Economic Benefits of Nature-Based Solutions for Climate Risk: A Meta-Analysis

G. Guillermo García Álvarez *Ph.D. Candidate, Institute for Environmental Studies (IVM), Vrije Universiteit, Amsterdam; g.garcia.alvarez@vu.nl*

W. J. Wouter Botzen *Professor and Director, Institute for Environmental Studies (IVM), Vrije Universiteit, Amsterdam; Professor, Utrecht University School of Economics, Netherlands; wouter.botzen@vu.nl*

Max Tesselaar *Assistant Professor, Institute for Environmental Studies (IVM), Vrije Universiteit, Amsterdam; max.tesselaar@vu.nl*

Jeroen C. J. H. Aerts *Professor, Institute for Environmental Studies (IVM), Vrije Universiteit, Amsterdam; Strategic Adviser, Deltares Institute, Delft, Netherlands; jeroen.aerts@vu.nl*

Andrea Staccione *Junior Scientist, CMCC Foundation (Euro-Mediterranean Center on Climate Change), Lecce, Italy; Ca'Foscari University of Venice, Italy; Institute of Meteorology and Climate Research, Karlsruhe Institute of Technology, Garmisch-Partenkirchen, Germany; andrea.staccione@cmcc.it*

Jaroslav Mysiak *Director and Principal Scientist, CMCC Foundation (Euro-Mediterranean Center on Climate Change), Lecce, Italy; Lecturer, Ca'Foscari University of Venice, Italy; jaroslav.mysiak@cmcc.it*

Marija Bockarjova *Assistant Professor, Faculty of Geo-Information Science and Earth Observation (ITC), University of Twente, Enschede, Netherlands; m.bockarjova@utwente.nl*

ABSTRACT *This meta-analysis of stated preference studies involving over 49,500 respondents quantifies the economic value of co-benefits from nature-based solutions (NBSs) that address climate risks. The results indicate that the willingness to pay for co-benefits increases with GDP per capita and decreases with NBS size. Recreational and aesthetic benefits, as well as NBSs developed in urban gray areas, are more valued than conservation and maintenance of current nature sites. The novel value transfer function can assist future research and policy makers in assessing the economic co-benefits of NBSs for climate risk based on the policy site characteristics.* (JEL Q54, Q57)

1. Introduction

The increasing frequency and severity of climate risk events highlights the need for investment in climate change mitigation and adaptation (IPCC 2021). At current trends, the number of climate-related disasters per year will increase from 400 in 2015 to approximately 560 by 2030.[1] If appropriate risk mitigation measures are not adopted in advance, floods, heat waves, wildfires, and comparably extreme events will devastate local communities. Global economic losses stemming from natural hazards have reached an annual estimate of US$150–$200 billion in recent years, compared with US$50 billion in 1980 (Munich Re 2022). Nature-based solutions (NBSs) are effective ways to reduce related risk, stemming economic losses and limiting climate hazards. NBSs are defined as solutions inspired and supported by nature that are cost-effective and simultaneously provide environmental, social, and economic benefits and help build resilience (European Commission 2025). NBSs may mitigate natural hazards by mediating flow and nuisances or maintaining stable physical, chemical, and biological conditions. For example, wetlands and natural floodplains can act as NBSs in buffering against floods, well-managed forests can reduce the risk of landslides, and green urban areas can mitigate high temperatures (European Environment Agency 2021).

Land Economics • May 2026 • 102 (2): 290–307
DOI:10.3368/le.102.2.110824-0105R1
ISSN 0023-7639; E-ISSN 1543-8325

[1] See the International Disaster Database at https://www.emdat.be (accessed April 1, 2025).

This study focuses on NBSs that limit climate change–related risks, such as societal impacts from droughts, storms, heat, rainfall, and floods. NBSs not only limit climate risk but also generate societal advantages (e.g., as recreational spaces), improve social cohesion, and support educational and physical activities, human health and well-being, and sustainable economic growth. Co-benefits have been variously defined, with each definition highlighting certain aspects. In general, co-benefits are "the goals of a natural hazard adaptation project that are additional to the project's primary function, but complementary to its objective of increasing community resilience" (Jones and Doberstein 2022). They are often overlooked in studies and rarely considered in NBS project design, implementation, or assessment. However, paying insufficient attention to co-benefits may lead to underinvestment in NBSs and distort their environmental, social, and economic impacts (Naumann 2020).

This article probes the economic value of NBS co-benefits by conducting a meta-analysis of studies applying stated preference (SP) methods for environmental valuation. In a meta-analysis, a researcher systematically reviews empirical results reported in the literature to generalize findings outside of the specific location and context of individual studies. By improving the ease and transparency of assigning economic values to NBS co-benefits, the meta-analysis results may lower the barriers of applying NBSs as a climate risk adaptation strategy. In recent years, the literature regarding NBSs in general, and co-benefit assessment specifically, has increased exponentially, as confirmed by the publication years of the articles in our database. We can include in our review recently published studies unavailable for previous meta-analyses. This meta-analysis focuses only on valuation studies that use SP methods (i.e., contingent valuation studies and choice experiments) because these can estimate the total value attributed to NBS co-benefits, including nonmarket values.

Meta-analysis is a popular method for disciplines outside of environmental economics, particularly medical sciences. Glass (1976, 3) first defined a meta-analysis as "a statistical analysis of a large collection of analysis results from individual studies for the purpose of integrating the findings." The popularity of meta-analyses has increased in recent decades because they entail a consolidated and quantitative review of a large, often complex, and sometimes conflicting body of literature (Haidich 2010). This is desirable because it allows a comparison of multiple studies on a particular topic before making conclusions based on a study that could be an outlier in its field. In addition, a meta-analysis can identify patterns and trends in the literature, such as geographic variation in NBS co-benefits. It also allows for determining gaps in the literature, detecting outliers in certain studies and identifying their characteristics in comparison to the rest of the literature. A meta-analysis also improves generalizability because of its ability to synthesize results from different studies.

In the case of the environmental valuation of NBS co-benefits, the meta-analysis value transfer function allows for estimation of the economic value of NBSs in areas for which no primary valuation data are available or where conducting a survey is not a viable option. Value transfer (also known as benefits transfer) allows existing economic evidence from a primary site to be applied in other policy sites (Brander and Koetse 2011). A meta-analysis allows for conducting value transfer analysis because it encompasses several studies and can explain variation in the values obtained in terms of the observable characteristics and local socioeconomic characteristics of, say, a policy site (Bergstrom and Taylor 2006). A value transfer function through a meta-analysis considers context-defining covariates such as socioeconomic and environmental conditions. The same analytical resolution can be attained through primary valuation studies, but these require significantly more effort and resources.

A common limitation of value transfer studies is the difficulty of accounting for all important differences in the characteristics of study and policy sites (Brander 2013). For example, unobserved contextual factors (e.g., cultural norms, attitudes, income inequality) could influence valuation outcomes. Moreover, the validity of a value transfer study depends on the quality of available primary studies (Spash and Vatn 2006). Hence, there is always a degree of uncertainty regarding the transferred values based on a meta-analysis. As an illustration, Kaul et al. (2013) found through a nonparametric meta-analysis that the median absolute error of applying value transfer compared with primary valuation studies was 33%, ranging from close to 0%–200%. Brouwer (2000) estimated that the error of using a value transfer function tends to be in the 20%–40% range. Despite these transfer errors, meta-analysis is commonly applied because it is a cost-efficient research method compared with primary valuation studies.

Our estimated value transfer function can be used together with estimates of risk reduction benefits to conduct a cost-benefit analysis of NBSs at a policy site. A sensitivity analysis should be part of such a cost-benefit analysis to examine the influence of uncertainty of the valuation estimates on the final results about the economic desirability of NBSs. An example of a practical application of the value transfer function would be the several ongoing NBS projects that the World Bank is developing or planning for the near future. Our value transfer function can support the NBS benefit assessment as part of the cost-benefit analysis framework proposed in the World Bank (2023) report.

This article is not the first to use a meta-analysis to examine the literature on the topics of NBS or ecosystem valuation. Table 1 illustrates previous meta-analyses and their scopes. The oldest study we found was Brander and Koetse's (2011) meta-analysis, which aimed to estimate the willingness to pay (WTP) for green spaces in cities, depending on site and socioeconomic characteristics. Bockarjova, Botzen, and Koetse's (2020) work updates Brander and Koetse's (2011) by including water bodies in urban settings, defined as "blue nature." Other studies have focused either on a particular type of NBS (Reynaud and Lanzanova 2017; Su, Friess, and Gasparatos 2021) or exclusively on the physical impacts and not economic values (Coventry et al. 2021). Filho et al.'s (2021) study estimates the economic value of particular ecosystem services of nature, based on data from the Environmental Services Valuation Database (ESVD).[2]

The number of observations in our study is higher than those in the previously discussed meta-analyses with a similar scope, mainly owing to studies published in the last few years. More than half of our observations are from studies published since 2021; the exceptions are Reynaud and Lanzanova (2017) and Filho et al. (2021). The former is not limited to SP studies and includes nonacademic literature, while the latter includes all valuations in the ESVD to estimate the value transfer function, regardless of the valuation method, intervention level, and purpose of the NBS. This study also does not include potential studies excluded from the ESVD. In addition, our study includes more explanatory variables than are common in the literature. In previous studies, the area, sample size, GDP per capita, and NBS type are common explanatory variables. We include land use change to provide a new perspective to explain how respondents value different NBS types, depending on the previous land use, which may be relevant to decision makers. One set of covariates is referred to as "land use" in Brander and Koetse (2011), but it refers to the type of nature or NBS: urban parks, forest, and so forth.

Our article fills the following gaps in this research field. First, we created a new database that includes SP studies to assess the WTP for NBSs that target climate risk reduction. Whereas previous research has developed such a database for SP studies in an urban setting (Bockarjova, Botzen, and Koetse 2020), we extend the scope of our database by also including nonurban NBSs, which are effective adaptation measures to reduce the impact of wildfires, floods, and storms. NBS valuation is context specific. One factor that may influence valuation is the previous use of the land taken to develop an NBS. Second, our work is the first to account for land use changes in the analysis.

[2] The database is available at https://www.esvd.net.

Table 1
Previous Meta-Analyses on Nature-Based Solutions (NBSs)

Author	Sample Size	Explanatory Variable	Type of Nature / NBS
Reynaud and Lanzanova (2017)	699	Ecosystem services, method, study site characteristics, GDP per capita, geospatial variables	Lakes
Bockarjova, Botzen, and Koetse (2020)	147	GDP per capita, region, area, population density, methodological variables (tax, choice experiment), type of nature	Urban nature
Su, Friess, and Gasparatos (2021)	167	Stand age, restoration method, species origin, regional variation	Mangroves
Coventry et al. (2021)	50	Different nature-based interventions' impacts on different physical and mental health indicators	NBSs for mental and physical health
Brander and Koetse (2011)	73	Type of nature (parks, agriculture), payment vehicle, area, ecosystem services (recreation, preservation, aesthetic), elicitation format, GDP per capita and population density	Urban nature
Filho et al. (2021)	1,350	Type of nature, biome, continent, protection status, ecosystem services, income, population density	All types of nature available in studies included in the Ecosystem Services Valuation Database

The location of an NBS is a key constraint for decision makers. For example, NBSs for flood risk reduction usually require substantially more space than traditional "gray" flood risk reduction measures, such as dikes, so implementing NBS strategies for flood risk reduction likely requires relinquishing some economically productive land, such as agricultural land. If, however, an NBS requires the conservation, enhancement, or reforestation of existing sites, it may face fewer obstacles, potentially increasing its desirability. We account for variability in NBS valuation due to land use changes in our meta-analysis by including the land use change variables in our models and value transfer function. These dummy variables control for the previous land use in the site where the NBS is planned in the hypothetical scenario (e.g., a floodplain to reduce flood risk to be developed into agricultural land).

This study's findings can inform public sector decision makers about the valuation of the co-benefits of different NBSs for climate risk to perform social cost-benefit analysis of the desirability of NBSs. The purpose of value transfer functions is to incorporate the value of ecosystem services into decision-making by revealing how valuable the natural world is to us, despite not being traded in markets and having no market prices to reflect their value (Brander, 2013). As explained in Brander (2013, 6), "Value transfer is the procedure of estimating the value of an ecosystem service of current policy interest (at a 'policy site') by assigning an existing valuation estimate for a similar ecosystem elsewhere (at a 'study site')." The value transfer function developed in this research informs the value of the co-benefits for future NBSs, which is more specific than the broader types of nature studied in previous research. Policy makers can gain insight into citizens' preferences for different NBS types, and that insight can be used along with climate risk-reduction estimations (i.e., expected annual damage reduction) in comprehensive cost-benefit analysis and comparisons with alternative adaptation measures. This comprehensive assessment can strengthen the case for investing in NBSs—given that the co-benefits can increase the return on investment—as they emerge, even if the adverse climate-related event does not occur. The public sector funds 88% of NBSs (Debele et al. 2023). As such, even without benefits increasing the return on investment for private sector stakeholders, co-benefits remain relevant for most NBSs funded by the public sector, as these benefits enhance public welfare.

2. Search Strategy and Methodology

Search Strategy

We performed a systematic review of peer-reviewed literature, following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (Page et al. 2021) approach. The selection of studies included in the analysis was based on Scopus. In addition, the ESVD (Brander et al. 2024) was reviewed because it compiles diverse articles assessing ecosystem services from NBSs. The final set of studies was updated on June 10, 2024, and the software Rayyan[3] was used for the screening process and for managing and organizing the database of selected papers. After uploading the Scopus search results, Rayyan compiled the abstracts and allowed searching for keywords and placing tags based on the inclusion and exclusion criteria. We submitted the review protocol to Open Science Framework Registries (Staccione et al. 2023). The methods for evaluating NBS co-benefits, based on the same review process, are detailed in the accompanying analysis (Staccione et al. n.d.). All included studies and their sample sizes are available in Appendix A.

The studies targeted by the search had to present the design, implementation, or use of different nature-based approaches aimed primarily to reduce the risks and impacts of climate-related hazards and disasters at different scales and in different ecosystems. Furthermore, included studies needed to clearly address the co-benefits generated by the NBS investigated, other than the primary goal of the solution. We categorized the ecosystem services in our database following the economics of ecosystem and biodiversity (TEEB 2011) framework. The framework groups such services into four broad categories: provisioning services (e.g., food, water, raw materials), regulating services (e.g., local climate regulation, air quality regulation, erosion control), habitat or supporting services (e.g., maintenance of diversity), and cultural services (e.g., recreation, aesthetic appreciation, tourism). This classification provided a standard structure to build the database, and we used the individual services as explanatory variables in the different model specifications.

We acknowledge the inherent subjectivity in categorizing co-benefits. We based our coding on how these benefits were explicitly presented in each SP study. These were usually quite clear in choice experiments because they were categorized as different attributes. Whereas local climate regulation, air quality, or carbon storage were usually straightforward to categorize, recreation and tourism were sometimes more interchangeable. Recreation was typically framed in terms of improved access or availability of recreational opportunities at the site, and tourism refers to an increase in visitor numbers. Finally, studies should present models, methods, and metrics to assess the effectiveness of co-benefits, prioritizing quantitative evaluation. Therefore, the keywords selected for the reviews refer to five main concepts: NBSs, risk reduction, disasters, co-benefits, and methods (see the list of keywords in Appendix B). We used the keywords listed in these five domains in a single search query, and they were connected by the AND operator.

The review of journal articles was limited to those published in English between January 2005 and June 2024. The time span was defined according to the first definition of ecosystem services as benefits that people can obtain from nature (Millennium Ecosystem Assessment 2005) and the successive development of related concepts, including NBS and co-benefits. Although other SP studies have examined ecosystem services before 2005, the lack of formalized jargon would have created an additional challenge in identifying relevant studies. We initially included all papers that explored NBSs designed for disaster risk reduction. However, we retained only those providing a monetary assessment of co-benefits, excluding those assessing only risk-reduction performance or addressing co-benefits without monetization. We also kept only studies providing a comparable monetary value that can be converted to US dollars per hectare per year.

[3] Available at https://www.rayyan.ai.

Coding of Key Variables

The dependent variable, similar to previous related meta-analyses, is the 2022 US dollar value prices of NBS co-benefits per hectare per year (Brander and Koetse 2011; Bockarjova, Botzen, and Koetse 2020; Filho et al. 2021). This is possible because most studies provide some indication of the price value, size of the site, and time component. This approach allows for comparisons of our results with previous meta-analyses. This process depends on the information available in the original studies, and it leads to the methodological choices and assumptions explained here. Missing data from the selected studies were complemented with information from official sources, such as the World Bank Open Data (e.g., exchange rates, GDP per capita, population density). First, to derive the dependent variable, all WTP values were converted to 2022 US dollars through official exchange rates and GDP deflators retrieved from the World Bank.[4]

Regarding the spatial component, if a study reported the value of the site as a whole, we divided the total value by the number of hectares. We retrieved this figure from either the study or external sources of information to convert the value to US dollars per hectare. When studies provided WTP per visit instead, the preferred option was to convert it to an annual basis by multiplying it by the annual number of visitors (Brander and Koetse 2011). We derived the aggregate WTP value by multiplying the "per year per household value" by the number of households in the area. When the value was reported per person instead of per household, we used the average household occupation from official sources.

We retrieved population density from the most accurate and granular data available (town/city, region/state, country)—the most granular data from government sources and, whenever needed, national averages from World Development Indicators. We estimated the number of households using the population totals in the area and the number of households for the region. Whenever the number of households was unavailable, we used the average number of people per household in the town (or country when data were unavailable) to estimate the number of households in the area. Table 2 presents an example of how the challenges of standardizing the data were dealt with through a systematic protocol.

In the regressions, we performed a log transformation of the dependent variable to deal with the WTP skewness. The main independent variables of interest in our meta-regression were the different types of NBSs and the co-benefits or ecosystem services. The co-benefits were coded as binary variables (taking the value of one if the site provides that ecosystem service and zero otherwise). Notably, one site could provide several ecosystem services. Similarly, NBS types were also coded as dummy variables taking a value of one when the site matched a certain type, and zero otherwise. We included the size of the nature site, geographical location, and other socioeconomic variables, such as population density and respondents' income, in the meta-regression. Although some papers included information about respondents' income, we retrieved this information from the World Bank data for consistency. The GDP per capita at the lowest level was used as a proxy for respondents' income. We converted these variables to 2022 US dollar values using the purchasing power parity exchange rates to US dollars to account for differences across countries. Geographical location was determined using continent dummy variables, and the size of the nature site was measured in hectares. Population density is defined as the number of people per square kilometer.

Last, with the objective of analyzing the impact of the previous land uses on the monetary valuation, we classified all studies according to the land use change of the NBS intervention in the following categories: conservation or maintenance of an existing nature site, enhancement or restoration of an existing site, and policies that proposed transforming a site from its current land use to an NBS. The last option was divided depending on the original use: urban (street/concrete or building), undeveloped nature site, and agricultural land. An overview on the coding of the

[4] Available at https://data.worldbank.org/indicator/NY.GDP.DEFL.ZS?skipRedirection=true&view=map.

Table 2
Systematic Standardization Protocol Example

Order of Steps	Value	Indicator	Source	Note
Extract original value	€0.15 per household per month	Original WTP for NBS	Viti et al. (2023)	Aarhus, Denmark
Obtain data from region	336,000	Population	Aarhus city hall data[a]	Official population (2022)
	173,000	Households	AdminStat[b]	No. of households (2021; latest)
	68,299	GDP per capita	World Bank data[c]	GDP per capita (2022 US$)
Adjust to 2022 prices	No operation needed	GDP deflators		
Exchange to US$ and correct for PPP	6.153561	PPP exchange rate (Danish kr. to US$)	World Bank data	PPP conversion factor, GDP (LCU per international US$) (2022)
	7.43	US$ to Danish kr. exchange rate	European Central Bank[d]	Euro Foreign Exchange Reference Rates (2022)
	1.11	WTP (Danish kr.)		WTP × exchange rate
	0.18	Monthly value (2022 US$)		Kr. WTP / PPP exchange rate
Obtain final per hectare per year WTP value	2.17	Annual value (2022 US$)		Monthly WTP × 12
	375,994	Aggregated value		Yearly WTP × HH
	2,426	WTP per hectare per year (2022 US$)		Aggregated WTP / size (ha)

Note: NBS = nature-based solution; WTP = willingness to pay.
[a] See https://aarhus.dk.
[b] See https://ugeo.urbistat.com/AdminStat/it/dk/demografia/dati-sintesi/danimarca/208/1.
[c] See https://data.worldbank.org/indicator/NY.GDP.PCAP.CD.
[d] See https://www.ecb.europa.eu/stats/exchange/eurofxref/shared/pdf/2022/12/20221230.pdf.

variables used in this analysis can be found in Appendix D.

Econometric Specification

The dependent variable is the log of the monetary value (US$/hectare/year) attributed to NBS co-benefits. The log transformation addresses the skewness of our dependent variable and residuals. The set of covariates (X) varies per specification. The simplest version (model 1) includes only GDP per capita, NBS size, and population density. This model allows for testing whether our results align with those of previous works, such as Koetse and Brander (2011) and Bockarjova, Botzen, and Koetse (2020). In addition, we control for study type by creating a dummy variable that takes the values one for contingent valuation (CV) studies and zero for choice experiment (CE) studies because previous studies have found that the elicitation format can influence the valuation outcome (Bockarjova, Botzen, and Koetse 2020). CV studies are also more likely to be susceptible to the payment vehicle (e.g., bidding games, dichotomous choices) and can yield a lower valuation compared with CE because they refer to bundled services instead of payment for individual improvements on NBS attributes.

The following models add complexity by including NBS types, geographical binary variables, land use changes, and co-benefit specific variables: model 2 includes the continent binary variables to control for geographical location; models 3 and 4 add the NBS type and the co-benefits, respectively; and model 5 combines the variables introduced in each previous iteration and adds the land use covariates.

Ordinary least squares (OLS) has limitations when addressing heteroskedasticity in meta-analysis data (Stanley 2013). To correct for these issues, we used weighted least squares (WLS) models. Unrestricted WLS has been demonstrated to be superior to OLS when there is publication or small-sample bias (Stanley and Doucouliagos 2014). WLS corrects for different observations having different error variances, which is the issue that violates the OLS assumption. In WLS, studies with smaller standard errors are given higher weights. Because it is a common challenge that has been encountered in previous meta-analyses, not all studies report standard errors. In case we opted to drop these observations, we would lose 71% of the observations of our meta-analysis since only 64 observations included standard errors. As an alternative WLS approach, the number of observations of the selected studies has been commonly in previous meta-analyses used as a proxy weight to account for the precision with which the effect sizes are estimated (Dalhuisen et al. 2003; Travisi and Nijkamp 2004; Nelson and Kennedy 2009; Nobel et al. 2020). This is the preferred approach for our analysis to prevent arriving at unreliable models based on a low number of observations. Each term in the WLS criterion includes an additional weight determining how much each observation in the dataset influences final parameter estimates:

$$Yw = Yi \times Wi \; / \; Wmax \qquad [1]$$

$$\begin{aligned} ln(WTPw) = a &+ ln\ (Area)\beta 1 + ln(GDP)\beta 2 \\ &+ ln(Pop.\ Density)\ \beta 3 \\ &+ Study\ Type\ \beta 4 \\ &+ Geographical\ variablesi\ \beta i \\ &+ NBS\ typei\ \beta i \\ &+ co-benefitsi\ \beta i \\ &+ land\ use\ changei\ \beta i + \varepsilon. \qquad [2] \end{aligned}$$

The study with the largest sample was used as the baseline. The remaining WTP values from the other studies, our dependent variable, were weighted according to the largest sample (*Wmax*). The WTP values were multiplied by their own sample size (*Wi*) and then divided by the largest sample (equation [1]). Equation [1] indicates the new dependent variable included in our model. The interpretation remains the same as before. Equation [2] was the model used in our WLS meta-regressions. The OLS models were also tested for the robustness of our results and whether the chosen method significantly influenced them. To account for within-study correlation of error terms, we clustered the errors at study ID level for studies that contributed more than one valuation to the database.

In Section 4, the coefficients of the meta-regression are applied to create a value transfer function, which is then used in two case studies to illustrate its utility. Notably, the outcome in terms of economic value per year refers to the NBS co-benefits, which means that the risk reduction benefits also must be considered when producing a cost-benefit analysis. For the value transfer function, we can use both the OLS and the WLS models. We focused on deriving a value transfer function employing the results of WLS because of its superior properties. We used model 5 for its superior performance in explaining the variance. Owing to collinearity concerns, model 5 does not include the log of GDP per capita and the continent dummies together, as flagged by the variance inflation factor. Equation [3] shows the value transfer function applied to the chosen case studies:

$$\begin{aligned} &Value\ of\ NBS\ per\ hectare\ per\ year \\ &= \big(exp\ a + \beta 1\ (ln(Area)) \\ &\quad + \beta 2\ (ln(GDP)) + \beta 3\ (ln(Density)) \\ &\quad + \beta i\ (NBS\ type) + \beta i\ (co-benefits) \\ &\quad + \beta i\ (land\ use)\big). \qquad [3] \end{aligned}$$

The coefficients from the meta-regression (model 5) are substituted for the unknown coefficients in the value transfer function (Table 3). Simultaneously, the variables were substituted by the policy site characteristics. We took the exponent of the value of the right side since our dependent variable was originally measured in natural logs. To obtain the

Table 3
Weighted Least Squares Regressions

	(1)	(2)	(3)	(4)	(5)
Area (ln)	–0.74***	–0.65***	–0.557***	–0.526***	–0.529***
	(0.114)	(0.125)	(0.144)	(0.121)	(0.075)
GDP (ln)	0.452			–0.361	0.071
	(0.522)			(0.477)	(0.295)
Density (ln)	–0.098	–0.091	–0.281	–0.376	–0.163
	(0.302)	(0.3)	(0.341)	(0.243)	(0.217)
Africa		0.084	0.601	0.162	
		(1.896)	(2.011)	(1.058)	
Europe		1.696	2.184*	1.497	
		(1.24)	(1.279)	(1.057)	
Asia		2.301	1.983	-0.192	
		(1.988)	(1.499)	(1.4)	
Contingent valuation		–2.889**	–2.986***	–3.024***	-3.551***
		(1.162)	(0.917)	(0.835)	(0.875)
Urban dummy			3.394**		
			(1.429)		
Coral reefs			2.336		1.102
			(1.816)		(1.196)
Mangroves			1.718		2.29*
			(1.795)		(1.176)
Lakes, ponds, rivers			1.593		–0.971
			(1.562)		(0.912)
Wetlands			1.448		0.353
			(1.484)		(1.007)
Forests			0.391		–0.599
			(1.721)		(0.92)
Local climate regulation				5.175***	6.052***
				(1.367)	(0.997)
Air quality regulation				–0.662	–0.299
				(0.892)	(0.755)
Carbon storage				–2.898**	–3.652***
				(1.18)	(1.247)
Habitats for species				–0.463	–0.27
				(0.737)	(0.699)
Maintenance of genetic diversity				1.076	0.909
				(0.791)	(0.715)
Recreation				0.967	0.934
				(0.787)	(0.609)
Aesthetic appreciation				1.899***	1.797***
				(0.572)	(0.563)
Tourism				–1.822**	–1.534
				(0.899)	(0.926)
Flood risk				1.875*	1.889**
				(1.049)	(0.777)
Urban (street level)					3.804***
					(1.111)
Urban (building)					–2.647**
					(1.105)
Reforestation					2.529
					(2.063)
Restoration					0.203
					(0.742)
Agricultural					3.681***
					(1.245)
Constant	8.172	11.346***	9.182***	13.005***	7.044*
	(6.555)	(2.339)	(2.992)	(4.658)	(3.825)
Observations	219	219	219	219	219
R-squared	0.446	0.512	0.579	0.689	0.768

Note: Standard errors are in parentheses.
*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

total value per year, we needed to multiply the result of that equation, after inserting the site characteristics, by the size of the policy site. The results are in Section 3.

3. Results

Descriptive Statistics

After the screening phase, the final database consisted of 216 observations across 61 studies (see Appendix A). This higher number of observations compared with those from similar studies is due mainly to new evidence published since 2022. The main reason for excluding studies was the lack of a comparable monetary value. Most studies provide more than one valuation because choice experiments usually elicit preferences for multiple co-benefits of a particular NBS or ecosystem. Sample sizes also vary considerably across the studies, with 120 as the lowest number of respondents and 6,172 as the highest. Table 4 shows the summary statistics. In total, the meta-analysis is based on 49,596 respondents, combining all studies together.

The final set of papers indicates that most of the SP studies were conducted in either Europe or North America, accounting for 40% and 25% of the total number of observations, respectively. This distribution aligns with that recorded not only in previous meta-analyses regarding co-benefits of NBSs (Bockarjova, Botzen, and Koetse 2020) but also in systematic reviews of the risk reduction aspect of NBSs (Sudmeier-Rieux et al. 2021; Debele et al. 2023). Regarding the publication year, we conclude that, as expected, the amount of evidence on the NBS co-benefits has been increasing exponentially in recent years: 77% of the included studies were published after 2017 and 52% since 2020. Regarding the NBS type, around 50% of our observations related to urban NBSs, mainly green roofs and urban parks. This result is also in line with those of Debele et al. (2023), who found that 48% of the studies they identified focused on urban NBSs. Wetlands and forests are also quite prominent in the literature, featuring in 15% and 16% of works, respectively. Similarly, flood risk and heat mitigation are the two most common objectives of NBSs for our selected studies; recreation, aesthetic appreciation, and biodiversity support were the more frequent co-benefits assessed.

Table 4
Summary Statistics of Key Variables

Variable	Mean	SD
Continent dummies		
North America	0.255	0.437
Europe	0.407	0.492
Africa	0.083	0.277
Asia	0.208	0.407
Type of nature-based solution		
Urban	0.5	0.501
Coral reefs	0.056	0.23
Mangroves	0.046	0.211
Lakes, ponds, rivers	0.213	0.41
Wetlands	0.153	0.361
Beach nourishment	0.051	0.22
Forests	0.167	0.374
Risk being addressed		
Flood	0.625	0.485
Heat/heatwave/urban heat island	0.431	0.496
Coastal erosion	0.144	0.351
Wildfire	0.056	0.23
Storm surge	0.069	0.255
Co-benefits		
Local climate regulation	0.208	0.407
Air quality regulation	0.227	0.42
Carbon storage	0.180	0.385
Recreation	0.319	0.467
Tourism	0.111	0.315
Aesthetic appreciation	0.356	0.48
Habitat for species	0.352	0.479
Maintenance genetic diversity	0.231	0.423
Land use change		
Conservation and maintenance of existing nature	0.231	0.422
Reforestation	0.185	0.389
Agricultural	0.023	0.150
Urban (buildings)	0.183	0.277
Urban (street)	0.133	0.346
Restoration	0.055	0.389

As expected, the monetary valuations differ considerably per study. The wide variations in population affected and hectares of the NBSs implemented lead to considerable variations in valuation per hectare per year. The median valuation per hectare per year was US$5,543 at 2022 prices. This valuation is similar to those of previous studies, reporting US$12,000 per hectare per year for urban NBSs such as parks, whereas the valuation of other types of urban nature ranged between US$1,250 and US$2,800 (Bockarjova, Botzen, and Koetse

Table 5
Economic Valuations by Previous Land Use Where a Nature-Based Solution Is Planned

Valuation by Land Use Change	Median Willingness to Pay
Conservation and maintenance of existing nature	1,192
Reforestation	58,161
Agricultural	17,482
Urban (building; e.g., green roofs)	19,953
Urban (street; e.g., parks, street trees)	208,916

Note: The valuation is US$ per hectare.

2020). The average GDP per capita in the study was US$40,348 at 2022 prices, whereas the median was US$42,337. According to World Bank data, the average GDP per capita in 2022 at the global scale was US$12,730, affirming that the studies valuing NBS co-benefits are mostly located in wealthier countries. More evidence is certainly needed in the most vulnerable countries because they will be impacted by climate change–related risks in the upcoming years. The median area of the NBSs in our database was 1,700 ha, and the median population density was 605 people per square kilometer. As expected, this figure is considerably higher than the world average of 59.24 people per square kilometer: unsurprising, given that this figure accounts for uninhabited areas and that almost 50% of our observations are from urban settings.

Table 5 distinguishes between two types of urban NBSs: The first encompasses those to be developed on existing buildings, such as green roofs or green walls. Ultimately, these urban NBSs may not have a wider impact on co-benefits such as recreation and would not require changing the economic purpose of land in an urban setting for a different use ($Urban - building$). The second category consists of urban NBSs that would be implemented at the street level or would mean to change the use of open urban spaces for NBS creation ($Urban - street$). As Table 5 shows, regarding the land use change variables, urban NBSs located at the street level (e.g., parks) are highly valued, with a median WTP per hectare of US$208,916. On the other hand, increasing the conservation efforts or improving the maintenance of existing urban nature to increase protection against climate risks has a lower median value of US$1,192 per hectare.

Approximately 9% of the studies sampled did not specify the land use change the intervention would entail. As expected, NBSs situated in urban settings had a higher median WTP (US$36,747 per hectare) than nonurban NBSs (US$785 per hectare). This outcome is in line with previous findings since urban areas are usually densely populated and have a higher GDP per capita, two variables associated with a higher WTP in previous studies.

Meta-Regression Results

The following meta-regressions consist of a series of WLS models where the dependent variable is the log of the monetary value (US$/ha/year) attributed to NBS co-benefits. The log transformation addresses the skewness of our dependent variable and residuals. In other words, the lack of symmetry around the mean caused by the outliers shown in the descriptive statistics. The five models presented below include several key variables by groups, starting from the basic specification in model 1 to the full specification in model 5 (Table 3). The final models show a higher adjusted R-squared compared with the basic specifications (from 0.47 in model 1 to 0.768 in model 5). Therefore, there is a higher percentage of the dependent variable variation explained by models with the co-benefits, continent dummies, land uses, and the types of NBSs. Compared with previous meta-analyses, our regressions show a relatively high adjusted R-squared since models in Filho et al. (2021) and Brander and Koetse (2011) produced R-squareds of 0.48 and 0.13, respectively.

Model 1 represents the basic specification, where we can observe that our findings align with those in the literature (Brander and Koetse 2011; Bockarjova, Botzen, and Koetse 2020). First, the NBS size coefficient shows diminishing returns. The larger the NBS size, the lower the economic value per hectare. Since this is a log-log coefficient, it represents an elasticity. In other words, a 1% increase in size is associated on average with a 0.53% decrease in the value per hectare, keeping everything else constant. This finding is also common across all specifications with a similar effect size, including the OLS models used as robustness checks (Appendix C). As in Bockarjova, Botzen, and Koetse (2020), CV studies estimate a lower average WTP compared with choice experiments.

Model 3 indicates that urban NBSs are strongly correlated with a higher value per hectare. Regarding the co-benefits, model 4 indicates that heat reduction, maintenance of genetic diversity, and aesthetic appreciation have positive and statistically significant coefficients. Therefore, NBSs providing these benefits will be, on average, more valued by respondents. Hence, respondents are willing to accept a higher tax (or other payment) to develop these NBSs or restore/maintain NBSs that provide these benefits.

On the other hand, air carbon storage has a negative coefficient while being statistically significant. This indicates a lower average per hectare value associated with this co-benefit while keeping everything else constant. A plausible interpretation is that respondents are more likely to be willing to pay for co-benefits that they can enjoy daily, such as reduced heat or recreation areas, whereas air quality or carbon sequestration cannot be perceived as valuable, despite the long-term negative health consequences. Tantiwat, Gan, and Wang (2021) found a positive relationship between awareness of current air quality problems and potential health consequences and higher valuation for air quality improvements. This could explain our findings since it is possible that the lack of awareness could also have influenced our results.

In addition, the Netherlands Bureau for Economic Policy Analysis found that air quality has a small impact on property prices compared with noise pollution or availability of accessible green and water amenities within close distance to one's house (CPB Netherlands Bureau for Economic Analysis 2022). This is consistent with our observed coefficients. Carbon sequestration can also be perceived as a global service that does not only affect the local area and the residents who are making the monetary contribution and, hence, should be considered a lower priority. Its contribution on a global scale may be seen as less significant by respondents. The null effect of flood risk reduction is another interesting finding, which is in line with some previous meta-analyses (Bockarjova, Botzen, and Koetse 2020). This could be related to potentially uncaptured disamenities (Dundas et al. 2017).

Similarly, an increase in tourism is also associated with lower WTP in model 4, which can be linked to several reasons, including noise, congestion, pollution, or crowding, potentially leading to decreased recreational quality (Gössling 2002; Sanz-Blas, Buzova, and Garrigos-Simon 2024). Ojijo and Steiger (2024) found that residents place high importance on tourism not altering land use change and on limiting the number of tourism accommodations. In all our models, local climate regulation is strongly correlated with a higher WTP on average, indicating a strong preference for NBSs that address this issue.

Last, we tested the correlation of previous land use with NBS valuation. It is important to note that the relevance of land use changes depends partially on how this is explained in the original studies because it may have not been explicitly presented in the choices. Therefore, our findings regarding previous land use should be interpreted as correlational and not necessarily a direct preference of respondents for land use change itself. Previous land use is relevant for policy-making, as significant differences in valuation may indicate which NBSs could be prioritized to maximize value for local communities. For example, we would expect that NBSs planned in urban settings with virtually no green areas would be well received by residents.

The main distinction between conservation and new developments is also insightful, as people may be used to the nature around them, lowering the marginal benefits of additional or improved nature. We excluded NBSs proposing conservation or maintenance measures as our baseline for these dummies. The adjusted *R*-squared increases considerably compared with model 1, and it increases more when included with co-benefits in model 5. In line with our previous findings, respondents highly valued repurposing urban land to create new green or blue spaces (urban lakes, ponds), particularly those at the street level rather than on top of buildings. In addition, model 5 shows that developing NBSs on agricultural land is a land use change that respondents respond to favorably and correlates with higher WTP. In Appendix C, our OLS models, without correcting the WTP variable by paper, point in the same direction as these models.

4. Value Transfer Function

Table 6 presents the description and characteristics of the chosen case studies to illustrate the application of our estimated value transfer function. These studies were retrieved from the Nature-Based Solutions Initiative website.[5] We chose three studies with different purposes (in terms of climate risk addressed) and geographical characteristics for the value transfer function. Before delving into the specific details of each case study, it is important to understand that because we are back-transforming from logs, the Jensen (1906) inequality, which may play a role in introducing a slight bias, may have led to monetary underestimation. As discussed in Section 2, it is important to note that value transfer is subject to transfer error ranges (approximately 30% on average). Hence, the case-study estimates presented below should be interpreted bearing this uncertainty in mind.

The first project consists of developing a green belt of 230 ha in the former site of the Krupp steel factory Essen. The green belt, among other co-benefits, is designed to reduce the impact of future floods. The second project is a restoration of 9,650 ha of coastal mangroves in Bangladesh to serve as coastal protection. The third project aims to improve the conservation strategy for wetlands across the Nile basin to protect from fluvial floods and limit droughts. These studies were selected with two main goals. First, these are actual NBS projects instead of potential future interventions. Second, there is sufficient variation in the key statistically significant variables in our meta-regressions to observe how these differences can influence per hectare valuation. Before calculation, we expect that the European project in an urban setting would most likely yield a high value per hectare for those reasons, whereas the project in Bangladesh has some factors correlated with a high WTP, such as high population density, but a lower GDP per capita. Moreover, the fact that it is a restoration project may produce lower WTP. Equation [4], based on model 5, displays the value transfer function:

$$\begin{aligned}&\textit{Value of NBS per hectare per year}\\&= \exp\,(7.044 + -0.529\,(\ln(\textit{Area}) + 0.071\\&\quad(\ln(\textit{GDP}) + -0.163 \times (\textit{Density})\\&\quad+ \beta(\textit{study type}) + \beta(\textit{NBS type})\\&\quad+ \beta(\textit{continent dummy})\\&\quad+ \beta(\textit{co-benefits}) + \beta(\textit{land use})).\end{aligned} \qquad [4]$$

The study type was assumed at sample average for the value transfer function, where approximately 80% of our studies are CE. As expected, the project in Essen had a high value per hectare per year (US$533,870), higher than Bockarjova, Botzen, and Koetse's (2020) value transfer estimate (US$229,030). This could be because of a combination of new evidence, including land use change variables (which increases the value for new urban developments), and the 2022 prices. On the other hand, although the mangrove restoration project presents very different characteristics, with an estimated WTP per hectare per year of US$160,000, it can be considered a valuable NBS. This value is approximately one-third that of the Essen example. However, owing to the large size of the intervention, the total value exceeds the previous example. The value per hectare is even lower for a conservation project in a rural setting across multiple countries in the river basin.

Appendix E shows the same valuations from a value transfer function without accounting for previous land use variables, while all the other variables are still included. As can be observed, the valuation is considerably impacted when applying a value transfer function accounting for change in land use. These three projects would have very different setup and maintenance costs because of their particular characteristics.

[5] Available at https://www.naturebasedsolutionsinitiative.org.

Table 6
Applications of Value Transfer Function in Three Nature-Based-Solution Pilots

Project	Essen's Transition (from Gray to Green)	Coastal Mangrove Restoration (Bangladesh)	Conserving Biodiversity (Nile Basin Transboundary Wetlands)
Type	Urban	Mangrove restoration	Wetland conservation
Description	Former site of Krupp cast-steel factory; transformed into a 230 ha green belt	Established 9,650 ha of mangrove plantation	To strengthen technical and institutional capabilities to sustainably manage the region to limit drought and flooding
Continent	Europe	Asia	Africa
Risk being addressed	Flooding	Flooding, coastal defense	Flooding, droughts
Area (ha)	230	9,650	320
Population density	2,715	1,180	1,280 (across Nile basin)
GDP per capita	50,070	2,688	1,100 (avg. Nile basin countries)
Type of nature-based solution	Park	Mangrove	Wetland
Co-benefits provided	Recreation, species habitat, air quality, climate regulation, carbon sequestration, flood risk, aesthetic appreciation	Recreation, habitat for species, climate regulation, flood risk	Recreation, habitat for species, air quality, climate regulation, flood risk
Previous land use	Urban	Restoration	Conservation
Annal value per hectare	533,870	160,764	96,244
Annual total value	122.7 million	1,512 million	30.8 million

Note: The GDP and values are in 2022 US$. The contingent valuation method is set at 0.2 to reflect the sample average.

Previous studies have focused mainly on the benefits of NBSs in terms of climate risk reduction through catastrophe models, such as flood damage models. However, considering only the average annual damage reduction in the above examples omits a key part of their total economic value, namely their co-benefits. This value transfer function, derived from over 49,500 respondents worldwide, can be used to monetize these co-benefits to provide a comprehensive assessment of the economic value of NBSs when combined with a climate risk assessment model estimating the risk reduction of such solutions in a specific case study.

5. Conclusion

This meta-analysis assessed the current state of SP literature on NBS co-benefits for climate risk. With the regression results, we developed a value transfer function applicable to future case studies. This function usefully accounts for the wide range of NBS co-benefits in decision-making processes. The results of the meta-analysis indicate that NBSs in more densely populated areas tend to be associated with higher economic value per hectare while keeping everything else constant. This outcome aligns with those of previous meta-analyses on ecosystem services. Benefits such as heat reduction, recreation, and aesthetic appreciation correlate with higher WTP, whereas air quality and carbon storage correlate with lower economic value per hectare, keeping everything else constant. A reasonable explanation is that respondents are more likely to be willing to pay for co-benefits they can enjoy daily, whereas air quality cannot be perceived as valuable, despite long-term health consequences.

Compared with previous meta-analyses, our study benefits from the increasing number of papers published in recent years. This has allowed for the building of an extensive database of SP studies on NBS co-benefits for climate risk reduction. Aside from the standard covariates for the meta-regression (size, GDP per capita, population density, type of NBS, and co-benefits), we recorded the climate risk being addressed and the land use change that would occur if the NBSs were to be implemented. This new analysis could be very valuable for decision makers because land use constraints are a common barrier of NBS policies in certain regions. Respondents show a higher WTP, on average, for NBSs that will change the use of current urban areas or agricultural land to green or blue spaces than for measures improving conservation of existent nature sites. The resulting value transfer function can inform policy makers in their design for climate adaptation strategies to maximize co-benefits for the wider society when planning NBSs for climate risk reduction.

Limitations persist on the available evidence on the economic co-benefits of NBSs for climate risk. Around two-thirds of all the studies included in the meta-analysis were from either Europe or North America. Owing to the difficulties in using monetary value estimations in other contexts, the lack of case studies in the Global South is a key limitation in co-benefit assessment. Unobserved factors, such as specific ecological characteristics or environmental attitudes (e.g., climate risk perception), could have influenced our estimates. Most of our estimates are in line with expectations. However, potential multicollinearity arising from the number of predictors can increase the difficulty of disentangling individual effects. This can be an explanation behind the counterintuitive coefficient for carbon storage.

The uncertainty of value transfer functions also depends on the quality of the primary valuation studies. This meta-analysis encompasses a wide variety of studies in terms of methodologies (CV or CE), geographical locations, and standardization assumptions, which depend on the missing data of the original study. For instance, we rely on sample size for weighting the regression owing to a lack of reporting of standard errors under the implicit assumption that sample size is a proxy of precision of the estimates. Our weighting does not account for other dimensions of study quality or design. Weighting according to the standard errors is in preferable principle, but we would have lost over 70% of the observations, hence justifying our decision to weight by sample size. Even though clustering of errors at the study level addresses the potential nonindependence of observations, studies that contribute a larger number of observations can still have a large influence on the coefficient estimates.

The comparability of estimates relies on having a comparable monetary value and sufficient information to derive the WTP in 2022 US dollars per hectare per year through a standardization process, as described in Table 2. Moreover, the analysis controls key variables, such as study type, geographical location, and socioeconomic characteristics. Nevertheless, the broad range of included studies could be considered a limitation. Future research could involve a more focused meta-analysis on, for example, WTP values from a particular region or NBS type once more primary valuation studies become available to arrive at a sufficiently large sample.

Future research should aim to expand the valuation of co-benefits to other regions. Moreover, to ensure comparability, SP studies could include more detailed information about the NBSs they present in their surveys, such as size or previous land use, as these have been proven relevant to estimating WTP. A clear trade-off of land use change from current economic use to NBSs should be clearly stated in future SP studies to accurately assess how this impacts respondents' preferences. Overall, conclusions extracted from similar meta-analyses in the future would benefit from a more standardized framework when it comes to presenting attributes to respondents and from a more consistent reporting of standard errors. In addition, future case studies can combine the value transfer function by inputting the policy site characteristics and risk-reduction models for a particular region where an adaptation policy is planned. This would provide a comprehensive assessment for policy makers about the total societal value (or return on investment) that NBSs would bring when compared with traditional measures, strengthening the case for investment in NBSs.

Acknowledgments

This research was funded by the European Union's Horizon Europe: Framework Programme for Research and Innovation (2021–2027) in the context of the NATURANCE project (grant 101060464), the ERC COAST-MOVE project (grant 8844442), and the EU ERC INSUREADAPT project (grant 101086783).

References

Bergstrom, J. C., and L. O Taylor. 2006. "Using Meta-Analysis for Benefits Transfer: Theory and Practice." *Ecological Economics* 60 (2): 351–60. https://doi.org/10.1016/j.ecolecon.2006.06.015.

Bockarjova, M., W. J. W. Botzen, and M. J. Koetse. 2020. "Economic Valuation of Green and Blue Nature in Cities: A Meta-Analysis." *Ecological Economics* 169: 106448. https://doi.org/10.1016/j.ecolecon.2019.106480.

Brander, L. M. 2013. "Guidance Manual on Value Transfer Methods for Ecosystem Services." Technical Report, Brander Environmental Economics. https://doi.org/10.13140/2.1.4203.8569.

Brander, L. M., R. de Groot, V. Guisado Goñi, V. van't Hoff, P. Schägner, S. Solomonides, A. McVittie, et al. 2024. "Ecosystem Services Valuation Database (ESVD)." Foundation for Sustainable Development and Brander Environmental Economics.

Brander, L. M., and M. J. Koetse. 2011. "The Value of Urban Open Space: Meta-Analyses of Contingent Valuation and Hedonic Pricing Results." *Journal of Environmental Management* 92 (10): 2763–73. https://doi.org/10.1016/j.jenvman.2011.06.019.

Brouwer, R. 2000. "Environmental Value Transfer: State of the Art and Future Prospects." *Ecological Economics* 32 (1): 137–52. https://doi.org/10.1016/S0921-8009(99)00070-1.

Coventry, P. A., J. E. Brown, J. Pervin, S. Brabyn, R. Pateman, J. Breedvelt, and P. C. White. 2021. "Nature-Based Outdoor Activities for Mental and Physical Health: Systematic Review and Meta-Analysis." *SSM: Population Health* 16: 100917. https://doi.org/10.1016/j.ssmph.2021.100917.

CPB Netherlands Bureau for Economic Policy Analysis. 2022. "Do People Value Environmental Goods? Evidence from the Netherlands." Available at https://www.cpb.nl/system/files/cpbmedia/omnidownload/CPB-Discussion-Paper-438-Do-people-value-environmental-goods.pdf.

Dalhuisen, J. M., R. J. G. M. Florax, H. L. F. de Groot, and P. Nijkamp. 2003. "Price and Income Elasticities of Residential Water Demand: A Meta-Analysis." *Land Economics* 79 (2): 292–308. https://doi.org/10.2307/3146872.

Debele, S. E., L. S. Leo, P. Kumar, J. Sahani, J. Ommer, E. Bucchignani, S. Vranić, et al. 2023. "Nature-Based Solutions Can Help Reduce the Impact of Natural Hazards: A Global Analysis of NBS Case Studies." *Science of the Total Environment* 902: 165824. https://doi.org/10.1016/j.scitotenv.2023.165824.

Dundas, S. J. 2017. "Benefits and Ancillary Costs of Natural Infrastructure: Evidence from the New Jersey Coast." *Journal of Environmental Economics and Management* 85: 62–80. https://doi.org/10.1016/j.jeem.2017.04.008.

European Commission. 2019. "Nature-Based Solutions." Directorate-General for Research and Innovation. Available at https://research-and-innovation.ec.europa.eu/research-area/environment/nature-based-solutions_en.

European Environment Agency. 2021. "Nature-Based Solutions in Europe: Policy, Knowledge and Practice for Climate Change Adaptation and Disaster Risk Reduction." EEA Report 01/2021. Available at https://www.eea.europa.eu/publications/nature-based-solutions-in-europe.

Filho, W. L., S. K. Tripathi, J. B. S. O. Andrade Guerra, R. Giné-Garriga, V. Orlovic Lovren, and J. Willats. 2021. "A Global Meta-Analysis for Estimating Local Ecosystem Service Value Functions." *Science of the Total Environment* 783: 146722. https://doi.org/10.1016/j.scitotenv.2021.146722.

Glass, G. V. 1976. "Primary, Secondary, and Meta-Analysis of Research." *Educational Researcher* 5 (10): 3–8. https://doi.org/10.3102/0013189X005010003.

Gössling, S. 2002. "Human–Environmental Relations with Tourism." *Annals of Tourism Research* 29 (2): 539–56. https://doi.org/10.1016/S0160-7383(01)00069-X.

Haidich, A. B. 2010. "Meta-Analysis in Medical Research." *Hippokratia* 14 (suppl. 1): 29–37. Available at https://www.hippokratia.gr/index.php/hippo/article/view/12.3.

IPCC (Intergovernmental Panel on Climate Change). 2021. "Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change." Cambridge, UK: Cambridge University Press.

Jensen, J. L. W. V. 1906. "Sur les fonctions convexes et les inégalités entre les valeurs moyennes" [On Convex Functions and Inequalities Between Mean Values]. *Acta Mathematica* 30: 175–93. https://doi.org/10.1007/BF02418571.

Jones, P., and B. Doberstein. 2022. "Encouraging Co-Benefits in Climate-Affected Hazard Adaptation: Developing and Testing a Scorecard for Project Design and Evaluation." *International Journal of Disaster Risk Reduction* 63: 102487. https://doi.org/10.1016/j.ijdrr.2021.102487

Kaul, S., K. J. Boyle, N. V. Kuminoff, C. F. Parmeter, and J. C. Pope. 2013. "What Can We Learn from Benefit Transfer Errors? Empirical Evidence from 20 Years of Research." *Journal of Environmental Economics and Management* 66 (3): 90–104. https://doi.org/10.1016/j.jeem.2013.05.001.

Millennium Ecosystem Assessment. 2005. "Ecosystems and Human Well-Being: Wetlands and Water Synthesis." Washington, DC: World Resources Institute.

Munich Re. 2022. "Natural Catastrophe Review: Series of Disasters in 2021 Dominated by US Weather Extremes." Available at https://www.munichre.com/en/company/media-relations/media-information-and-corporate-news/media-information/2022/natural-catastrophe-review-2021.html.

Naumann, S. 2020. "The Underinvestment in Nature-Based Solutions: Evidence from a Systematic Review." *Journal of Environmental Management* 260: 110076. https://doi.org/10.1016/j.jenvman.2020.110076.

Nelson, J. P., and P. E. Kennedy. 2009. "The Use (and Abuse) of Meta-Analysis in Environmental and Natural Resource Economics: An Assessment." *Environmental and Resource Economics* 42 (3): 345–77. https://doi.org/10.1007/s10640-008-9253-5.

Nobel, A., S. Lizin, R. Brouwer, S. B. Bruns, D. I. Stern, and R. Malina. 2020. "Are Biodiversity Losses Valued Differently When They Are Caused by Human Activities? A Meta-Analysis of the Non-Use Valuation Literature." *Environmental Research Letters* 15 (7): 073003. https://doi.org/10.1088/1748-9326/ab8ec2.

Ojijo, A., and R. Steiger. 2024. "Resident Perceptions of Tourism Development and Land-Use Change in Protected Areas: Evidence from East Africa." *Journal of Sustainable Tourism* 32 (5): 845–61. https://doi.org/10.1108/TR-10-2023-0713.

Page, M. J., J. E. McKenzie, P. M. Bossuyt, I. Boutron, T. C. Hoffmann, C. D. Mulrow, L. Shamseer, et al. 2021. "The PRISMA 2020 Statement: An Updated Guideline for Reporting Systematic Reviews." *BMJ* 372: n71. https://doi.org/10.1136/bmj.n71.

Reynaud, A., and D. Lanzanova. 2017. "A Global Meta-Analysis of the Value of Ecosystem Services Provided by Lakes." *Ecological Economics* 137: 184–94. https://doi.org/10.1016/j.ecolecon.2017.03.001.

Sanz-Blas, S., D. Buzova, and F. J. Garrigos-Simon. 2024. "Understanding Crowding Perceptions and Their Impact on Place Experience: Insights from a Mixed-Methods Study." *Psychology and Marketing* 41 (5): 1022–35. https://doi.org/10.1002/mar.21964.

Spash, C. L., and A. Vatn. 2006. "Transferring Environmental Value Estimates: Issues and Alternatives." *Ecological Economics* 60 (2): 379–88. https://doi.org/10.1016/j.ecolecon.2006.06.010.

Staccione, A., G. García Alvarez, M. Tesselaar, A. Arneth, and W. J. W. Botzen. 2023. "Methods for Assessing Risk Reduction and Co-Benefits by Nature-Based Solutions." Open Science Framework Registries. https://doi.org/10.17605/OSF.IO/FUT97.

Staccione A., G. Garcia Alvarez, M. Tesselaar, W. J. W. Botzen, and A. Arneth. n.d. "Nature-Based Solutions' Co-Benefits Beyond Risk Reduction: A Review of Assessment Methods." Under review at *Journal of Environmental Management*.

Stanley, T. D. 2013. "Meta-Regression Methods for Detecting and Estimating Empirical Effects in the Presence of Publication Selection." *Oxford Bulletin of Economics and Statistics* 75 (1): 103–27. https://doi.org/10.1111/j.1468-0084.2011.00652.x.

Stanley, T. D., and H. Doucouliagos. 2014. "Meta-Regression Approximations to Reduce Publication Selection Bias." *Research Synthesis Methods* 5 (1): 60–78. https://doi.org/10.1002/jrsm.1095.

Su, J., D. A. Friess, and A. Gasparatos. 2021. "A Meta-Analysis of the Ecological and Economic Outcomes of Mangrove Restoration." *Nature Communications* 12: 5050. https://doi.org/10.1038/s41467-021-25349-1.

Sudmeier-Rieux, K., T. Arce-Mojica, H. J. Boehmer, N. Doswald, L. Emerton, D. A. Friess, and Y. Walz. 2021. "Ecosystem-Based Disaster Risk Reduction: An Overview of Risk and Policy." *International Journal of Disaster Risk Reduction* 50: 101798. https://doi.org/10.1016/j.ijdrr.2020.101798.

Tantiwat, W., C. Gan, and W. Yang. 2021. "The Estimation of the Willingness to Pay for Air-Quality Improvement in Thailand." *Sustainability* 13 (21): 12313. https://doi.org/10.3390/su132112313.

TEEB. 2011. *The Economics of Ecosystems and Biodiversity in National and International Policy Making*. Edited by Patrick ten Brink. London: Earthscan.

Travisi, C. M., and P. Nijkamp. 2004. "Are Italians Willing to Pay for Agricultural Environmental Safety? A Stated Choice Approach." Paper presented at the European Association of Agricultural Economists 84th Conference, Zeist, Netherlands, February 8–11. https://doi.org/10.22004/ag.econ.24988.

Viti, M., R. Löwe, H. J. D. Sørup, J. Ladenburg, O. Gebhardt, S. Iversen, U. S. McKnight, and K. Arnbjerg-Nielsen. 2023. "Holistic Valuation of Nature-Based Solutions Accounting for Human Perceptions and Nature Benefits." *Journal of Environmental Management* 334: 117498. https://doi.org/10.1016/j.jenvman.2023.117498.

World Bank. 2023. "Assessing the Benefits and Costs of Nature-Based Solutions for Climate Resilience: A Guideline for Project Developers." Available at http://hdl.handle.net/10986/39811.