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Review

Assessing the recreational value of small-scale nature-based solutions when planning urban flood adaptation

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ABSTRACT

Nature-based solutions may actively reduce hydro-meteorological risks in urban areas as a part of climate change adaptation. However, the main reason for the increasing uptake of this type of solution is their many benefits for the local inhabitants, including recreational value. Previous studies on recreational value focus on studies of existing nature sites that are often much larger than what is considered as new NBS for flood adaptation studies in urban areas. We thus prioritized studies with smaller areas and nature types suitable for urban flood adaptation and divided them into four common nature types for urban flood adaptation: sustainable urban drainage systems, city parks, nature areas and rivers. We identified 23 primary valuation studies, including both stated and revealed preference studies, and derived two value transfer functions based on meta-regression analysis on existing areas. We investigated trends between values and variables and found that for the purpose of planning of new NBS the size of NBS and population density were determining factors of recreational value. For existing NBS the maximum travelling distance may be included as well. We find that existing state-of-the-art studies overestimate the recreational with more than a factor of 4 for NBS sizes below 5 ha. Our results are valid in a European context for nature-based solutions below 250 ha and can be applied across different NBS types and sizes.

1. Introduction

Climate change and urbanisation will substantially increase the risk from pluvial floods in cities (Arnbjerg-Nielsen, 2012; Kaspersen et al., 2017). Measures to reduce risk are increasingly above-ground and multifunctional to be relevant for other stakeholders with the aim of increasing their uptake (Fletcher et al., 2015; Fratini et al., 2012). Within Europe, the most recent term for these measures is nature-based solutions (NBS) (Nesshöver et al., 2017). NBS are inspired and supported by nature and deemed more cost-effective than traditional grey solutions (European Commission, 2015; Nesshöver et al., 2017; Raymond et al., 2017). NBS, however, require more space than traditional grey solutions; hence, their uptake is limited by competing with other agendas for allocation of space in the urban fabric (Fratini et al., 2012; Skrydstrup et al., 2020). Thus, in the planning phase, it is necessary to quantify also intangible benefits to avoid cost benefit assessments that are biased towards the monofunctional "grey" solutions.

The many benefits of NBS are being increasingly monetized (Bockarjova et al., 2020a; Brander et al., 2006; Brander and Koetse, 2011; Van Oijstaeijen et al., 2020). Monetary estimates can convey information and deliver stronger arguments for the business case of NBS, as a lack of economic arguments is seen as a barrier for their implementation (Aerts, 2018; Van Oijstaeijen et al., 2020). The benefits, including recreation, improved air and water quality, and noise reduction, have no observable markets and thus require special valuation techniques. Overall, these valuation techniques are divided into stated and revealed preference techniques. Stated preference techniques use surveys to elicit the willingness-to-pay (WTP) for any non-market good and can thus estimate both use and non-use values. Revealed preference techniques elicit the WTP for non-market goods through related real markets (e.g. house prices and travel behaviour), and can only estimate direct use values (Pearce et al., 2006). Performing primary valuation studies is time-consuming and costly; thus, it is often not feasible to perform such studies for individual sites (Freeman et al., 2014; Pearce et al., 2006). Benefit transfer is typically applied to transfer values from primary valuation sites to a given case study. Values vary in time and

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space, and thus, the primary valuation context should be identical to the applied case study context (Pearce et al., 2006). However, few studies have been conducted under identical conditions (e.g., income levels, population density, or nature type). One way forward is to perform a direct unit transfer, accepting the errors it entails due to the difference in context. Alternatively, values must be adjusted before they are transferred. The state-of-the-art method for adjusting WTP includes meta-regressions analysis, a statistical method that compensates for variation in key influencing variables from selected relevant primary valuation studies (e.g. Bockarjova et al., 2020a; Johnston et al., 2017; Schägner et al., 2018). These variations are often explained by different socio-economic characteristics, scope, location, and methodology.

Existing meta-analyses of non-market values of NBS have several limitations. Firstly, the existing studies are not applicable for most urban planning contexts. We are aware of only three studies that attempt to transfer values of urban nature (Brander and Koetse, 2011; Bockarjova et al., 2020a, 2020b). Value estimates in Brander and Koetse (2011) and Bockarjova et al. (2020a) are biased towards large NBS with average areas of 9918 ha and 472 ha, respectively. As discussed by the authors, the study results have limited applicability for, and likely overestimate values of smaller NBS (<50 ha). However, urban solutions, specifically new ones, must fit in areas where space is limited and it is quite rare to establish new NBS locations in urban areas that are larger than 50 ha (Rogers et al., 2020; Rosenzweig et al., 2019; Zhou et al., 2013). Bockarjova et al. (2020b) identify value estimates from hedonic pricing studies. They were not able to control for NBS size due to lack of suitable data, implying that their estimates hold for the average size of NBS sites included in their database. Since NBS size clearly is a key variable in explaining the value of NBS, additional research is needed on values of smaller NBS in cities.

Secondly, mixed results were obtained in terms of which explanatory variables should be included in the models. Meta-analysis on the WTP for nature considers many explanatory variables, e.g., income, population density, area, nature type, ecosystem services, valuation method, payment vehicle. Out of 19 explanatory variables, Bockarjova et al. (2020a) found that GDP per capita (reflecting income levels), NBS size, population density, nature type (parks) and payment vehicle (tax) had a significant effect on value per hectare. Similarly, Brander and Koetse (2011) found population density, the area, nature type (parks) and payment vehicle (tax) to be significant but not GDP per capita. In general, income is the most frequently used variable to adjust for differences between the primary study and the application site (Freeman et al., 2014; Pearce et al., 2006). Czajkowski et al. (2017) found higher quality transfers when only adjusting for income. Similar to Brander and Koetse (2011), other meta-analysis on urban (Bockarjova et al., 2020b) and non-urban nature (Schägner et al., 2018) find no income effect. From the large pool of tested explanatory variables, less than half turns out to be statistically significant (e.g. Bockarjova et al., 2020a and Schägner et al. (2018)) and mixed results with respect to sign and magnitude of the effects are obtained. While all studies report the statistical significance of explanatory variables, the exploratory data analysis is never reported, and visual inspection of model residuals is not provided. This hinders an interpretation of why different models yield different results. The mixed results from previous studies suggest a need for further investigation on explanatory variables as well as the rationale underlying meta-studies.

Thirdly, value estimates obtained from benefit transfer are uncertain due to benefit transfer itself and due to the uncertainty surrounding value estimates from underlying primary studies (Boman and Doctorman, 2017). The latter can be described by standard deviations, while the first inevitably introduces subjectivity and assumptions (Pearce et al., 2006). Benefit transfers, and in particular those that use value functions obtained from a meta-analysis, requires a high level of details and information, specifically on distance decay and on the number of affected households (population size), income, or hard-to-find input variables (e.g., visitor count). Often, these are not sufficiently described, which leads to an increase in assumptions or exclusion of studies and thus ultimately in higher uncertainty. The impact of these uncertainties and assumptions on benefit transfer estimates is not well studied, but it is clear that errors and uncertainties made in benefit transfer remain substantial in spite of substantial efforts to improve the methods have been made over the past 30 years (e.g. Smith, 1989; Smith and Pattanayak, 2002; Kaul et al., 2013; Johnston et al., 2015).

The above-mentioned shortcomings have framed the scope of our study. We perform a review of primary valuation studies that are applicable to NBS in urban areas, with the aim of providing a value transfer function that can capture the value of urban nature when planning urban scale flood adaptation. Several studies state that the transfer function should not be over-parametrized, and they suggest a mix between simple mean transfer and meta-analysis, which is simple to implement for decision-analysts (Bateman et al., 2011; Czajkowski et al., 2017; Lindhjem and Navrud, 2008; Nelson and Kennedy, 2009). Thus, we combine a transparent interpretation of data, which makes connections that are hidden in statistical models explicit with a standard meta-regression analysis for only the relevant studies. This enables a direct understanding of the effect of different assumptions and can help to clarify why contradicting results have been obtained in the literature. We can further use the analysis to derive reasonable value ranges that are not normally presented. We focus on the recreational value as this is deemed one of the most important benefits of using NBS in urban areas (Derkzen et al., 2017; Hermes et al., 2018; Skrydstrup et al., 2020).

2. Methodology

This methodology section is divided into five parts (Fig. 1). The first part describes the context and terminology in which we operate and is followed by the search strategy to gather the primary valuation studies to apply in our analysis. The third part outlines the visual data inspection to identify important variables for the regression analysis. The fourth part contains the identification of the value transfer function, i.e., meta-model, for establishing of new NBS locations. The final part presents the recreational value for two illustrative case examples.

2.1. Definition of nature types

We focus on NBS that can change the hydrological balance to reduce urban flooding. Existing valuation studies can roughly be divided into the following groups:

- *Sustainable urban drainage systems (SUDS):* Small green areas with limited recreational activity. Examples are accessible green roofs, swales and/or series of rain gardens. These solutions are flexible, as they require little or no space. The typical spatial scale is < 1 ha.
- *City parks (CP):* Green areas with room for different types of recreation that might contain blue areas, for example, a lake. In this study, a city park is 1–50 ha.
- *Nature areas (NAT):* Green areas with room for different types of recreation that might contain blue areas, for example, a wetland. Compared to a city park, *NAT*s are wilder and provide more biodiversity. *NAT*s in this study are larger than 50 ha and are typically adjacent to a city, for example, a forest.
- *Rivers/streams (R):* A majority of the area is water, so there may be a riverbank or flood plain along the river where people can access the river. We did not consider entire river catchments but focused on sections of the river with urban recreational activity. The spatial scale is 1–60 ha.

2.2. Search strategy

For our literature search, we aimed to select studies that represent common methods, definitions, and issues in valuating recreation as well as a broad range of geographical locations. We searched for literature in electronic journal databases (Web of Science and Scopus) and mined

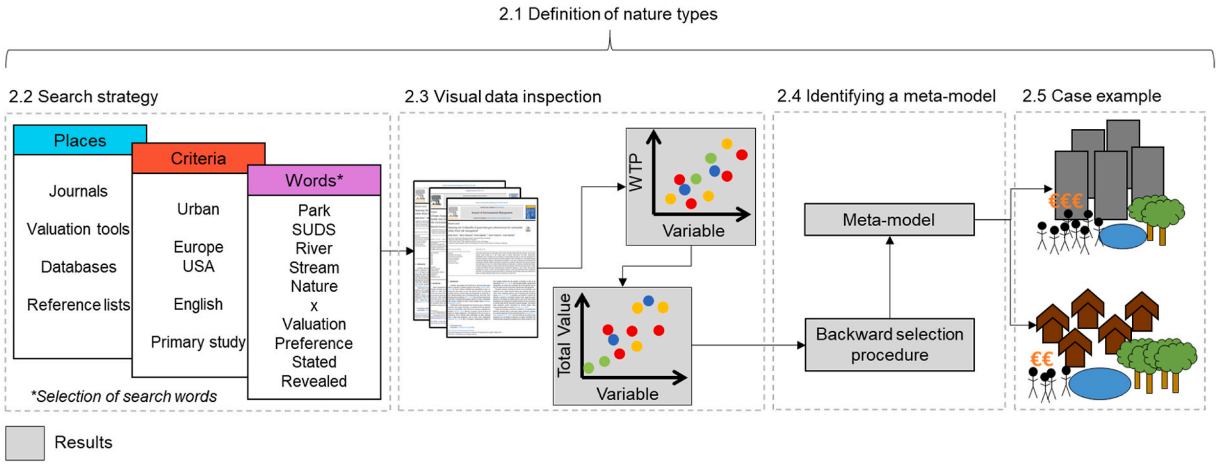

Fig. 1. Methodology used in this study. We analyse scatterplots between values and explanatory variables to identify important variables to derive a meta-model using standard assumptions. The model is applied on two case examples: a city centre and a suburb.

existing tools (BeST (Horton et al., 2019) and INFFEWS Value Tool (Iftekar et al., 2019)) and databases (TEEB (Van der Ploeg and de Groot, 2010)). Some studies were found in the reference lists of other identified studies. We included peer-reviewed articles, other articles, books, and official reports. We only considered studies from developed countries and prioritized studies from Europe, the USA, and Australia with an urban setting and nature types related to NBS for flood protection, as previously defined. We included only primary valuation studies to elicit recreational value, and we excluded studies performed before the year 2000 to ensure up-to-date valuation results.

We searched for recreation in the title, but we also included studies with no specific mention of recreation that still had a recreational potential. Main search words other than the considered nature types covered types that might exist within the defined nature types (wetland, lake, park, green roof, river, stream, *SUDS*, trees) and terms capturing monetary valuation (preference, stated, revealed, valuation, choice experiment, contingent, hedonic).

We set an upper size constraint of 250 ha for green urban areas. Additionally, we expected that NBS in urban areas would typically be *CPs* or *SUDS*, so we only included one large forest area in the sample. Furthermore, we prioritized studies on city or neighbourhood levels with a maximum travel distance of 10 km, as we focus on measures that mostly provide value to local citizens rather than value through tourism.

Lastly, we include both stated and revealed preference studies to increase the data sample size. We acknowledge the fundamental differences between these two valuation methods and therefore test the impact of combing these two valuation techniques on the results.

2.3. Visual data inspection

We performed a visual interpretation of the data and tested linear adjustments based on the trends observed in the data and used this information to establish a regression model to elicit the value transfer function. This approach makes trends in the data and assumptions for benefit transfer explicit. These are frequently hidden in the mathematical models in existing meta-studies, which limits their interpretability and makes it difficult to determine in which situations the model may not be applicable.

Table 1 summarizes the considered valuation studies, valuation approach and the input variables used to specify the total recreational value of a measure in each study. Overall, these studies vary in income levels, NBS size, population density, existing nature options and the valuation method applied. Apart from being performed in different cities and for different types of NBS, the primary valuation studies also vary in what types of data are used to quantify the value of an NBS and the level of detail provided for the specific study. Table 1 also includes information on specific characteristics of each study that may limit its transferability to other locations.

Conceptually, the recreational value of an urban NBS is determined by two main factors:

1) The value that an individual household assigns to the NBS
2) The total number of households that benefit from the NBS

In contrast to previous studies, we explicitly structured our analysis around these factors that represent distinctly different influences on the total recreational value of an NBS. Section 2.3.1 investigates the variables that cause differences in WTP for individual households. The individual WTP is used for the initial analysis because it is available from many primary studies and thus minimizes the interpretation of data. In this step, we excluded studies in which we cannot estimate an individual WTP directly from the data given in the primary study. This excluded many revealed preference studies, meaning that the final set of studies mainly included stated preference studies (Table 1).

Section 2.3.2 investigates which variables impact the number of people affected, which required an analysis of the total recreational value of an NBS from each study. All studies in Table 1 are included in this step. Each step is further elaborated below, and all calculated values and estimated variables are in the supplemental material.

2.3.1. WTP for individual households

The first step in the analysis was to check the WTP of individual households determined in each primary study, which is denoted as WTP_{hh} and adjusted with purchasing power parities (PPP) (OECD, 2021). We analysed WTP_{hh} dependence on the main study characteristics as described by previous research and thus include income, population density, NBS size and maximum travel distance, that is, the maximum distance at which people still assign a value. We consider these independent variables and apply a stepwise approach and plot the dependent variable against the independent variables. If the plots indicate any co-variation, e.g. linear correlation, the independent variables are used to normalize WTP_{hh}, e.g. by division by the independent variable.

Income levels might affect households' WTP because they affect the budget that households can spend freely. We use GDP to reflect income levels, as income levels are frequently not specified in primary studies. We use GDP per capita for the city where the study was conducted. GDPs for 2018 were collected from OECD databases (reference year 2015), where PPP have been accounted (OECD, 2020a; 2020b). We denote this GDP_{PPP}.

Table 1
Valuation studies eliciting the recreational value of NBS nature types. Input variables list the data needed to aggregate values. The column Transfer issues comments on the lack of information or scope that decreases the quality of the transfer. *Not included in analysis on individual level (Section 2.3.1 and 3.2).

Study	Nature type	Nature description	Country	Method	Input variables	Transfer issues
Treadwell (2019)	*CP*	2.6 ha park adjacent to a green cemetery used recreationally	DK	SP	No. of households	Maximum travel distance[a] not specified and distance decay not analysed
Bertram et al. (2017)	*CP*	Parks around the city. Majority less than 10 ha	DE	SP	No. of households	Maximum travel distance not specified. Values provided for weekend and weekdays, so average was taken
Panduro and Veie (2013) [a]	*CP*	Parks around the city. Min. 0.24 ha and max 32.9 ha	DK	RP	House price, distance from area	Conversion of changes in house price to annual value requires rough assumptions. Value estimates decline with distance, so the application in other studies required detailed spatial data and house prices
Bjørner et al. (2014) [a]	*CP*, *NAT*	Nature all over Denmark. Urban parks from largest cities. Average area of nature included is 135 ha, with parks around 20 ha	DK	RP	Size of natural area	National study, which is difficult to apply on city level. Households excluded from results, thus values only depended on the area of nature
Tu et al. (2016)	*CP*, *NAT*	23 Parks and 5118 ha of forests in and around the city	FR	SP	No. of tenants and house owners, residence time	Maximum travel distance not specified, and distance decay not analysed. Size of parks not given. Value assumes residence moves 100 m (parks) and 1000 m closer (forests), which require additional spatial data. For forests, visitor number observations are required
Andrews et al. (2017)	*CP*	Park in city centre and in suburb	UK	SP	No. of households	No specifics of the park are given, only location information
Zhou et al. (2013) [a]	*CP*, *SUDS*	Parks and green pockets around the area. Min. 1 ha, max. 741 ha, and mean 9.5 ha	DK	RP	House price, No. of households	Value is given per 100 m a house moves closer to a green area and is only valid within 500 m, which requires detailed housing information
Saz-Salazar and Rausell-Köster (2008)	*CP*, *NAT*	117 ha urban park. Transversal layout with sections having different characteristics. Size wise is classified as NA, but looks and functions more as CP	ES	SP	No. of households	Distance decay not reported, but the entire city limit is given as the maximum travel distance. Payment vehicle is real estate tax. WTP varies for the different sections of the park and depends on facilities and income level of adjacent areas
Hasler et al. (2009)	*R*	Improvement of river water quality. Three stretches of 15–20 km (out of 60 km) are investigated	DK	SP	No. of households	The study was conducted on a regional level. Recreational use and non-use values in the form of nature protection are presented. Questions are formulated as recreational activities possible at different water qualities, i.e., values are reflected through water quality, which is different from other evaluated studies
Latinopoulos et al. (2016)	*CP*	18.4 ha metropolitan park	GR	SP	No. of households	Park is placed outside city centre. City has a low rate of green per capita (2.6 m^2), which might result in overestimation of values in places with higher rate of green. Only average travel time is given (in minutes), instead of maximum travel distance
Mell et al. (2016)	*R*	Greening and access to river. Approx. 0.5 ha	UK	SP	No. of households	Value is just for one stretch of the river and on a neighbourhood scale. Payment vehicle is presented as additional rental/mortgage payments, which is different from other tax-based studies. Distance decay and maximum travel distance is not reported
Koetse et al. (2017)	*CP*, *NAT*	Generic value function for nature with areas between 200 and 1600 ha	NL	SP	No. of households	National study. Most municipalities included in the study already live in green areas and are small. Found that differences in preference between municipalities implicates the use of the generic value function on regional and local scales
Plant et al. (2017) [a]	*SUDS*	Greening of footpaths with trees, given a 100 m boundary	AU	RP	House price, No. of households, Increased footpath cover	Value given as percentage annual property value premium per 1% increase in tree cover within 100 m, which require detailed housing data. Australia has a high need for shade from threes, which might overestimate values in colder climates
Reynaud et al. (2017)	*CP*, *SUDS*	Water infrastructure project of 6.5 ha that contains both SUDS (2 ha) and more traditional park elements	IT	SP	No. of households	Distance decay not analysed. Very low response rate. Value includes multiple benefits, as the site is constructed for water pollution removal, flood reduction, recreation, and biodiversity/wildlife support
Sarvilinna et al. (2017)	*R*	Restoration of urban streams with a catchment less than 10,000 ha. Total recreational area is around 70 ha	FI	SP	No. of households	Payment vehicle is 10 annual donations into a Small Water Fund, unlike other considered studies. Value includes multiple benefits of reducing flooding, increase biodiversity and provide recreation areas. Distance decay not described. Considers a very large catchment,

(*continued on next page*)

Table 1 (*continued*)

Study	Nature type	Nature description	Country	Method	Input variables	Transfer issues
						which might not be feasible for other areas. Not solely urban
Votsis (2017) [a]	*CP*, *NAT*	Parks and forest areas within the city	FI	RP	Average m^2 price, No. of apartments	Only includes block apartments. Only average travel distance (instead of max.) to the green areas are given. Value is given as a percentage of the average price per m^2 within a certain distance from the CBD, which requires more data.
Liebelt et al. (2018) [a]	*CP*	Urban green spaces are valued and includes parks, forests, woods, and cemeteries. Areas are between 0.0025 and 568.3 ha, with an average of 5.89 ha.	GE	RP	Average apartment and house size, No. of apartments and houses	Value is given for apartments and houses that experience a 1% increase in shared green spaces within 300 m (both rent and sale), which require detailed housing data. The study is on a municipal level, but operates in bands of 300 m
Panduro et al. (2018)	*CP*	Urban parks with an average density of 19.6 ha within 1000 m	DK	RP	Size of park, no. of households,	Large variation in park preferences across households, which makes local application difficult. Only includes apartments in the inner city, where house prices are very high. Two value estimates; one is reflected as an additional ha of park (availability) and the other as a scenario with no park vs. existing parks (accessibility)
Jarvie et al. (2017) [a]	*S*	Natural and artificial SUDS ponds with a surface area between 240 and 8099 m^2	UK	SP	No. of persons	Survey respondents' values biodiversity and recreation. Distance decays not analysed, but suggests a boundary of 500 m (i.e., maximum travel distance)
Giergiczny and Kronenberg (2014)	*SUDS*	Street trees in a city centre	PL	SP	No. of households, length of roads	The city centre has the lowest density of street greening among major Polish cities. Maximum travel distance, population density, and area is not provided
Kenney et al. (2012)	*R*	Restoration of urban streams, focusing in recreational and aesthetic value. 400 m being valued	US	SP	No. of households, Length of restoration	Payment vehicle is a one-time tax, making it hard to compare to other studies. However, the study does provide an annual value assuming a 7% discount rate and 50-year planning horizon, which introduces additional uncertainty
Fruth et al. (2019)	*SUDS*	Greening of a 1 km street	GE	SP	No. of households	Street is in very densely populated area, and noticeable lack trees and vegetation. Distance decay not analysed.
Hampson et al. (2017)	*R*	Restoration of river running along the outskirt of urban area. 20 km being valued	UK	SP	No. of households, Length of restoration	Anglers and swimmers are oversampled, which might lead to overestimation of value. 20 km of river is valued, but not all of it is urban. Distance decay is not analysed

[a] Maximum travel distance denotes the maximum radius, with the NBS as centre point, where values are approximating zero.

Population density can be considered an indirect measure of nature scarcity, where high densities indicate less green spaces (Bockarjova et al., 2020a), and at the same time, indicate how many people will use and share a measure. We used population densities from statistical registers (OECD and Eurostat). Where the studies provided enough information, we calculated the local population density, for example, based on the number of affected households and maximum travel distance.

The maximum travel distance indicates the quality of the NBS experience, that is, if people are willing to travel further, they assign a higher value. The maximum travel distance varied between studies. Some include households within 1000 m of the recreational area, while others include households up to 5000 m or more. Other studies (Bockarjova et al., 2020a; Brander and Koetse, 2011) have assumed that the entire urban population will benefit from a piece of nature. We consider the number of households considered in the original valuation studies in our analysis. In this way, we only include the number of households where the value is most likely to occur. If studies simply state that the entire city will be affected, then the radius of the city (manually assessed) is calculated. For a few studies it was impossible to derive a maximum travel distance. For these cases we used the average travel distance of respondents as the maximum travel distance. If the total number of households was not provided, the area estimated from the travel distance was multiplied with the population density and divided by the national average of persons per household.

The size of the NBS might indicate where the measure is placed, leaving more flexibility for smaller areas to be placed in areas with higher WTP. The NBS size is frequently not clearly specified in the evaluated studies. Some studies provide a range but no mean/median, whereas others provide no information at all. If no information could be obtained from the study or its authors, we either estimated its area on Google maps (if the measure is well-confined) or excluded the study from our analysis when the size could not be determined.

We only consider studies where we can obtain an annual WTP_{hh} (Table 1) and define this as the dependent variable. We selected the mean WTP_{hh} that best reflects the recreational value, but some studies inherently include multiple values (e.g., habitat creation and biodiversity). Most studies used *number of households* as input variable, but a few studies used number of *number of people* or *Visitors*. Since the conversion from WTP/visitor or WTP/person is missing from the primary studies (Table 1), we excluded them from this analysis but included them in the

Table 2
Main characteristics of the cases used to illustrate the results.

Characteristics	Suburb	City centre
GDP per capita [2018 USD]	40,000	60,000
Population density [Pers./km2]	219	761
NBS types	**Size of NBS [ha]**	
SUDS	1	
CP	10	
NAT	200	
R	60	

analysis outlined in Section 2.3.2.

All values are extrapolated to 2019 to account for inflation. To do this, we used the difference in consumer price index (CPI) from the year 2019 and divided it with the CPI from the year the valuation study was conducted. The CPI values were identified for the respective countries (Worldbank, 2020). This factor was then multiplied by the WTP_{hh} from the valuation study. Furthermore, all values were converted to euros at the 2019 value rate.

2.3.2. Total recreational values of NBS

We investigated how variables correlate with the total recreational value of NBS and thus the number of people benefitting from an NBS. Hence, we derived the total recreational value from each primary study, denoted as VA_{tot}, and attempted to identify influential variables.

The number of affected households is determined by the number of people living in an area and the willingness of people to travel to the NBS. Population density (*PD*) could be readily obtained worldwide to quantify the number of people living in an area. The maximum travel distance $D_{\max}$ could not be readily estimated from data when estimating values for a new NBS. However, we hypothesised a relationship between the spatial extent of an NBS (area *A*) and $D_{\max}$, in line with previous studies that found area *A* of the NBS to be a significant predictor of total recreational value (Bockarjova et al., 2020a; Brander and Koetse, 2011).

Unlike the first analysis, we included all studies in which VA_{tot} could be obtained, i.e., also studies that were excluded in the first step. For revealed preference studies we estimated a total recreational value based on the average house price/premium provided in the primary studies and an asset return rate of 5% (Panduro et al., 2018). We assumed that all houses within the given maximum travel distance were affected and that the magnitude of the effect was given by the unit value. More details are provided in the supplemental material.

For the two stated preference studies we excluded in Section 2.3.1 due to *people* and *visitor* as input variable, we assumed that WTP/visitor/year and WTP/person/year could be converted to WTP/household/year by multiplying with the average number of people per household from the city where the study was conducted (See supplemental material). As we did not know how many of these visitors were tourists, we assumed conversion without further adjustments. This might result in slightly higher total recreational values, compared to studies with households as input.

2.4. Identifying a meta-model

Inspired by meta-models for larger NBS (e.g. Bockarjova et al. (2020a)) we considered $log_{10}(VA_{tot})$ as the dependent variable. A double-logarithmic relation between VA_{tot} and the potential explanatory variables are identified. All variables from the visual data inspection were included in the full model:

$$log_{10}\left(VA_{tot,\ i}\right) = \alpha + \beta^{A}\cdot log_{10}\left(X_i^{A}\right) + \beta^{PD}\cdot log_{10}\left(X_i^{PD}\right) + \beta^{D_{max}}\cdot \log_{10}\left(X_i^{D_{max}}\right) + \beta^{GDP}\cdot X_i^{GDP} + \beta^{Type}\cdot X_i^{Type} + \beta^{Method}\cdot X_i^{Method} + \varepsilon_i \quad (1)$$

where α is the intercept, β are the coefficients describing the impact of the vector *X*, with one vector for each of the independent variables explained in previous sections, that contain values for all observations represented by the subscript *i*. The independent variables *A*, *PD*, and $D_{\max}$ are log-log transformed as this better describes the relation between the dependent and independent variables (Bockarjova et al., 2020a; Brander and Koetse, 2011). These assumptions are tested in the visual data inspection. The independent variables *Type* and *Method* describes the nature types as explained in Section 2.1 and the overall valuation technique applied (i.e., stated preference or revealed preference), respectively. These are represented as binary variables in the model. The full model was then reduced in a guided model selection based on standard statistical tests, including backward elimination and forward selection, as well as considerations on model suitability for the purpose of assessing NBS values in a planning context.

2.5. Illustrative case example

To evaluate the range of results for different urban NBS types, we defined two urban areas that are representative for Northern Europe. The resulting $VA_{adj,x}$ and the value transfer function derived from the regression model were used to estimate recreational value. We distinguished between two locations: a city centre and a suburb. A city centre is typically different from a suburb by having a higher density of people, higher house prices, and more people share recreational areas. The two cases are generic and likely occur in Northern Europe. The four nature types will have the same properties in the two locations. The only parameters that distinguish the two case studies are GDP and population density (Table 2). To highlight the skewness of the calculated distributions of the recreational value both median and mean values are presented.

3. Results

3.1. Review of valuation studies

We screened more than 100 primary valuation studies, and identified 23 articles that included the urban setting, the small scale of NBS, and the relevance for urban flood adaptation. The 23 articles contained 33 observations covering the recreational value of the four defined nature types, needed to estimate the value of urban small-scale NBS for urban flood adaptation (Table 1). This section provides a short review of the valuation studies.

We identified 16 stated preference studies and 7 revealed preference studies, located in Denmark, Finland, Germany, France, the United Kingdom, Spain, Italy, Australia, the United States, and Poland. The GDP per capita (2018, PPP) ranged from 24,287 USD to 61,970 USD, with a median of 44,998 USD, only slightly higher than the European average of 44,370 USD (2018, PPP) (TradingEconomics, 2020). The average population density of the urban areas ranged from 188 pers./km^2 to 25,670 pers./km^2, with a median value of 1949 pers./km^2, which is slightly lower than the urban European average of 2065 inhabitants/km^2 (estimated from OECD, 2020c).

The average size of the nature types was 44 ha, with a median of 7 ha, skewing sizes toward smaller areas. Less than 10% of our observations were 200 ha or more. Most of our studies elicit the value for *CP*s (16 observations), followed by *NAT*s (6 observations), *SUDS* (6 observations), and *Rs* (5 observations). This represents the availability of urban recreational studies for specific nature types. Many studies were conducted at the city scale, but three were conducted at the neighbourhood scale and one on a regional scale. The scale was only reflected by the maximum travel distance in the analysis.

3.2. Analysing WTP for individual households

The annual WTP at the individual level, that is, per household (WTP_{hh}), is not found to be dependent on any of the independent variables identified in the literature (Fig. 2), including GDP. We applied statistical tests based on bootstrapping and permutation of the WTP_{hh} from the primary studies to test whether there was a difference in means between the four nature types (Brockhoff et al., 2018). This was not the case (Supplemental material). Thus, the WTP_{hh} should not be adjusted or distinguished by nature types.

3.3. Analysing total recreational value of NBS

Next, we analysed variables influence on the total recreational value (VA_{tot}) and thus the influence on the number of affected households. Similar to the previous analysis, we used key variables that we

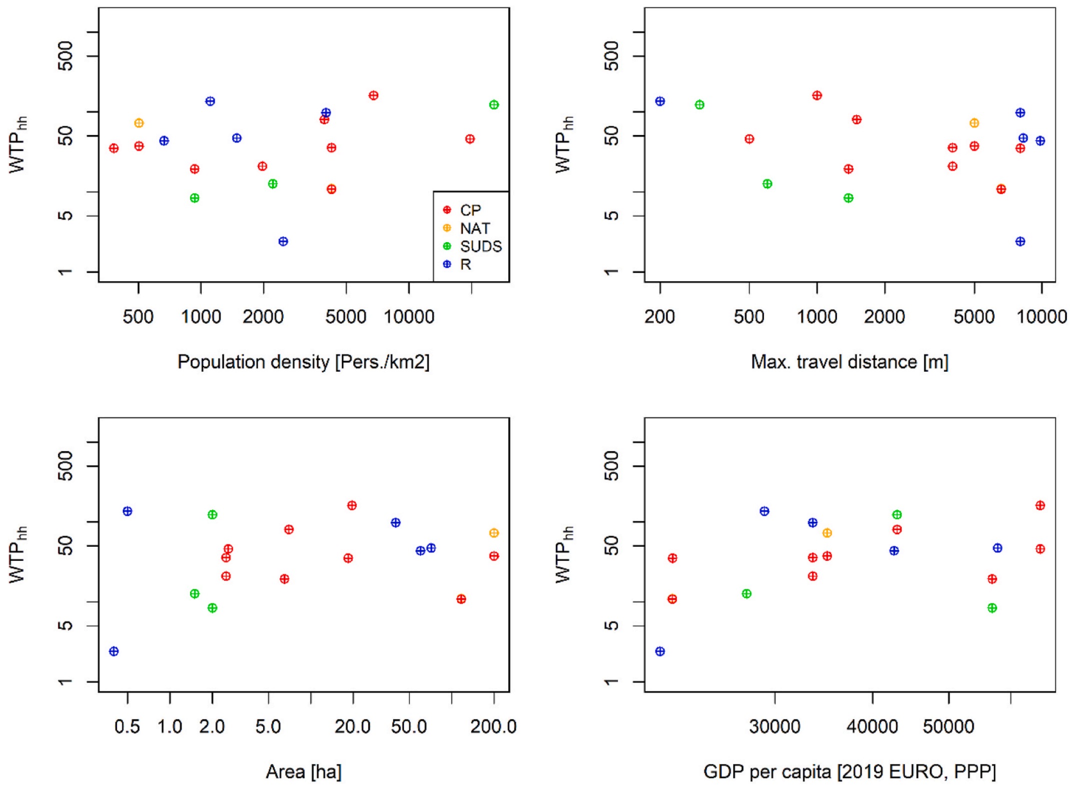

Fig. 2. Analysing the dependencies of population density, maximum travel distance, area, and GDP_{PPP} on the individual WTP (WTP_{hh}) given as €/household/year. Both axes area on a logarithmic scale. There is a very low correlation between WTP_{hh} and the studied variable. Only WTP values derived using stated preference approaches were included in this assessment. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

hypothesised to have an impact; population density, maximum travel distance, and the NBS area (Fig. 3).

Fig. 3 shows that the total recreational value seems linearly related to area and maximum travel distance. The size of the NBS and travel distance are related such that bigger areas result in larger maximum travel distances (Fig. 3). Since NBS area and the maximum travel distance are linked, we removed the effect from both by dividing with the NBS area from the primary studies, thus obtaining a value per hectare, denoted as $VA_{adj\text{-}ha} = VA_{tot}/A$ (Fig. 4). Based on Figs. 3 and 4, we can identify a clear dependence on population density and a less clear dependence on maximum travel distance.

3.4. Meta-model

The parameter estimates and significance levels are shown for the full model in Table 3 as well as two models where all independent variables are significant. We tested a number of different alternative models and found that the lowest residual standard error was a model where A, PD, $D_{\max}$ and a distinction between NAT and the three other NBS types were used as independent variables. Overall the model results confirm the results obtained by the visual data inspection.

The variables A and $D_{\max}$ are expected to be correlated and indeed the calculated R^2 is 0.55 between these two variables while all other correlations between the input variables are insignificant (supplemental information). In a planning context D_{max} is difficult context which is why we recommend to apply a value transfer function that only includes A and PD as independent variables:

$$\log_{10}(VA_{tot}) = 1.273 + 0.643\log_{10}(A) + 1.148\log_{10}(PD) \quad (2)$$

We recognize that this model has a higher residual standard error than a model including the maximum travelling distance. To compensate for this we suggest that the planners at least qualitatively consider whether there will be properties of the NBS in question that may be impacting the typical relationship between travelling distance and size of the NBS. Further, the model results may indicate that the more natural the NBS is the higher value is has. A more systematic assessment of the properties of the NBS, including which characteristics may increase or decrease recreations value, can be found in Lin (2016).

Since the meta-model uses log-transforms and has a non-negligible residual uncertainty the calculated VA_{tot} will be a random variable with a skewed distribution where the median and the mean values are quite different. Hence we suggest to calculate both values to indicate the importance of the uncertainty of the calculated values.

3.5. Illustrative case example

The statistical tests (mean WTP_{hh}) and the meta-regression analysis (total recreational value) showed no significant relation between values and the four nature types. Therefore, the value transfer function can be used for all nature types with a recreational purpose and varying population densities (Table 4). Table 4 summarizes the results of using the transfer function to estimate the total recreational value for illustrative case examples. Differences across nature types are largely driven by the area of the measure, while the value differences between the suburb and city centre are driven by different population densities (Table 4). As discussed previously the results are indicative and probably more precise results can be obtained for existing NBS if the maximum travelling distance is obtained.

3.6. Comparison to existing meta-regression analyses

We compared our meta-model to the most recent meta-study on urban nature for which it was possible to obtain a value per hectare (Fig. 5). Compared to our study, the data of the other meta-studies

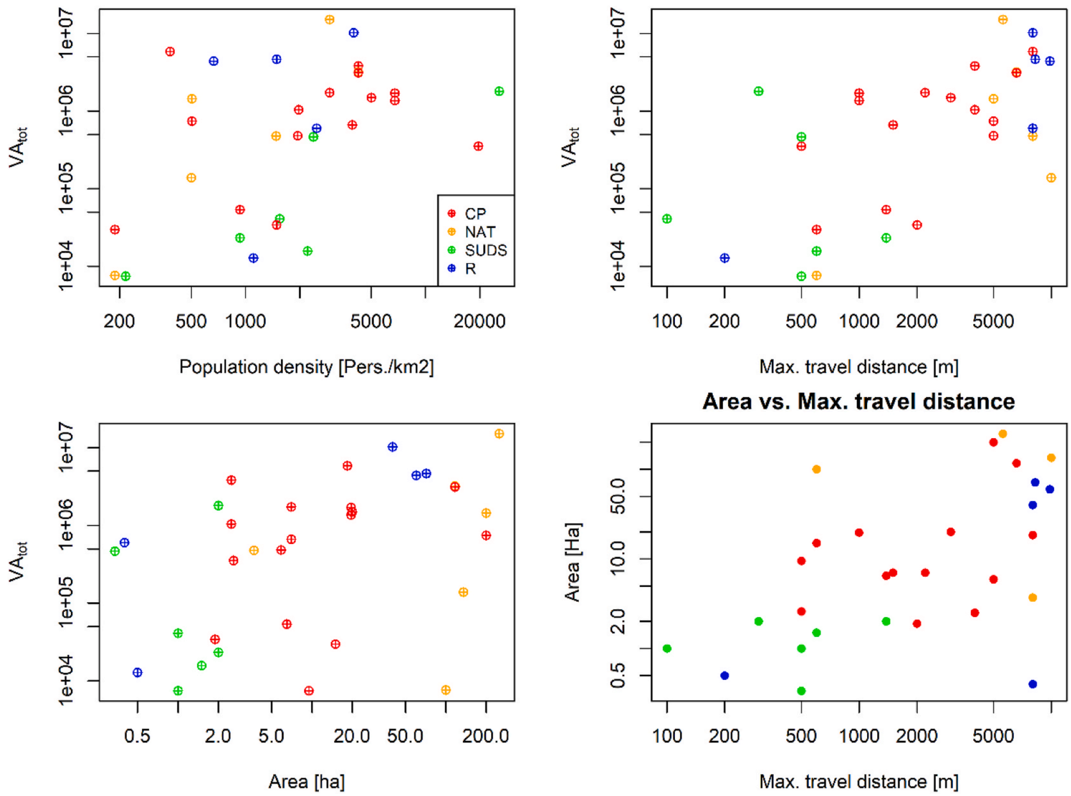

Fig. 3. Analysing the dependencies of population density, travel distance, and area on the total recreational value (VA_{tot}) given as €/year. Both axes are on a logarithmic scale. The dependencies of area and travel distance are linearly positive, whereas population density is random. This makes sense since the relation between maximum travel distance and area also are linear and positive. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

contain locations with very low population densities and very large nature areas. The applicability of these meta-studies to small urban nature sites (<50 ha) is very limited because they were developed on datasets that are biased towards large NBS (Fig. 5). We find that using their model compared to ours lead to an overestimation of a factor of at least 2 for areas below 7 ha. For areas above 14 ha our model leads to a calculated recreational value that is higher than their model. These rather abrupt differences in the model outputs are intrinsic to the log-normal meta-models employed in valuation studies and as indicated in e.g. Fig. 3 our model implicitly assumes a log-linear relationship between the NBS area and maximum travel distance which will be unrealistic for larger NBS areas.

4. Discussion

4.1. Comparison to meta-regression analyses

We found no effect of income levels (reflected as GDP per capita) on the WTP, which is similar to the findings of Brander and Koetse (2011), Bockarjova et al. (2020b) and Schägner et al. (2018) but dissimilar to Bockarjova et al. (2020a). Brander and Koetse (2011) and Bockarjova et al. (2020a, 2020b) focus on urban nature in general and Schägner et al. (2018) on the recreational value of nature (not limited to urban areas). We excluded any type of nature that does not provide a recreational value, and our results thus indicate that the recreational value of urban nature is not affected by an increase in household income.

As hypothesised, the number of people benefitting from a measure can be linked to population density and the size of the measure. Bockarjova et al. (2020a) and Brander and Koetse (2011) found a positive and significant effect from population density on the individual WTP per hectare, similar to our results (Fig. 4). Schägner et al. (2018) found a negative dependence on population density on WTP per visit, which may suggest that people prefer recreational experiences in areas with lower population densities. Schägner et al. (2018) include very large *NAT*s, where people travel far to experience it. This often results in higher expectations to the natural area and a real nature experience, i.e., with less people around. Hence, the urban setting results in a reversed effect from population density compared to non-urban settings. Population density may be a proxy for nature scarcity in urban areas, as land is allocated for other purposes (e.g., housing, transport, schools, etc.). This might be reflected in higher values per household and total recreational value of NBS. Given the mixed results, an interesting hypothesis for further research is that marginal and total recreational values increase with population density at first, but eventually decrease when spaces become overcrowded.

Out of several nature types (e.g., park or forest), Bockarjova et al. (2020a) found that only the park was a significant predictor. Similarly, we found no impact from nature types through statistical comparisons of individual households' WTP across different nature types (Section 3.2), nor from the regression analysis (Section 3.4). This provides some evidence that primary valuation studies performed for different types of urban nature can be used when performing benefit transfer for NBS in an urban setting. This greatly increases the available data. However, for more detailed assessment of the recreational value, it is necessary to consider the impact of park facilities. For example, Lin (2016) applied a hedonic regression model to assess the impacts of park facilities, e.g., playgrounds, skate park, water features, on residential property values. Results showed that facilities have an effect on house prices, where water features had a positive impact, and playground and sport activities (e.g., tennis, skateboard, etc) had a negative impact. Considering which facilities are planned to be available in new NBS may hence give an indication of whether the value will be in the higher or lower than the typical values calculated by means of applying the suggested transfer model.

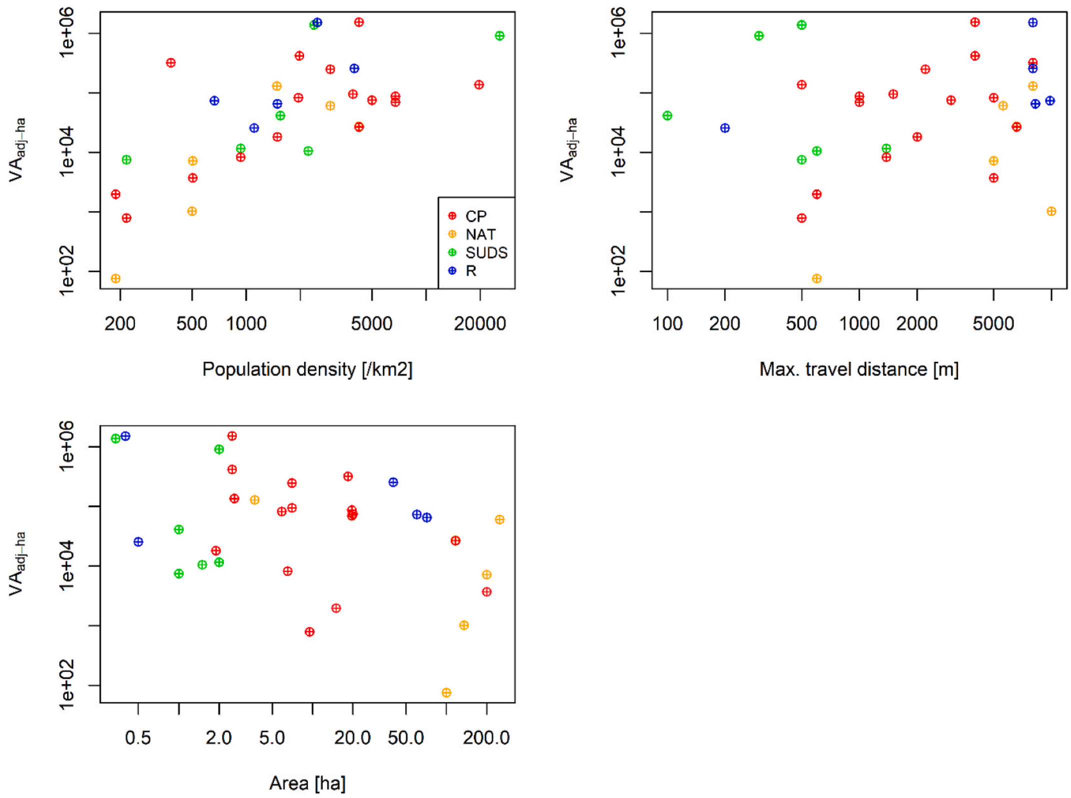

Fig. 4. Analysing the dependencies of population density, maximum travel distance, and area on the adjusted value $VA_{adj\text{-}ha}$ given as €/ha/year. Both axes are on a logarithmic scale. The effect from travel distance and area have largely been removed, but now there is a linear dependency on population density. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Table 3
Parameter estimates and residual standard error for the full regression model as well as the model consisting of all significant variables as well as the model suggested for planning of new locations of NBS sites. This final model excludes the maximum travel distance to obtain a value transfer function that is readily applicable in a planning context.

Variable	Full model	Reduced model	Planning model
(Intercept) [log(€/year)]	−0.718	−1.243	1.273
log(*A*, 10) [log(ha)]	0.406*	0.292*	0.643***
log(*PD*, 10) [log(persons/km2)]	1.022***	1.071***	1.148***
factor(Method)*SP*	−0.162		
factor(Type)*NAT*	−0.324		
factor(Type)*R*	0.081		
factor(Type)*SUDS*	0.091		
GDP [log(€)]	$-7.8\cdot10^{-6}$		
log(D_{max}, 10) [log(km)]	0.877***	0.945***	
Residual standard error	0.513	0.515	0.681

***, **, *, ˙ = statistically significant at 0.1%, 1%, 5%, and 10% respectively.

4.2. Uncertainties and limitations

We included both stated and revealed preference studies to increase our data sample at the cost of rough assumptions. By visual inspection, we found a larger spread of values from stated preference studies with the regression analysis confirming that there was not a statistically significant variation between the mean values. We performed the regression analysis without the revealed preference studies and obtained different results, as we end up having too few values, especially for smaller NBS (Supplemental material). Revealed and stated preference studies should in theory not be mixed but it seems a necessary means to obtain enough data as the availability of valuation studies on small-scale urban NBS is limited. A more thorough exploration of differences in value estimates between the two valuation techniques require additional explanatory variables and additional data.

Table 4
Predicted median and mean values for the case examples using the derived value transfer function.

	Median	Mean
City park (*CP*) (10 ha)		
Suburb [€/year]	39,988	136,705
City centre [€/year]	166,951	570,839
Nature Area (*NAT*) (200 ha)		
Suburb [€/year]	274,671	939,154
City centre [€/year]	1,146,942	3,921,625
River/stream (*R*) (60 ha)		
Suburb [€/year]	126,603	432,881
City centre [€/year]	528,657	1,807,583
SUDS (1 ha)		
Suburb [€/year]	9,090	31,080
City centre [€/year]	37,957	129,782

The valuation method, spatial scale, socio-economic characteristics, and nature type's details among the evaluated studies varied. We included relatively few variables in our analysis as most variables included in other meta-analyses turned out to be statistically insignificant. We tested variables that were found statistically significant by other meta-analysis studies on urban nature, and variables that are readily available in a planning context. Unlike other meta-analysis, we review and report the predictions of our regression model with our data/observations (Supplemental material). While we ultimately estimated a relatively simpler model, we transparently justified the results and ensured its relevance for planning by including input variables with readily available data.

The main limitations regarding benefit transfer are the lack of data from primary valuation studies (e.g., NBS size, population density and

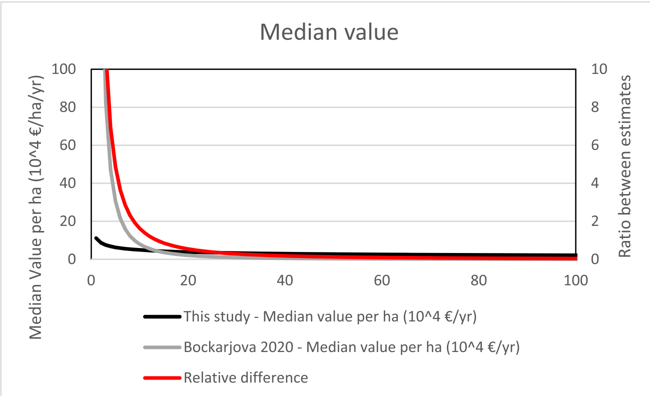

Fig. 5. Comparing results from this study (green) with the results from the most recent meta-study. Figure is based on the median population density of our sample (1949 pers./km^2). The model by Bockarjova et al. (2020a) was based on data with an average population density of 211 pers./km^2 and average NBS size of 472 ha. The relative difference is shown on the y-axis to the right. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

properties of the NBS). We attempted to overcome this by making our own estimates by means of data from Google Maps and statistical registers (e.g., Eurostat) but were unable to do so for the properties of the NBS. From the beginning, we set out to analyse theory-driven variables, which should have an impact on values; however, for most studies, the required data were not provided and could not be obtained from external sources. Many studies elaborate on the importance of spatial characteristics, such as distance decay (e.g. Johnston et al., 2017), but this information was often omitted, and it is also likely to be difficult to obtain in a planning context. A standardized approach to reporting valuation studies would greatly facilitate their application in initial planning stages for water management, where NBS compete with cheaper structural measures.

4.3. Implementation recommendations

The NBS size (in ha) and the population density (in inhabitants/km^2) are needed to calculate the recreational value. First, we recommend calculating the local population density within 1–2 km of the NBS (Median travel distance in our data is 2.2 km and 1st quartile is 600 m). If that is not possible, a city-level population density is the best approximation.

The size of the NBS area should include the entire area where the recreation is taking place. This should be straightforward for *CPs*, *NATs* and *Rs*. *SUDS* can be very small, for example, a swale with no or very limited recreational value. Measures with a minimum area of 0.3–0.5 ha (e.g., a road where trees and rain beds are added) are considered the lower boundary of where our results can be applied, as this is the smallest areas included in our data. In addition, caution should be taken if applied to NBS above 250 ha, as this is outside the range of sizes in our data.

Finally, values might overestimate the recreational value if applied in areas with an abundance of green opportunities, and underestimate values in areas with no other green options nearby.

5. Conclusions

We developed an approach to transfer the recreational value of NBS in an urban European context. Based on an analysis of 23 primary valuation studies, we conclude the following:

- Existing meta-studies overestimate the value of small scale urban NBS.
- WTP results can be applied across different nature types, thus increasing the database for valuation of urban NBS.
- The maximum distance that people are willing to travel to an NBS is linked to the area evaluated, allowing for a straightforward prediction of the number of persons affected by an NBS.
- Few, readily accessible data are required to obtain reasonable quantifications of the recreational value of NBS on small urban scales. These entail the expected size of the NBS and population density.
- The meta-regression is applicable for areas below 250 ha, representing the upper bound of likely sizes of NSB for urban flood adaptation.

The large range of recreational values represents the uncertainty associated with benefit transfer. This uncertainty is greatly affected by primary valuation studies omitting information that is required for transferring their results or reporting this information in an inconsistent manner as well as lack of understanding of how willingness to travel depend on NBS characteristics. A standardized approach would greatly enhance the wider application of these studies as suggested already by Smith (1989). Our methodology can easily be applied with new studies with better information once available. We consider our value estimates and uncertainty ranges to reflect the best current knowledge on estimating the recreational value of NBS for urban flood adaptation. Our results facilitate the valuation of hidden benefits of NBS in initial planning stages for urban water management and may increase the broad well-being of citizens in urban contexts.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.jenvman.2022.115724.

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