

Beyond meta-studies: Learnings from a large multi-site primary dataset on non-tangible benefits of nature-based solutions

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ABSTRACT

Nature-Based Solutions (NBS) are growing in popularity as approaches for, among others, the reduction of hydro-meteorological risks. However, their uptake is still slow despite the recognition of their role in enabling a smarter, more systemic, and faster adaptation to climate change. Uncertainties regarding the valuation and subsequent economic feasibility of NBS are deemed to be a substantial barrier to their uptake. The monetary valuation of the non-tangible benefits of NBS (e.g., increased recreation and enhanced biodiversity) is seen as a plausible strategy to get closer to providing a holistic assessment. However, the quantification of these non-tangible benefits is often not integrated into economic assessments of NBS, partly as methods that can be replicated across sites have been lacking. This situation risks leading to inconsistent and/or biased valuations, which may negatively influence or delay the prioritization of NBS. Thus, our study aims to collect primary data on the non-tangible benefits of NBS across different European study sites and to identify patterns in how the different types and contexts of NBS influence people's valuation. We applied a contingent valuation survey to six different peri-urban NBS study sites, where the focus is on the reduction of hydro-meteorological risks. The target of the survey was the general public, and we used willingness-to-pay questions to quantify the value given by the respondents to the NBS. Our results highlighted that people value the multiple benefits of NBS, and positively react to implementations improving nature across all sites. Moreover, similar variables seem to influence the value attributed to NBS across sites, with income and personal preferences ranking highly among them. These insights indicate that decision-makers and NBS-planners can learn more broadly from past experiences from a variety of (cultural) contexts, which can assist in delivering more targeted and multi-functional NBS.

1. Introduction

Nature-Based Solutions (NBS) are defined as “actions to protect, conserve, restore, sustainably use and manage natural or modified terrestrial, freshwater, coastal and marine ecosystems which address social, economic and environmental challenges effectively and adaptively, while simultaneously providing human well-being, ecosystem services, resilience and biodiversity benefits” [1]. What sets NBS apart from other ecosystem-based initiatives is their integrated perspective for tackling societal challenges (i.e. including biodiversity conservation, climate change adaptation, disaster risk reduction, human health and

well-being), as well as their role in promoting a transition from a resource-intensive growth model towards a more sustainable and inclusive one [2]. In 2015, the EU Horizon 2020 research and innovation program launched the NBS concept as one of its major research areas [3], which greatly increased the interest on the subject and the level of scientific activity around it. Moreover, in its most recent strategy for adaptation to climate change, with a focus on stimulating smarter, more systemic and faster adaptation, the EU has committed to promoting NBS as essential actions to reach a climate-resilient EU in 2050 [4].

Despite this popularity, the implementation of NBS appears to be lagging behind [5,6]. Uncertainties regarding the valuation and

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subsequent economic feasibility of NBS are deemed to be a significant obstacle to their uptake [7]. Therefore, the monetary valuation of non-tangible benefits of NBS (including e.g. increased recreation and well-being, enhanced biodiversity) is seen as a plausible strategy to get closer to a holistic assessment and support the prioritization of these solutions as alternatives to “business-as-usual” approaches [8,9,10]. Both science-based organizations and the scientific literature are calling for more data and evidence base to better quantify the non-tangible benefits of NBS [11,12,13]. Guidelines and frameworks have been produced to streamline the data collection process for the non-tangible benefits of NBS and to identify possible approaches to their quantification. Regarding the latter, Stated Preference (SP) methods have been highlighted as suitable approaches, as they are typically used to quantify the non-market benefits of goods [14,15].

Various studies have used SP methods to assess the non-tangible benefits of NBS [16,17]. However, there appears to be a lack of studies that apply the same methodology across different types of NBS and contexts. Because of this, it is difficult to understand whether the collected values can be transferred in different planning situations or what limitations there might be to these value transfers. Some efforts have been previously made to perform comparable valuations across sites. For example, Scarpa et al. [18] did a study across 26 forests, but they were all the same type of NBS, and all were found across the UK and Ireland. While Bateman et al. [19] examined five different study sites in different European countries, their focus was restricted to assessing only water quality improvements. Therefore, we still have very limited insights into what drives the differences in value attributed to multiple non-tangible benefits between different locations and NBS types. Existing meta-studies yield contradicting results [20] [21], and mostly point to the size of the NBS, population density and sometimes GDP as main influences on the value given to an NBS. A common study using a homogeneous dataset could help us understand these effects better and address the need for easily collectable and comparable data to fill the gap regarding the evidence base on the valuation of non-tangible benefits for NBS [9,21].

Therefore, with this study, we aim to use a transferable SP method to assess the non-tangible NBS benefits in six different European sites. This approach will allow us to obtain a unique dataset linking the characteristics of the respondents, their relationship with the NBS area, and their preferences regarding non-tangible benefits to a monetary value across different cultural contexts. Moreover, all these data will be

completely comparable across sites, having originated from the same survey scheme applied to various NBS. In this paper, we want to additionally test the value of our approach by examining its results to determine the drivers of NBS valuation heterogeneity across several European contexts. Furthermore, we aim to summarize these drivers into a joint, up-scalable value function. This way, we believe that we can take a first step in defining new up-scalable assessment methods for the valuation of non-tangible benefits of NBS.

2. Materials and methods

2.1. Case studies

Our primary data was collected in six different case studies, all part of the EU Horizon 2020 project RECONNECT. All case studies are large-scale NBS, aiming at reducing different kinds of hydro-meteorological risks (see Table 1). The case studies' locations are shown in Fig. 1, and their case-specific characteristics are presented in Table 1. The two NBS sites comprising the Greater Aarhus site (see [22] and Supplementary Information) are examined separately as two “sub-cases”: Lake Egå and Hovmarksparken.

2.2. Survey creation, distribution and responses

Given the focus on transferability and comparability of results, a common approach was used in all study sites. Specifically, a modular Contingent Valuation (CV) [23,14] survey previously developed was applied in this study (see the SI for the complete text of the survey). The survey is comprised of four sections assessing, respectively: the relationship between the NBS and the respondent (e.g. frequency and length of visits), the personal preferences of the respondents regarding the benefits of NBS (e.g. interest in the increase of recreational opportunities or enhancement of biodiversity), the value attributed to the NBS as it is and with an increase in the benefits for nature via two Willingness-To-Pay (WTP) questions, and finally the socio-demographic characteristics of the respondents (e.g. age, gender, income). The two WTP questions offered a list of options in local currency units but represented identical amounts in all sites when converted into Euros. This setup produced two variables: WTP_{base} , representing the WTP for maintaining the NBS (project) as it is; and WTP_{total} , the sum of WTP_{base} and the extra bid expressed by the respondents for further actions to

Table 1
Summary of the characteristics of the study sites.

Study sites	Type of NBS ¹	Extent of the site	Counteracted risks	Recreation facilities	Main type of respondent	Year of completion
Greater Aarhus – Lake Egå	Retention basin	115ha	Pluvial floods	Paths, benches, birdwatching towers, shelters	Residents	2006
Greater Aarhus - Hovmarksparken	Retention basin	6ha	Pluvial floods	Paths, benches, sport facilities	Residents	2017
Seden Strand, Odense	Coastal salt meadows restoration	27ha	Coastal floods	Paths, birdwatching tower	Residents	2021/2022
IJssel River Basin	Floodplain restoration	N/A ²	Pluvial floods, riverine floods	(Biking) paths, benches, sport facilities	Residents	2016
Elbe River Delta	Floodplain restoration	Punctual interventions in 11,000 ha of floodplain	Pluvial floods	N/A	Residents	Ongoing
Inn River Basin	Reforestation and grassland creation	N/A ³	Flash floods, landslides	Hiking trails, mountain-biking trails, ski slopes	Residents	1950
Portofino Natural Park	Reforestation and restoration of terraces	Punctual interventions in the Park's grounds	Flash floods, landslides	Hiking trails, historical monuments, information signs	Visitors	Ongoing

More details and the maps of the sites can be found in the SI (Figures S1 to S6) and in the RECONNECT project's website: Network of Cases – RECONNECT (<http://www.reconnect.eu/network-of-cases/>).

¹ Most of the sites use a combination of different interventions, we report here the main NBS features of these projects.

² The IJssel River Basin case is composed of 6 different large-scale sites. Their specific extents are not specified.

³ The Inn River Basin case includes large reforested and grassland areas in the torrential catchments Geroldsbach (12 km²) and Marbach (1.2 km²). Their specific extents are not specified.

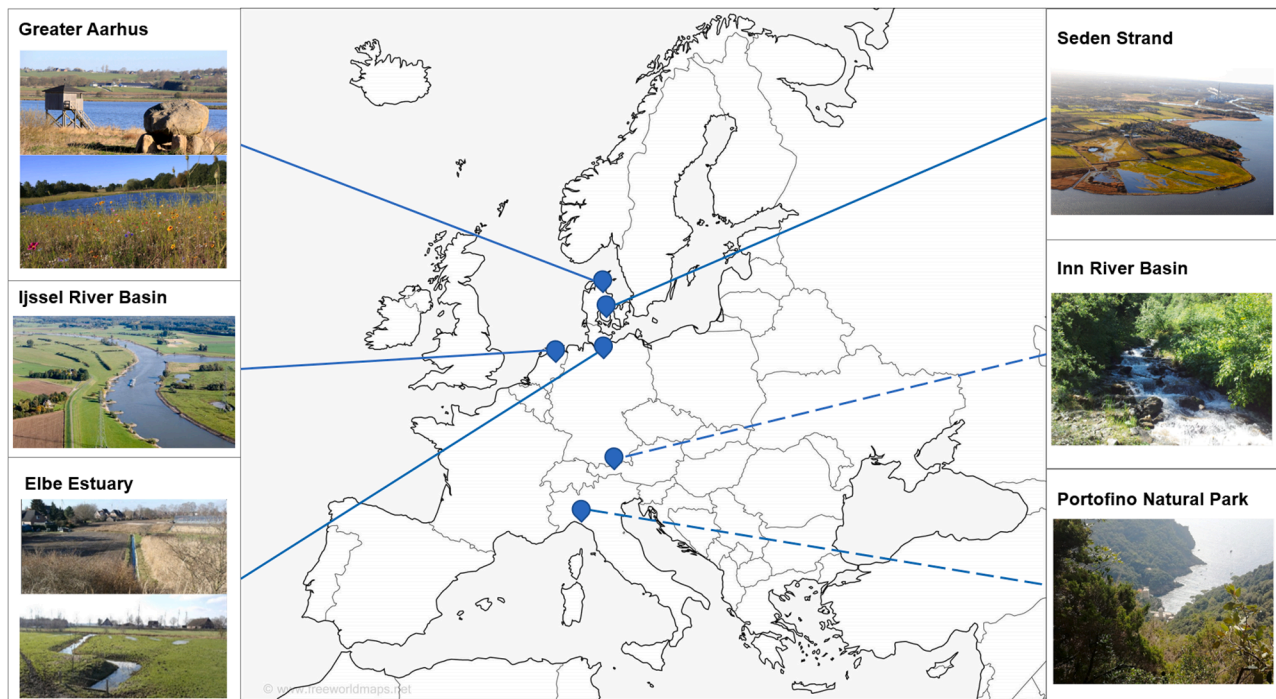


Fig. 1. Map of all study sites. The dashed lines indicate touristic sites.

improve the quality of the nature in the area. The latter is included both to obtain additional values and to test if the WTP increases with further refinement in the CV experiment (a scope test) [24,25,26].

The survey's sections have been co-designed with the "coordinators" of each study site (e.g., Municipalities, Park direction), who are also part of the RECONNECT project. This approach tailored the survey to reach a satisfactory level of site-specificity, allowing for a proper valuation of each site. The survey was pre-tested by administering it to colleagues of the site coordinators (e.g., other employees of the Municipalities responsible for the NBS sites) who had not participated in the co-design.

The data collection process was anonymous (in compliance with EU GDPR requirements) in all study sites. The distribution of the surveys was carried out differently for each study site according to the responsible partners' preferences and availabilities. Due to the COVID-19 pandemic, in-person survey distribution was greatly challenged, and the collection of responses had to run almost exclusively online. The two exceptions were the IJssel and Elbe Estuary sites, where the responses could partly be collected in person. The sites whose data collection suffered the most from the pandemic's impact were the touristic sites (i. e., Inn River Basin and Portofino Natural Park), as the challenge of reaching visiting respondents was exacerbated by the reduced travel flows. In the Danish sites of Greater Aarhus and Seden Strand, it was possible to email the survey directly to the citizens' digital postbox, thanks to, respectively, the Municipality of Aarhus and the Municipality of Odense's support. In these cases, the sampling was completely randomized. Table 2 summarizes the methods and outcomes of each case study's distribution campaign. The complete dataset collected is made

available with this article.

2.3. Analyses

In a first step, the data collected was assessed and compared across all sites to provide an overview of any general trends. Subsequently, a series of statistical models were set up in order to identify patterns in the value attributed to the NBS.

When collecting data, we distinguished between protest and non-protest voters. Protest voters are defined as respondents who do not accept the hypothetical valuation scenario and, therefore, refuse to state a genuine WTP [27]. For all of the following statistical analyses, protest votes were eliminated from the datasets. This is a standard procedure in the analysis of SP results, despite the critiques to this approach [28,29]. Detailed analyses of the protest votes were done in the first study on the application of this survey in the Aarhus site [22]. Despite differences between non-protest and protest groups, they were nevertheless determined to be not so significant as to be repeated for each examined site in this study. The distinction between protest and non-protest votes carried out via the questionnaire was thus accepted without any further testing. This distinction was based on a debriefing question presented only to the respondents stating a WTP of 0 EUR for both valuation scenarios. Respondents stating the motive for a zero bid was "I think that exclusively public funds should be used to finance the maintenance of the areas and their functions", or "I don't have enough information to choose a fee", were classified as protest bidders. If the respondents chose the options "I do not have the possibility to pay extra money each month", or "I do not

Table 2
Summary of the distribution details across all study sites.

Study sites	Number of responses	Distribution method	Sample type	Collection period
Greater Aarhus – Lake Egå	576	Digital mailbox	Random stratified sample	June/July 2021
Greater Aarhus - Hovmarksparken	258	Digital mailbox	Random stratified sample	June/July 2021
Seden Strand	360	Digital mailbox	Random stratified sample	November/December 2021
Elbe River Delta	351	In person and physical letters	On-site sample	July/August/September 2022
IJssel River Basin	180	In person, flyers and through social media	On-site sample	July 2021
Portofino Natural Park	99	Digital newsletter and social media	On-site sample	June/July/August 2022
Inn River Basin	48	Digital newsletter	On-site sample	May/June 2022

think that it is important to maintain this site and its functions”, they were classified as genuine zero bids. According to the guidelines for international value transfers [30], WTP responses and income data were corrected for differences in purchasing power parity (PPP) between countries using indices from the European Statistical Office [31] and converted into 2021 Euros (EU27). Purchasing power parity corrections allowed for a direct comparison of the WTP bids across sites.

Our statistical analyses were divided into three steps, namely the definition of: single-site models, a joint descriptive model (aimed at explaining WTP differences between sites), and a joint predictive model (containing only objective variables that would be available in a planning situation). Because of the limited number of responses obtained from the Inn River Basin site (Table 2), the data from this study site had to be excluded from the statistical modelling, leaving us with six study sites for the first step in our analyses.

First, the impact of explanatory variables on the WTP bids was assessed using Ordinary Least Squares (OLS) linear regression models, as seen in the literature [28,32] (Eq. (1)). The list of the explanatory variables collected with the survey and included in the model can be found listed in Table 3.

Due to the skewed data distribution, WTP values were log-transformed with a small off-set value to allow for 0 WTP values. The model was repeated two times for each site, one model using WTP_{base} and the other WTP_{total} as the dependent variable. This gives a total of 12 estimated models.

$$\log(WTP + y_0) = \alpha + \beta X + \gamma Y + \delta Z + \varepsilon \quad (1)$$

where $y_0 = 1$ to allow WTP bids of zero value, X , Y , Z are vectors of explanatory variables regarding preferences, uses and socio-demographic characteristics of the respondents, respectively (see Table 3 for full details); α , β , γ , δ are vectors of parameters to be estimated in the linear regression models; ε is the error term.

Once the linear regression models were estimated for each study site, we defined a joint descriptive model, i.e. a single model effectively summarizing which variables influenced the WTP of respondents across sites. In order to do that, we pooled the datasets from all the study sites excluding only Portofino. In Portofino, the respondents were for the most part “visitors”, travelling longer distances and for longer times in order to visit the site for more extended periods (Fig. S7 and S8). Given their different background and use of the NBS (i.e., likely being tourists rather than locals), it would be difficult to argue for joining these evaluations with those of the other sites.

The descriptive model was built using only those explanatory variables that were identified as significant in at least one of the single-site models. Furthermore, to better explore correlations between the data across sites, the values of the variables were transformed to zero mean and variance 1. The log-transformed WTP bids were once again used as the dependent variables.

Our models needed to cater for the differences in the way the responses were collected (Table 2). Namely, the fact that in some sites (specifically the Elbe Estuary and IJssel River), we did not manage to collect a randomized sample, but rather a sample including only individuals actively using/living in the NBS areas. Therefore, in our model, we split the dataset in two groups: “on-site sample” sites (i.e., Elbe Estuary and IJssel River) and “stratified sample” sites (i.e., the Danish sites). This was done by adding a dummy (ONSITE) to the model, as well as adding interactions between the dummy and the explanatory variables ($ONSITE * (\theta_1 X, \theta_2 Y, \theta_3 Z)$) (Eq. (2)). The rest of the variable letters in the model are the same as described for Eq. (1).

$$\log(WTP + y_0) = \alpha + \theta_0 ONSITE + \beta X + \gamma Y + \delta Z + ONSITE * (\theta_1 X, \theta_2 Y, \theta_3 Z) + \varepsilon \quad (2)$$

All of the respondents from the “on-site sample” are assumed to also be users of the NBS area. However, we collected responses from both users and non-users of the NBS site in the “stratified sample” sites. We

Table 3

Summary of the collected variables, including description and quantification methods, classified in four groups.

Variable name	Description	Answer method	Letter used in equations
Relationship between people and the study site			
Distance to the area	Distance from the study site chosen	Multiple options	Y in Eq. 1,2,3 W in Eq. 4
Frequency of visit	Frequency of visit to the study site	Multiple options	Y in Eq. 1,2,3
Travel time to the area	Length of travel time to the study site	Multiple options	Y in Eq. 1,2,3 W in Eq. 4
Length of visit	Time spent visiting the study site	Multiple options	Y in Eq. 1,2,3
Concern over risk	Respondent's concern regarding the hydro-meteorological risk	Likert scale (1–7)*	Y in Eq. 1,2,3
Direct risk experience	Direct experience of the respondent with the hydro-meteorological risk	Dichotomous	Y in Eq. 1,2,3 W in Eq. 4
Indirect risk experience	Knowing someone who had a direct experience with the hydro-meteorological risk	Dichotomous	Y in Eq. 1,2,3
Personal preferences			
Importance of green areas	How important it is for the respondent to access green areas	Likert scale (1–7)	X in Eq. 1,2,3
Importance of recreation facilities	How important it is for the respondent to have access to recreation facilities	Likert scale (1–7)	X in Eq. 1,2,3
Importance of biodiversity enhancements	How important it is for the respondent that biodiversity enhancement features are in place	Likert scale (1–7)	X in Eq. 1,2,3
Importance of “nature for nature” areas	How important it is for the respondent that areas set aside for nature (i.e. without access for people) are present	Likert scale (1–7)	X in Eq. 1,2,3
Visit the area to enjoy nature	Visiting the area to enjoy nature	Dichotomous	Y in Eq. 1,2,3
Visit the area for social activities	Visiting the area to spend time with family/friends	Dichotomous	Y in Eq. 1,2,3
Visit the area for sport	Visiting the area to practice sport	Dichotomous	Y in Eq. 1,2,3
Visit pass	Visiting the area just passing by (e.g., on the way to work)	Dichotomous	Y in Eq. 1,2,3
Valuation questions			
WTP base	Respondent's WTP for the maintenance of the area	Multiple options	
WTP nature	Respondent's WTP for the enhancement of nature benefitting features (additive)	Multiple options	
Protest	Respondent's reason for expressing 0 WTP in both valuations	Multiple options	
Socio-demographic information			
Age	Age	Multiple options	Z in Eq. 1,2,3 W in Eq. 4
Sex	Sex	Dichotomous	Z in Eq. 1,2,3 W in Eq. 4
People in the household	Number of people in the household	Open ended	Z in Eq. 1,2,3 W in Eq. 4
Children in the household	Presence of people younger than 18 in the household	Dichotomous	Z in Eq. 1,2,3
Income	Household income	Multiple options	Z in Eq. 1,2,3 W in Eq. 4

therefore tested a second approach that also distinguished between these two groups (Eq. (3)). Based on the responses to the question on the frequency of visits, we split up the “stratified” sample in “users” (frequency of visits > 0) and “non-users” (frequency of visit = 0). Thus, in addition to the variables described in Eq. (2), we introduced in Eq. (3) a separate factor variable for the “stratified sample” users (USER_S). No distinction is added for the “on-site” sample, as all the registered

responses are from users of the area. The “stratified sample” non-users are defined as the reference category. We follow the same approach as shown in Eq. (2) in considering interactions with the other explanatory variables. The differences between the two descriptive models are summarized in Table 3.

$$\begin{aligned} \log(WTP + y_0) = & \alpha + \theta_{00}USER_S + \theta_{10}ONSITE + \beta X + \gamma Y + \delta Z \\ & + USER_S * (\theta_{01}X, \theta_{02}Y, \theta_{03}Z) + ONSITE \\ & * (\theta_{11}X, \theta_{12}Y, \theta_{13}Z) + \varepsilon \end{aligned} \quad (3)$$

Similar to the distinction between responses based on their sampling method, we could also differentiate between two types of collected variables. Namely, the variables that could be gathered only through direct questioning of the respondents (i.e. personal preferences and concerns, reasons for visiting the area), and those that could only be collected through statistical or open access data (i.e. distance from the NBS, mean income, average age – for the complete list see Table 3). Creating a model (Eq. (4)) based only on the latter (W), would allow us to determine the explanatory power of these “objective” variables and compare it to the outcomes of the full models. Moreover, a model that distinguishes between different samples on a site level (i.e., users vs. population) can be more easily upscaled and applied in different contexts (i.e., a predictive model considering only the dummy for population), whereas a model that distinguishes individual users cannot be easily upscaled and transferred, as we do not know the distribution of user types (Table 4).

To determine Eq. (4), we employed the same pooled dataset as for the descriptive models, with the standardized variables and log-transformed WTP.

$$\log(WTP + y_0) = \alpha + \theta_0 ONSITE + \beta W + ONSITE * \theta_1 W + \varepsilon \quad (4)$$

All the above-mentioned analyses have been carried out in R using the car, ggplot2 and mvtnorm packages.

3. Results

3.1. Descriptive statistics and similarities between study sites

Table 5 presents the descriptive statistics for each sample together with WTP bids. The short distance, high visit frequency and low travel

times indicate that we mostly managed to capture respondents living close to the NBS sites, except for the Portofino site. The short visit times highlight how most of the respondents routinely pass by most of the areas. The longer visits to the German site reflect the perspective of people residing in the area where the NBS is going to be implemented.

The socio-demographic characteristics of the respondents are quite uniform. On average, we have collected answers from individuals slightly older than the median age [33], living with a partner but not necessarily with children, with a slight majority (excluding Portofino) of male respondents. The percentage of protest votes peaked in areas where the NBS is located in a residential area, while in the touristic sites, the valuation scenario seems to be more accepted.

The WTP, however, differs in the various sites. A clear subgroup can be highlighted comprising the three Danish NBS sites, where the bids were found to be the lowest among the sites and remarkably close to each other, despite two sites being older and well-established (Lake Egå and Hovmarksparken) while the other site has only recently been completed (Seden Strand). These lower bids likely reflect the average value across an entire urban population that has been randomly sampled. Therefore, it is not surprising that the highest bids came from the German site, since the respondents were, for the most part, living in the area where the NBS project is going to be implemented. As shown in the SI (Table S1), the difference in means between WTP_{base} and WTP_{total} was significant across all sites. The significantly higher WTP_{total} suggests that respondents on average allocate value to the enhancement of the nature benefits in addition to maintaining the NBS areas. Accordingly, the respondents across all sites seem sensitive to scope, though this has not been externally tested via a split sample [34, 35].

3.2. Results of the models explaining WTP bids for each site

Table 6 summarizes the outcomes for each of the single site models, while the actual coefficients can be found in the SI (Tables S2, S3, S4a&b). Taken together, these models show some transversally significant variables, such as high household income, the importance of nature for nature areas and biodiversity enhancement. The influence of personal preferences is more prominent in the models using WTP_{total} as the dependent variable. Notably, the variables indicating the use of the NBS area for exercise and/or to pass by (e.g., dog walking or on the way to

Table 4

Overview of the models developed. The WTP bids were the dependent variables in all models, which were repeated twice – once for WTP_{base} and once for WTP_{total}.

Single-site models (Eq. (1))						
Sites used	Lake Egå	Hovmarksparken	Seden Strand	Elbe Estuary	Ijssel River	Portofino Park
N# of respondents	378	156	251	238	126	89
Explanatory variables	All the collected variables.					
First joint descriptive model (Eq. (2))						
Name of group	STRATIFIED SAMPLE (ONSITE=0)				ON-SITE SAMPLE (ONSITE=1)	
N# of respondents	785				364	
Description	Responses collected through a random stratified sample (corresponding to the responses from the Danish sites)				Responses collected through on-site sampling, with most respondents residing on the NBS area (Elbe and Ijssel sites)	
Explanatory variables	Variables that were found to be significant in the single-site models (X,Y,Z), and the interactions between the ONSITE dummy and the same variables (ONSITE*(X,Y,Z)).					
Second joint descriptive model (Eq. (3))						
Name of group	STRATIFIED SAMPLE NON-USERS (USER_S = 0, ONSITE=0)		STRATIFIED SAMPLE USERS (USER_S = 1, ONSITE=0)		ON-SITE SAMPLE USERS (ONSITE=1)	
N# of respondents	145		640		364	
Description	Respondents from a Danish site, frequency of visit = 0		Respondents from a Danish site, frequency of visit > 0		Same as above	
Explanatory variables	Variables that were found to be significant in the single-site models (X,Y,Z), and the interactions between the “stratified sample” users (USER_S) and “on-site sample” users dummies (ONSITE) and the same variables ((USER_S,ONSITE)*(X,Y,Z)).					
Joint predictive model (Eq. (4))						
Name of group	STRATIFIED SAMPLE (ONSITE=0)				ON-SITE SAMPLE (ONSITE=1)	
N# of respondents	785				364	
Description	Same as in the first joint descriptive model				Same as in the first joint descriptive model	
Explanatory variables	Variables that could be gathered without questioning of the respondents (W in Eq. (4)), and the interactions between the ONSITE dummy and the same variables (ONSITE*W in Eq. (4)).					

Table 5

Descriptive statistics by site, including the 95 % confidence interval (in brackets). Here non-transformed values are used.

Variables	Aarhus – Lake Egå	Aarhus - Hovmarksparken	Seden Strand	Ijssel	Elbe Estuary	Portofino	Inn River
Mean distance from NBS (km)	12 (11,15–13,74)	9,6 (7,7–11,62)	15 (13,07–16,73)	10,7 (7,78–13,55)	3 (2,56–3,31)	33 (27,8–37,4)	5 (3,14–7,13)
Mean visit frequency	Weekly	More than once a week	Monthly	More than once a week	More than 5 times per week	Ca. twice a month	More than once a week
Mean travel time (min)	31 (29,43–32,65)	27(25,15–28,8)	26 (23,79–28,71)	33 (31,02–35,98)	33 (31,61–34,71)	101 (91,2–111,8)	34 (28,79–38,71)
Mean visit time (min)	66 (62,52–69,56)	31 (29,17–33,85)	48 (42,70–53,30)	91 (83,43–99,23)	157 (152,46–161,90)	112 (101,4–123,4)	97 (80,98–112,77)
Mean age	53 (51,60–54,32)	51 (49,38–53,56)	53 (51,57–54,82)	47 (44,48–48,86)	53 (51,97–54,81)	52 (49,6–54,6)	47 (42,98–51,19)
Gender (% women)	49	49	49	44	42	56	41
Mean family size	2,5 (2,38–2,64)	2,6 (2,42–2,85)	2,3 (2,16–2,42)	2,9 (2,62–3,11)	2,76 (2,63–2,89)	2,7 (2,4–2,9)	3 (2,58 – 3,38)
Mean income (EUR/month/hh)	3276 (3120–3433)	3428 (3181–3675)	3562 (3292–3831)	2859 (2681–3036)	3459 (3267–3651)	2689 (2457–2920)	2921 (2592–3250)
Mean WTP base (excl. protest) (EUR/month)	3,74 (3,15–4,32)	3,27 (2,36–4,17)	3,95 (3,16–4,73)	4,15 (3,25–5,04)	11,32 (9,53–13,12)	4,44 (2,9–5,9)	5,8 (4,5–7,2)
Mean WTP total (excl. protest) (EUR/month)	6,23 (5,18–7,27)	5,46 (3,89–7,02)	6,65 (5,31–8)	11,78 (9,13–14,43)	18,45 (15,58–21,32)	8,8 (5,6–11,9)	10,6 (8,2–12,9)
Protest votes (%)	34	39	30	30	32	27	21

Table 6

Outcomes of the single site linear regression models for WTPbase and WTPtotal. Only the significant variables are reported. The full table with the explicit estimates and standard errors is reported in the SI (Tables S2, S3, and S4a&b).

		 = p<0.01  = p<0.1										
		Frequency of visit	Sex (male)	People in household	Household income	Concern over risk	Direct risk experience	Importance of nature areas	Importance of biodiversity	Visiting the area to enjoy nature	Visiting the area to exercise	Passing by the area
WTP base	Lake Egå											
	Hovmarksparken											
	Seden Strand											
	Elbe Estuary											
	Ijssel River											
	Portofino Park											
WTP total	Lake Egå											
	Hovmarksparken											
	Seden Strand											
	Elbe Estuary											
	Ijssel River											
	Portofino Park											

work) are significant in the Danish sites (i.e., Lake Egå, Hovmarksparken and Seden Strand). In the case of Hovmarksparken, the only significant variables are found within the personal preference variables, while in Portofino no personal preference variable seems to be influencing the WTP. Although the latter result may be influenced by the fact that almost all of the Portofino respondents attributed a very high importance to nature and recreation (Fig. S9), and thus no explanatory power could be picked up by the model for these variables. The frequency of

visit is particularly relevant in the Elbe Estuary site, while the gender of the respondent is highlighted in Portofino and Ijssel. The concern over hydro-meteorological risks increases the WTP in Seden Strand, while it decreases it in Portofino, likely because most of the Portofino respondents were visitors. Thus, the risk reduction in Portofino Park's area is not really connected to the respondents' concern over the risk in their residence area. Alternatively, we cannot exclude that the homogeneous high ratings given to the concern over hydro-meteorological risks

(Fig. S9) could have made it impossible for the model to pick up the correlations between the WTP and the respondents' level of worry.

Overall, high income and high interest in areas left for nature led to an increase in WTP amounts across the study sites. However, while the connection between income and WTP appears to be genuinely transversal, the influence of the importance attributed to areas for nature and to the enhancement of biodiversity seems to be predominant in the three Danish sites. The significant income effects increase the validity of the stated preferences, as they denote that people have expressed their preferences based on the content of their wallet [14]; this finding is expected considering it is a well-established driver of WTP. The lower share of significant income effects in the WTP_{total} relative to the WTP_{base} , however, suggests that income effects might be conditional on the scope of the environmental change in some areas.

3.3. Estimation of joint descriptive models

For the estimation of a joint value function with WTP_{base} as the dependent variable, the independent variables included were the eight variables that emerged as significant in the full linear regression model (Table 6). And for the model using WTP_{total} , the same method was used, but with ten independent variables (Table 6).

As outlined in Section 2, two approaches were used to formulate models of the collected data, leading to two joint descriptive models hereafter referred to as the first and second joint descriptive model (Table 4). Table 7 shows the results of the first approach, which distinguished between those sites where the sample was randomly drawn from the population (ONSITE=0, used as reference category) and those where we collected responses from people living on-site

Table 7

Outcomes of the first joint descriptive regression models (Eq. (2)) for WTP_{base} and WTP_{total} . Standardized variables were used here. Standard errors are reported in the square brackets. Only variables identified as significant in the single site models (Table 6) were included, leading to different numbers of independent variables for WTP_{base} and WTP_{total} . Variables included for only one of the models are indicated as NA in the other. * $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$ **** $p < 0.001$.

	WTP_{base}		WTP_{total}	
	ONSITE=0	ONSITE=1	ONSITE=0	ONSITE=1
Intercept	-0.28 [0.06]***		-0.45 [0.07]***	
Frequency of visit	-0.01 [0.04]	0.15 [0.07]*	-0.06 [0.05]	0.22 [0.07] **
People in the household	-0.05 [0.04]	-0.09 [0.06]	-0.05 [0.03]	-0.08 [0.06]
Sex (male)	NA	NA	0.09 [0.06]	0.16 [0.12]
Household income	0.13 [0.04] ***	0.30 [0.08] ***	0.14 [0.03] ***	0.17 [0.08] *
Concern over risk	0.12 [0.04] **	0.02 [0.07]	0.11 [0.03] **	-0.08 [0.06]
Direct risk experience	0.01 [0.08]	-0.01 [0.13]	NA	NA
Importance of "nature for nature" areas	0.15 [0.03] ***	-0.001 [0.07]	0.18 [0.03] ***	-0.03 [0.07]
Importance of biodiversity enhancements	0.11 [0.04] **	-0.05 [0.06]	0.11 [0.04] **	0.005 [0.06]
Visiting the area to enjoy nature	0.20 [0.06] **	-0.36 [0.12]**	0.20 [0.07] **	-0.28 [0.13]*
Visiting the area to practice a sport	NA	NA	0.15 [0.07] *	-0.25 [0.13] ‘
Visiting the area just passing by	NA	NA	0.15 [0.08] *	0.03 [0.16]
Number of observations	1092			
Adjusted R^2	0.23		0.26	
AIC	2823.87		2780.66	
BIC	2918.79		2895.57	

(ONSITE=1).

The results follow quite closely the outcomes registered across the single-site models, with a strong influence of household income and preferences on the WTP in the randomized sample of respondents. This model allows us to note that when the sample is collected on-site only (thus is comprised mostly by people using the area), the influence of income on the WTP appears to be significantly greater than in the randomized group. These results are noteworthy and have, to the authors' knowledge, only been addressed in a few studies [36]. Interestingly, Huhtala and Pouta [36] only find strong income effects among non-users.

Then, for the second model, which distinguishes users and non-users on the level of individual respondents, the results are reported in Table 8. For this model, the non-users group from the "stratified sample" sites was used as the reference, while "stratified sample" users (USER_S = 1) and "on-site sample" users (ONSITE=1) were represented by dummies.

The second descriptive model appears to add some nuances between the different user groups. Preferences go from being the main drivers of valuation for the "stratified sample" group (USER_S = 1), to almost entirely testing insignificant. This could be read as preferences being a proxy for the frequency of visit in the sites including users and non-users (i.e., it is mostly the people actively visiting the NBS areas who attribute high value to natural sites and biodiversity enhancements). In the "on-site sample" (ONSITE=1) valuation, income and frequency of visit still are the main drivers of WTP. However, the higher WTP among "on-site sample" sites regarding income and visit frequency denote important differences in the WTP structures, though similarities in the respondents' valuation drivers are evident. Thus, a more significant impact on WTP should be further examined from within these sites' socio-cultural contexts.

3.4. Estimation of a joint predictive model

The results of our predictive models (i.e., using only variables that could be collected through statistical or open access data) for WTP_{base} and WTP_{total} are shown in Table 9.

As expected, the results of the predictive model show a significant impact of the household income on WTP, which gets even higher in the "on-site sample" (ONSITE=1) sites. Without the influence of preference variables, the negative correlation between the distance to the NBS and the WTP is picked up in both models, confirming a recognized pattern of higher WTP for NBS closer to one's home [37,38]. In the model explaining the influences on WTP_{total} , the positive influence of travel time becomes significant. This result is likely due to the fact that people who travel longer to visit the NBS site do so for features which are supposed to be improved in the scenario proposed to elicit the WTP_{total} . Overall, the differences between the randomized and user groups appear to get smaller when looking at this specific group of variables.

4. Discussion

4.1. Summary of results

Our results show common drivers of valuation across the various sites we investigated, reflecting more well-known indicators for WTP, as well as providing some novel insights related to respondents' personal preferences. First, respondents appear to attach a positive value to the multiple benefits of NBS, and positively react to implementations improving nature. Moreover, income was shown to be the primary influence on the WTP stated, but the personal preferences of the respondents (e.g., importance of biodiversity, visiting the area to enjoy nature) ranked highly as well. The degree of significance of the other investigated variables appeared to change according to the different NBS contexts. Within the "on-site sample" cases, it appears that the valuation of users living on or very close to the site of the NBS area is mostly

Table 8

Outcomes of the second joint descriptive regression models (Eq. (3)) for WTPbase and WTP total. Standardized variables were used here. Standard errors are reported in the square brackets. Only variables identified as significant in the single site models (Table 6) were included, leading to different numbers of independent variables for WTPbase and WTPtotal. Variables included for only one of the models are indicated as NA in the other. The “x” sign indicates those variables that could only be determined as interacted variables. $p < 0.1$ * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$.

	WTPbase			WTPtotal		
	USER_S = 0, ONSITE=0	USER_S = 1, ONSITE=0	ONSITE=1	USER_S = 0, ONSITE=0	USER_S = 1, ONSITE=0	ONSITE=1
Intercept	−0.24 [0.11]*			−0.28 [0.10]**		
Frequency of visit	x	−0.03 [0.04]	0.14 [0.05]*	x	−0.06 [0.05]	0.16 [0.05]**
People in the household	−0.03 [0.06]	−0.02 [0.07]	−0.11 [0.08]	−0.05 [0.06]	−0.01 [0.07]	−0.08 [0.07]
Sex (male)	NA	NA	NA	−0.20 [0.15]	0.35 [0.17]*	0.45 [0.18]*
Household income	0.04 [0.06]	0.11 [0.07]	0.39 [0.10]***	0.11 [0.06]	0.05 [0.07]	0.20 [0.10]*
Concern over risk	0.22 [0.11]*	−0.11 [0.12]	−0.07 [0.12]	0.17 [0.09] ‘	−0.07 [0.10]	−0.13 [0.10]
Direct risk experience	−0.23 [0.23]	0.26 [0.25]	0.23 [0.26]	NA	NA	NA
Importance of “nature for nature” areas	0.15 [0.08] ‘	−0.002 [0.09]	0.0004 [0.10]	0.15 [0.08]	0.03 [0.10]	0.01 [0.10]
Importance of biodiversity enhancements	0.04 [0.07]	0.09 [0.08]	0.009 [0.09]	0.10 [0.07]	0.02 [0.08]	0.01 [0.09]
Visiting the area to enjoy nature	x	0.16 [0.07]*	−0.16 [0.11]	x	0.19 [0.07]**	−0.08 [0.11]
Visiting the area to practice a sport	NA	NA	NA	x	0.15 [0.07]*	−0.09 [0.11]
Visiting the area just passing by	NA	NA	NA	x	0.14 [0.08] ‘	0.18 [0.14]
Number of observations	1092					
Adjusted R ²	0.22			0.26		
AIC	2832.17			2788.18		
BIC	2962.06			2938.05		

Table 9

Outcomes of the joint predictive regression models (Eq. (4)) for WTP base and WTP total. Standard errors are reported in the square brackets. Standardized variables were used here. $p < 0.1$ * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$.

	WTPbase		WTPtotal	
	ONSITE=0	ONSITE=1	ONSITE=0	ONSITE=1
Intercept	−0.23 [0.05]***		−0.25 [0.05]***	
People in the household	−0.05 [0.03]	−0.11 [0.06] ‘	−0.05 [0.04]	−0.10 [0.06]
Age of the respondent	0.003 [0.03]	0.09 [0.07]	0.006 [0.03]	0.06 [0.07]
Sex (male)	0.04 [0.07]	−0.04 [0.13]	0.04 [0.06]	0.16 [0.12]
Household income	0.10 [0.03]**	0.35 [0.08]***	0.12 [0.03]	0.23 [0.08]**
Direct risk experience	0.10 [0.07]	−0.05 [0.13]	0.09 [0.07]	−0.12 [0.13]
Distance from the NBS area	−0.09 [0.02]**	0.02 [0.07]	−0.08 [0.03]**	0.04 [0.07]
Travel time to the NBS area	0.05 [0.03]	0.02 [0.07]	0.08 [0.03]*	−0.006 [0.07]
Number of observations	1092			
Adjusted R ²	0.15	0.18		
AIC	2918.25	3003.17		
BIC	2887.18	2972.11		

influenced by income and visit frequency, rather than by reason to visit or personal preferences. Conversely, for the “stratified sample” sites, respondents specifically visiting the NBS site seem to be influenced in their valuation mostly by their preferences and activities done in the area. These insights are useful because city and regional planners can learn from past experiences (regardless of location/culture) to deliver more targeted and meaningful NBS projects.

Despite some site-specific differences, the similarity of the significant variables to explain WTP across sites allowed for the creation of joint valuation models, at least for a sub-group of sites (i.e., the “on-site sample” ones). Joint valuation models allow us to generalize the findings stemming from primary data collection activities and provide transferable models for quantifying benefits in other NBS sites. Joint models, including personal preferences of the respondents, appeared to

describe our dataset better. Nevertheless, it was also possible to develop a predictive model using only variables that do not need to be gathered via primary data collection. The results of the predictive model would be more useful for an up-scaling approach, possibly as a complementary method to meta-analyses.

4.2. Influence of personal preference variables on WTP across sites

In accordance with what is found in the literature [28,16,39,17], and in our first application of this survey approach [22], the contribution of personal preferences appears to explain a significant part of the value attributed to NBS projects. For example, the importance given to areas “set aside for nature” was proven to have a significant influence on the WTP across all Danish case studies. Specifically, preferences regarding the increased benefits for nature (i.e., areas with limited access for people, enhancement for biodiversity) were highlighted as having an influence on WTP. Preferences linked to more direct “people benefits” (e.g., presence of accessible green areas and recreation facilities) were not significant in the models. This could likely be due to the homogeneously high importance attributed to the benefits for nature by the respondents (Fig. S9). Nonetheless, the dependency of the WTP on income still seems to be the most transversal across sites. This is also an expected outcome, as the tendency to find higher WTP bids at higher incomes is well documented [19,28,39,29,17,40]. In contrast to previous studies, we find a limited influence on WTP of other variables such as length or frequency of visits. However, at least in the “stratified sample” sites, the personal preferences variables (e.g., visiting the area to enjoy nature, or to practice a sport) might have acted as proxies for variables related to the relationship and use of NBS, as discussed in Section 3.3 (Table 8).

Based on our results, it seems that the benefits of NBS for nature (e.g., biodiversity enhancement) have the highest value for the respondents. This finding is also strengthened by the significant difference between WTPbase and WTPtotal registered in all sites (Table S1). Thus, the capacity of NBS to benefit nature appears to be a strong “selling point” for these strategies. However, whether these results are due to a higher willingness to pay a fee for the protection and/or enhancement of nature rather than to pay for access to recreational areas is also debatable. These insights are crucial, however, to ensure that protection and enhancement of biodiversity are considered from the start rather than

implemented as an after-thought if single purpose NBS are under development (vs. multifunctional NBS). Being able to learn from existing and previous projects, on a larger scale (across Europe and globally), will be critical to reduce and mitigate unintended consequences (due to e.g., lack of funding or knowledge gaps; [41]), and promote more versatile and multifunctional NBS concepts from the planning phase.

Despite the overall significance of personal preferences, our results nonetheless highlight differences throughout the various contexts. Particularly clear is the influence of the “Danish context”, with three sites that present a lower dependency of the WTP on the income of the respondents, and a higher dependency on the WTP on the preferences regarding nature and using the NBS. While the reason for this may be difficult to pinpoint from our results, these findings could point towards, for example, a higher sensitivity of the Danish population to the topic of biodiversity and/or benefits for nature, as well as the effect of the close cooperation undertaken between Danish authorities and citizens to ensure an optimal design and thus use of the proposed NBS. The latter point is further supported by the fact that co-creation approaches were indeed used in some of the Danish sites to strengthen the connection between citizens and green spaces [42].

While it's more difficult to speak of a specific “context” for the two “on-site” samples, the IJssel River and Elbe Estuary cases are similar in being very large projects including residential settlements from which respondents were answering to the survey. Thus, it can be assumed that in these cases the NBS is seen as a “change in one's home” rather than as a “creation of a visit destination”. This might have lead the project to be perceived mostly as a (necessary) protection against hydro-meteorological risks more strictly linked to objective variables such as available income. Nevertheless, the influence, however minor, of preferences for biodiversity and nature only areas shows that the tendency of preferring multifunctional measures is relevant for these cases as well.

Our models suggest that the differences in the perceived benefits by NBS improvements are conditional on being a user or non-user of the NBS site. As shown in Table 8, the relationship between visit frequency and WTP is only significant among the on-site sampled users. Tests furthermore reveal that the difference in the visit frequency and WTP relationship between users in the stratified sample and on-site sample is significantly different on a 95 % confidence level. The same differences appear when we compare the income effects across non-users and user types. Table 8 reveals that the income effects are not significantly different between non-users and users in the stratified samples. However, the income effects among the on-site users are significantly stronger than the non-users. Again, tests reveal that the difference in the income and WTP relationship between users in the stratified sample and on-site sample is significantly different on a 95 % confidence level. Finally, when we compare the relationship between visiting the area to enjoy nature in Table 8, the WTP estimate is significant and positive for the stratified users, while negative and insignificant for the on-site users. The difference in WTP estimates is significant on a 95 % confidence level. Accordingly, the positive relationship between visiting the area to enjoy nature and WTP is significantly stronger among users in the stratified samples compared to users in the on-site samples. On the one hand, the above mentioned WTP differences can reflect differences in site values between the on-site samples and stratified samples. On the other hand, the differences can also be a function of on-site sampling vs. stratified sampling. That is, the on-site sampling tends to monitor frequent visitors relative to non-frequent visitors, who, on average among users, might have different demand properties than users from a stratified sampling. It is not possible with our data to identify the correct link between the identified WTP differences, however; the user type differences in visit frequency and WTP relationships calls for further research.

4.3. Challenges and impacts of defining joint models

Given the premise of a primary data collection across several NBS

with different characteristics and contexts, obtaining overlapping results (Table 6) that could be (partly) summarized with value functions obtained through joint models is a fact not to be underestimated. Value functions are used to define the value of a good or service of interest starting from the available knowledge about it. We thus tried to determine whether the outcomes of our survey could also provide transferable value functions for sites where the distribution of questionnaires is challenging, if not impossible. It is also a good sign of our methodology's applicability and “up-scalability”. Nevertheless, the definition of joint models was not completely seamless since we had to account for having collected responses non-homogeneously (partly due to the COVID-19 pandemic), and thus risking to obtain skewed results (e.g., because of cases with many more responses than others, or multiple cases located in one country). Consequently, different approaches (Eq. 2&3) were used to align the available responses, but some potential biases have to be pointed out. In particular, the distinction between the dummy variables “on-site sample” and “stratified sample” is a bit blurry in some cases. The division between “on-site” and “stratified” samples was used to distinguish the users living within the NBS area from those who are not. However, e.g., in the case of the urban park Hovmarksparken, the two groups could be overlapping. This, combined with the impossibility of defining to which group (e.g., “on-site” or “stratified”) respondents belong to unless asked directly, supported the use of the model including only the ONSITE dummy for our definition of a predictive joint model (Eq. (4)).

The results of our models can be compared to that of meta-analyses. However, to our knowledge, meta-analyses to-date focusing on NBS (or similar strategies) have not been gathering such a comprehensive set of variables (especially including personal preferences) that can be linked to a monetary evaluation across multiple NBS (in our case, large-scale peri-urban) sites. Among the studies we could find, the influence on WTP of the importance of the “existential” value of nature was also shown in [20]. Moreover, and similarly to Skrydstrup et al. [21] the value associated with an NBS did not seem to be influenced by the type of strategy used (see the similar valuations and significant variables for the three different Danish sites). These results seem to point towards the use of replicable primary data collection methods not only as a basis for but also as a complementary knowledge source to meta-studies, as they allow us to derive a better understanding of what may drive people's preferences, which is difficult to obtain through meta-studies. When analyzed together with prior experiences in rolling out NBS, knowledge of people's preferences is crucial for enhancing the uptake and implementation of NBS in Europe and globally. It is an important aspect likely underutilized by city/regional planners to-date, in part as they lack methods and thus data on how to ensure these projects are prioritized over the status quo.

Data collection through replicable surveys has some limitations regarding its reliance on generalizable scenarios and questions. In contingent valuation approaches, creating credible hypothetical scenarios often depends on using highly site-specific information. Therefore, limiting the site-specificity of the surveys might have increased the risk of respondents across sites interpreting questions differently, or of missing the collection of variables relevant for a specific context. This study tried to minimize these risks by including sections in the survey that were highly site-specific, which had to be (almost) completely rewritten for each case study (e.g., the description of the NBS site, the WTP scenarios), and sections that could be re-used across sites with minimal adjustments (e.g., socio-demographic information, options for use of the area). Admittedly, this approach, especially when combined with the distribution of multiple surveys, is highly time and resource intensive. However, when considering the applications shown in this study, these limitations may appear as counterbalanced by the range of possible analyses on their results. A wider use of replicable primary data collection methods to assess non-tangible NBS benefits could, therefore, offer a first step to test potential uses of the data, on top of providing more easily comparable datasets for secondary analyses to build upon.

4.4. Limitations of the methods

In this study, we focus on the application of a CV approach across different sites, which has encountered various challenges. Ideally, we would have liked to use the same data collection approach in all sites, specifically a randomized email distribution coupled with face-to-face interviews, which could then have been supplemented with other methods based on their availability (e.g., social media links). However, the on-and-off lockdowns of the COVID-19 pandemic did not allow for such an approach, and we had to adapt by finding the most suitable alternative method for each site. Due to the different contexts and resource availability, it was not possible to find a single alternative method of distribution. These circumstances have led to differences in the number and quality of the collected data. In particular, the tourist sites (i.e., Portofino Park and Inn River Basin) suffered from being unable to collect responses in other ways than social media. This outcome hindered the possibility of gathering enough data on the tourist NBS sites, which could then have been compared to the other examined sites. Similarly, on-site sampling did not allow for the collection of data from non-users of the NBS, making the comparison with non-users from the “stratified samples” impossible. In addition to this, the use of different sampling methods might have introduced biases in the two respondent groups. For example, the “stratified sample” might have been more subject to self-selection bias. We have attempted to minimize the impacts of these potential biases in our analyses, as specified in Section 4.3. However, as the type of distribution is crucial to ensure a replicable assessment, it would be recommendable for future studies to carefully consider the distribution options, preferably using only one approach across all sites. This is one of the most challenging aspects of replicating a (partly co-designed) survey across different sites.

Another limitation may be the fact that the creation of the survey layout was strongly influenced by the first case study we collaborated with, namely the Greater Aarhus site. The survey may therefore have had an implicit bias for case studies with similar characteristics (e.g., completed NBS project, residential setting). However, to compare the collected variables, significant changes to the structure were no longer possible once the survey was distributed for the first time. Therefore, despite the co-creation step undergone with the other sites, some site bias could still have been transferred, for example, with the small intervals chosen for the distance (to NBS) or relating the fear of risk with the WTP (see Section 3.2). A “collective” co-design approach may have prevented this, but the limited timeframe and the disruption of the regular in-person meetings within the RECONNECT project due to the pandemic significantly restricted our options.

5. Conclusions

In our study, we aimed at examining the differences in NBS valuation across Europe through the use of a novel approach. The main outcomes of our analyses can be summarized as such:

- We observed a substantial WTP for the implementation of NBS across all examined sites and a significant additional WTP for the implementation of extra natural features (supporting/enhancing biodiversity).
- Income is a main driver of individual WTP. However, when we distinguished respondents from “on-site samples” (i.e., including only users of the NBS site) in the model, this dependence seemed to be stronger for this group than for the stratified sample group (i.e., including both users and non-users of the NBS site). Conversely, preferences regarding nature benefits appear to be more strongly correlated to the WTP in the stratified sample rather than in the samples of users only.
- The influence of the preference for natural benefits on WTP appears to be a proxy for the visit frequencies of the respondents from the sites where both users and non-users answered the survey.

Specifically, the WTP bids of the respondents who visit the NBS are more strongly influenced by preferences for nature-enhancing features.

- When removing preference variables from the model, distance and travel time appear to become relevant variables for the WTP of the randomized sample.

Key insights stemming from our study indicate that city and regional planners can learn more broadly from past experiences (regardless of location/culture), which may enable them to deliver more targeted and meaningful NBS projects in the future. In addition, it is clear that NBS planners should work together (i.e. co-design) with citizens in order to ensure multi-functionality is optimized, since personal preferences and visit frequency are additional variables of importance driving valuation. Being able to learn from existing and previous projects, and on a larger scale (across Europe and globally), is essential to reducing and mitigating unintended consequences that may appear, especially when upscaling and/or adapting existing solutions to enable and/or enhance multi-functionality.

In conclusion, we believe that our methodology for assessment across study sites and cultural contexts can be used as the starting point for a broader initiative to standardize the quantification of non-tangible benefits for NBS. The survey and analysis approaches used can be applied to other sites, and the unique dataset gathered can be used for further studies. Overall, we took an important step to learn about the variation of preferences across European sites, which can form the basis upon which to build a solid and more holistic knowledge base for these solutions.

NBS impact and implications

- Social benefits need to be included in a holistic assessment, but can be complex to quantify, especially when they are non-tangible. Our study provides a replicable methodology for their assessment, and shows the widely positive value associated with non-market human benefits of various NBS for climate change adaptation.
- This study links the valuation of social benefits to that of environmental benefits. Our results show how the users of NBS associate significantly more value to greener, more multifunctional NBS.
- Our method involves the use of a monetary evaluation of non-tangible benefits of NBS, so our results can complement and/or be the starting point for assessing the cost-effectiveness and positive economic impacts of NBS.

CRedit authorship contribution statement

Martina Viti: Writing – original draft, Visualization, Methodology, Investigation, Data curation, Conceptualization. **Jacob Ladenburg:** Writing – review & editing, Visualization, Validation, Methodology, Conceptualization. **Roland Löwe:** Writing – review & editing, Visualization, Methodology, Conceptualization. **Hjalte J.D. Sørup:** Writing – review & editing, Methodology. **Ursula S. McKnight:** Writing – review & editing, Validation, Supervision, Conceptualization. **Karsten Arnbjerg-Nielsen:** Writing – review & editing, Supervision, Project administration, Methodology, Funding acquisition, Conceptualization.

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.

Data availability

See data linked below. <https://doi.org/10.11583/DTU.24126624>.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at [doi:10.1016/j.nbsj.2024.100146](https://doi.org/10.1016/j.nbsj.2024.100146).

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