publications that study the effect of gardens on UHI mention the most different ESS sections. Provisioning services are mentioned here because the gardens studied in the analyzed publications provide food for the users of the gardens (Egerer, Lin et al. 2019, Rost, A. T., Liste et al. 2020).Within the 12 analyzed publications, the biotic and abiotic provisioning services were mentioned the least, as both were mentioned twice. Only the water areas mention abiotic provisioning services. Cultural services were mentioned in 3 different publications. Within the unspecified GBI section, there was one ESS that could not be placed in one of the categories of the CICES classification system. In Johnson et al. (2021), the monetary value of ESS were calculated for different cities in Austria. Here, human health (decrease in mortality and morbidity when living in a green city compared to not living in a green city) was calculated. A general ESS for improved human health could not be found within the CICES classification.

3.3 Quantified Ecosystem Services

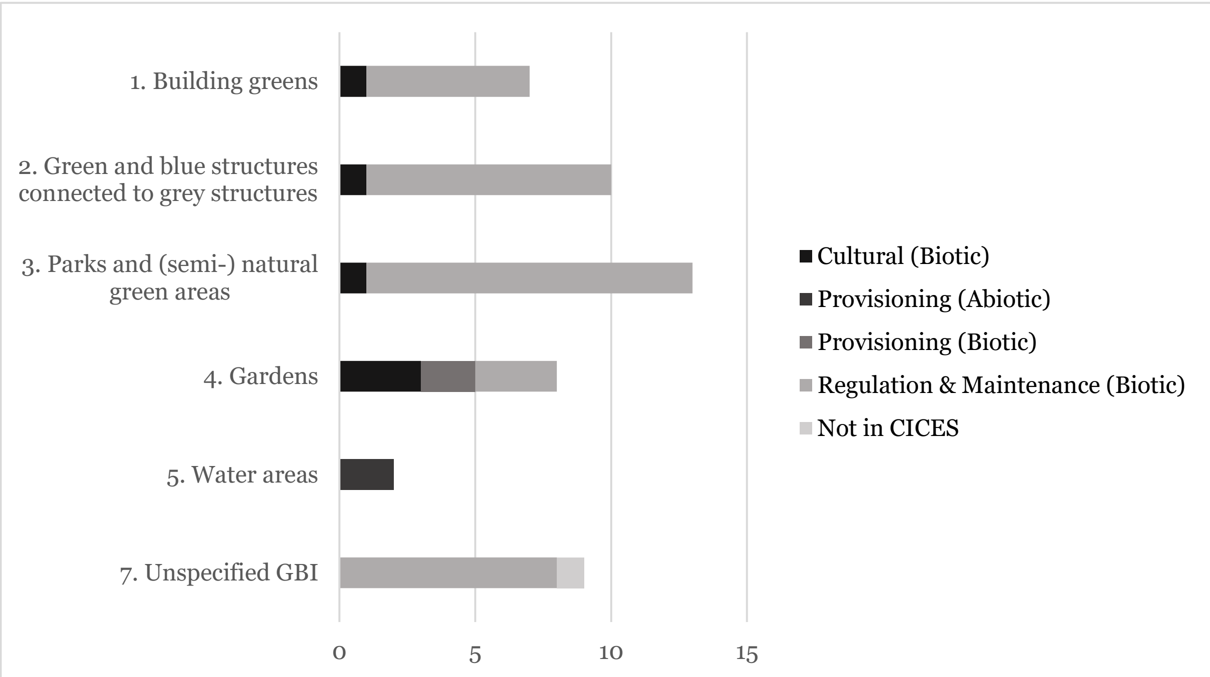

Figure 4. Number of ESS sections mentioned in the publication, per urban GBI type. Mostly, Regulation & Maintenance (Biotic) services were studied.

By analyzing the publications, it was also determined if, and how, the mentioned ESS were quantified in each study (table 2). Often, multiple ESS for the solution were mentioned in the introduction of the publication, but were not actually researched in the study. Within Regulation & Maintenance services, temperature regulation was quantified most in the studies by measuring differences in temperature through an assortment of methods, from handheld thermometers to satellite data. The publication by Klok et al. (2019) was the only study that also measured the perceived thermal comfort through a questionnaire. Carbon sequestration was calculated through either measuring the growth of the tree (Roetzer, Moser-Reischl et al. 2021) or using the avoided cost approach (De Valck, Beames et al. 2019, Johnson, See et al. 2021). With the exception of 'Recreation' as a cultural service in the study by de Valck et al. (2019), in which monetary value was given to the increased number of visitors of the study area, cultural ESS were not quantified in these publications. The biotic provisioning services from the gardens were not quantified in the analyzed studies. When ESS were mentioned in the study but not quantified, this was explained by the limited scope of the studies. The urban GBI type did not necessarily determine which ESS was provided. There was also a difference between ESS provision efficacy within the urban GBI types. Within GBI type 2, Roetzer et al. (2021) studied the differences in amount of CO_2 fixation and transpiration between two tree species. They concluded that it is important to also take into account which species to use when selecting for the anticipated ESS.

Discussion

In this literature review, 56 out of 813 publications about green UHI effect solutions were categorized based on the main urban GBI types of each solution (Veerkamp, Schipper et al. 2021). After that, 12 publications were selected and read in full to classify the ESS that were mentioned in the publications and to check whether or not these ESS were quantified in the studies. A comprehensive picture of the quantification of all ESS provided through the different green solutions is still lacking.

Selection of publications

During the selection procedure of the articles, care was given as to not accidentally exclude publications of interest. However, it is still possible that some studies were missed because they used different terminologies than the terms that were used to search on Web of Science (See methods 2.1). Because of the limited scope of this study, only recent publications (from 2019 onwards) were selected. Although this should have provided the most recent, state-of-the-art solutions, it is possible that earlier studies might have contained valuable information for this review. With more time, a more comprehensive analysis could have been done. The analysis could then not only include more than 12 publications, but also include the search for grey literature on green UHI solutions. (Local) governmental organizations might implement different green UHI solutions without full backing of scientific literature, but making policy decisions based on, for instance, aesthetics and safety as well (Dubbeld 2021). This study excluded non-science based solutions. The scope of this review was limited to nature-based solutions. A multitude of technical solutions for the UHI also exist. These technical solutions are for instance 'cool/ white roofs' or high-albedo materials for roofs, facades, or pavements (Costanzo, Evola et al. 2016, Herath, Thatcher et al. 2021, U.S. EPA 2012). A benefit compared to green roofs and facades are the lower maintenance costs (Johnson, See et al. 2021), but it does only mitigate one problem concerning the UHI (namely reducing heat). Green roofs, facades do bring additional benefits, such as air pollution removal, carbon sequestration, stormwater retention, and habitat creation (Hoeben, Posch 2021). Which solution works best is context dependent.

Urban GBI types

The different articles that were selected, were categorized based on the different urban GBI types used by Veerkamp et al. (2021). Through this categorization, 13 out of the 48 solutions were grouped in the 'unspecified GBI' category. This label was used when very broad terms such as 'green space' were used, but also when multiple solutions were mentioned in the same publication (table 1). The selection on urban GBI types was done based solely on the abstracts of the 42 different publications, because of time constraints. In future research, it might be wise to read these publications in full. During the full analysis, publications that contained more than one solution - such as De Valck et al. (2019) - were labeled with multiple urban GBI types instead of the general 'unspecified GBI'. It is important to be consistent in this categorization in future research efforts. The classification of the publications into 7 different main types might be too broad altogether. Within each category there is a lot of diversity, and even within each specific subtype a difference in delivered ESS can be observed. Urban GBI type 2, 'green and blue structures connected to grey structures', contains the subtype 'urban trees'. Roetzer et al. (2021) showed the difference in ESS delivery between two species of trees.

More extreme differences even within the same subtype 'urban trees' therefore exist. In previous research, it was shown that, depending on the tree species, the cooling effect in the urban environment can vary up to four times (Stratópoulos, Duthweiler et al. 2018, Rahman, Mohammad A., Armson et al. 2015, Rahman, M. A., Moser et al. 2019) . Besides that, seasonal changes may have an effect on the intensity of UHI but also on the efficacy of green UHI solutions (Schatz, Kucharik 2014). In future studies, it might be wise to categorize the solutions through a different classification method. Using for instance the classification system of nature based solutions (NBS) from Castellar et al. (2021), which aims to find a common classification and assessment system for NBS.

Quantification of ESS

While classifying the different ESS that were mentioned in the publications, the lack of a full quantification for each service could be noted. As multiple different ESS were usually covered when the authors of the studies publications described a specific solution, it can be concluded that the knowledge of the multitude of provided ESS by each solution is present. A lack of quantification for each mentioned ESS was often justified through the limited scope of each publication. Most publications quantified the differences in temperature that were observed (table 2). There were also multiple publications that mentioned and measured the impact on air quality that these solutions have in the urban environment. Usually, the publications mention an increase in air quality when implementing the solutions. Tiwari et al. (2021) was the only publication that mentioned the possible reduction of air quality by pollen from trees. This can be an important factor to take into account when selecting for specific GI in UHI solutions. The study by Hartigan et al. (2021) was the only one that quantified biodiversity benefits, through the modeling of potential birds habitats in urban forests. If the main problem to address is the UHI, biodiversity benefits are not the main focus when trying to quantify the efficacy of the solution. It is, however, an important ESS that the solutions can provide and it is therefore important to study which solution fits best in the local environment. Quantification of ESS based on their monetary value, as was done by Johnson et al. (2021) can provide a understandable picture for policy makers when deciding which solutions to implement. It is important to consider that ESS cannot always be reduced to their monetary value, because of the inherent complex reality of ecosystems and their services (Boerema, Rebelo et al. 2017). Lastly, in ecosystem services monitoring, it is important to differentiate between stocks and flows in natural capital, to create a comprehensive picture of possible benefits from NBS (Jones, Norton et al. 2016, Mancini, Galli et al. 2017).

It should be noted that in the classical reductionistic approach of the scientific method there is an inherent flaw when trying to classify the services that nature provides. Ecosystems are innate complex systems, which makes it ever more difficult to determine which services are provided and their respective quantity. Again, this is very context dependent (Fisher, Turner et al. 2009). Further, it is important to mention that the lack of quantification of provided ESS can have an adverse effect on the scientific coherence of ecosystem research. As mentioned before, most studies do qualify multiple ESS that a NBS can provide, but a quantification of the ESS lacks. It is therefore possible that multiple ESS are indicated while their actual benefit is not (yet) studied. The benefits that we derive from nature are still understudied, and perceiving a certain service as a given without studying and monitoring the factual benefits can cause a disparity between perceived and actual provided ESS. Ecosystem functioning in the natural environment is different than in the build environment. It is therefore not advisable to assume that the benefits that for example trees provide in nature are identical to the benefits trees would provide in cities. Monitoring of ESS in the urban environment is advised. This could be done through case studies in which science and industry work together to create more climate-adaptable buildings where monitoring of ESS benefits are integrated in the design of the building.

Conclusion

Research into different nature-based solutions for the urban heat island in Cfb climates is an extensive and evolving field of science. Studies focused on UHI solutions often mention multiple ESS, but fail to quantify the mentioned ESS. It remains difficult to determine exactly how different nature-based solutions benefit humans in its totality, because of the complex reality of ecosystems and their services (Boerema, Rebelo et al. 2017, Fisher, Turner et al. 2009) and because of the differences between the natural and urban environment. It is therefore important to find a common classification system of ESS and a common quantification system of these services (Boerema, Rebelo et al. 2017, Haines-Young, Potschin 2018). It is also important to connect science and industry together to create case studies where the full potential of provided ESS from NBS in the urban environment can be quantified and monitored. A common and clear way of classifying and documenting the benefits that arise from these NBS for the UHI, and case studies in which the actual benefits are monitored, will help policy- and decisionmakers create futureproof and nature-inclusive cities.

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