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Andrea Ghermandi and
Paulo A.L.D. Nunes

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A Global Map of Coastal Recreation Values: results from a spatially explicit meta-analysis

Andrea Ghermandi[1], Paulo A.L.D. Nunes[2,3]
[1] *Department of Economics, Cà Foscari University of Venice, Italy*
[2] *Marine Economics Research Programme, The Mediterranean Science Commission – CIESM, Principauté de Monaco*
[3] *Department of Agriculture and Natural Resources Economics – TESAF, University of Padova, Italy*

Abstract

The welfare dimension of the recreational services provided by global coastal ecosystems is examined through a meta-analytical regression based valuation approach. First, we construct a global, state-of-the-art database of stated and revealed preference estimates on coastal recreation, which includes also the grey literature and with the latest entry updated to February 2010. Second, the profile of each of the 253 observations of our dataset, which correspond to individual value estimates, was further enriched with characteristics of the built coastal environment (site accessibility, anthropogenic pressure, level of human development), characteristics of the natural coastal environment (presence of protected area, type of ecosystem, and marine biodiversity richness), geo-climatic factors (temperature and precipitation), as well as sociopolitical characteristics, such as the political stability index. In this context, the proposed meta-analytical valuation exercise explores the spatially explicit dimension of the values building upon Geographic Information System (GIS) tools. GIS are relied upon for the spatial characterization of the valued ecosystems, the determination of the role of spatially explicit variables in the meta-analytical value transfer model, as well as for the value transfer exercise. The GIS characterization reveals to be extremely significant in explaining the spatial diversity of the estimates values and underlying explanatory factors. The resulting integrated valuation framework constitutes a worldwide *première* and it results in the first global map of the recreational value of coastal ecosystems. We argue that the presented global map may play an important role in studying the prioritization for the conservation of coastal areas from a social perspective.

Keywords

Built coastal environment, Natural coastal environment, Ecosystem service valuation, Geographic Information Systems, Mapping ecosystem values, Marine biodiversity, Scaling up, Spatial analysis, Spatial economic valuation, Value transfer

JEL Codes

C53, Q26, Q57, R12

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Address for correspondence:
Andrea Ghermandi
Department of Economics
Ca' Foscari University of Venice
Cannaregio 873, Fondamenta S.Giobbe
30121 Venezia - Italy
Phone: (++39) 041 8627702
Fax: (++39) 041 2349176
e-mail: andrea.ghermandi@unive.it

1 Introduction

The sustainable management of recreational activities is of increasing importance for the stewardship of the natural capital in coastal areas worldwide. Coastal tourism and recreation have dramatically increased over the past decades becoming a primary contributor to the gross domestic product (GDP) of several countries and well-being of large coastal populations. On the other hand, tourism and recreation-related development are among the principal causes of conversion and degradation of coastal habitats such as forests, wetlands and coral reefs. Together with nutrient pollution, habitat conversion is the main anthropogenic threat to the capacity of coastal ecosystems to sustain the provision of services, including support of tourism and recreation (Millennium Ecosystem Assessment 2005). Analysis of the current trends indicates that the impact of both nutrient pollution and habitat conversion will substantially increase in particular in developing countries, where coastal tourism is often among the primary economic development strategies.

From an economic perspective, sustainable management strategies for coastal tourism and recreation are founded on a thorough assessment of their value in the relevant policy context. In this context, the economic valuation of recreational activities is a particularly challenging undertaking. Recreationally oriented activities taking place in the coastal zone include both extractive (e.g., hunting, fishing, and shellfishing) and non-extractive uses (e.g., swimming, sun-bathing, boating, wind-surfing, bird-watching, snorkeling, and diving). The true welfare impact of these activities is for a large part not reflected in market transactions or remains out of the scope of most analyses because embedded in related markets. A series of valuation techniques capable of capturing such values has been developed over the past decades, some based on the observation of the actual consumption behavior of recreationists, such as the travel cost method (Bockstael et al. 1991), others relying on the response to changes in hypothetical markets, such as the contingent valuation (Mitchell & Carson 1989) and contingent behavior methods (Hanley et al. 2003). Although the number of applications of such techniques to coastal recreation is rapidly growing, non-market valuation studies typically have a limited geographical scope and are restricted in the range of socio-economic contexts that they consider.

Value transfer techniques are an attractive option for policy-makers facing pressing time and budget constraints when reliable primary valuation data are absent. Value transfer makes use of results from earlier empirical studies and applies their conclusions – according to a well-codified set of rules – to a policy site that differs from that of the study for which the values were originally estimated (Boyle & Bergstrom 1992; Florax et al. 2002; Nijkamp et al. 2008). Since local characteristics such as the accessibility of a site to potential users are crucial in determining the extent of coastal tourism and recreation, value transfer is particularly challenging when study and policy sites are located in different geographic and socio-economic contexts. This is because valuation studies generally focus on a single site or group of sites within a homogeneous context and such dependence from the context is left implicit in the analysis (Liu et al. forthcoming). Meta-analysis is the only tool available in value transfer to distinguish between phenomenon-intrinsic factors and context-specific factors, including the valuation method used in the primary valuation study (Florax et al. 2002). Meta-analysis has been applied to the valuation of coastal ecosystems, but with a restricted focus on a specific ecosystem type, i.e., coral reefs (Brander et al. 2007), or valuation method, i.e., contingent valuation (Liu & Stern 2008), and relying on a relatively small sample of value observations. Furthermore, such meta-analyses rely on a substantial simplification of the geographic context that underpins the provision and fruition of the coastal ecosystem services and no attempt is made to scale up the results to support strategic policy planning and evaluation in a larger geographical setting than the case-by-case value transfer.

In this study, a comprehensive framework meta-analytical transfer of the value of recreational activities is developed and applied to produce a global map of coastal recreation values. The structure of the paper is as follows. Section 2 presents the global valuation dataset created for the present exercise, identifies the moderator variables as well as describes the methodology for integrating spatially explicit information in the analytical framework. Section 3 puts forward the meta-regression models and discusses the underlying econometric estimation results. Section 4 defines the procedure for value transfer and scaling up, provides the global map of coastal recreation values and discusses the accuracy of the transferred values. Section 5 concludes.

2 Preparation of a global dataset

2.1 Primary values of coastal recreation

The analysis in this paper relies on a global data set of non-market valuations of the cultural services of coastal and estuarine ecosystems, which is described in more detail elsewhere (Ghermandi et al. forthcoming). For the present investigation, we work with 253 distinct value observations from 79 primary valuation studies, all associated to geo-referenced information regarding the valued sites and the context-specific moderator variables of the meta-analytical value transfer model. The main characteristics of the valuation studies and the location of the valued sites are summarized in Table 1. The investigation was not limited to peer-reviewed scientific publications but also explored "grey literature", which include unpublished working papers, reports for both public and private institutions, and constitutes 40% of the primary valuation studies of our dataset. The geographic extent of each of the valued coastal ecosystems was characterized in a spatially explicit manner by means of GIS tools. For each of the sites, a linear shapefile (polyline) of coastline was created, which features the shoreline path as identified based on remote sensing Landsat imagery accessed through Google Earth (http://earth.google.com). Table 1 shows the range of coastline length of the valued sites calculated as the length of the polyline features (see also Figure 3).

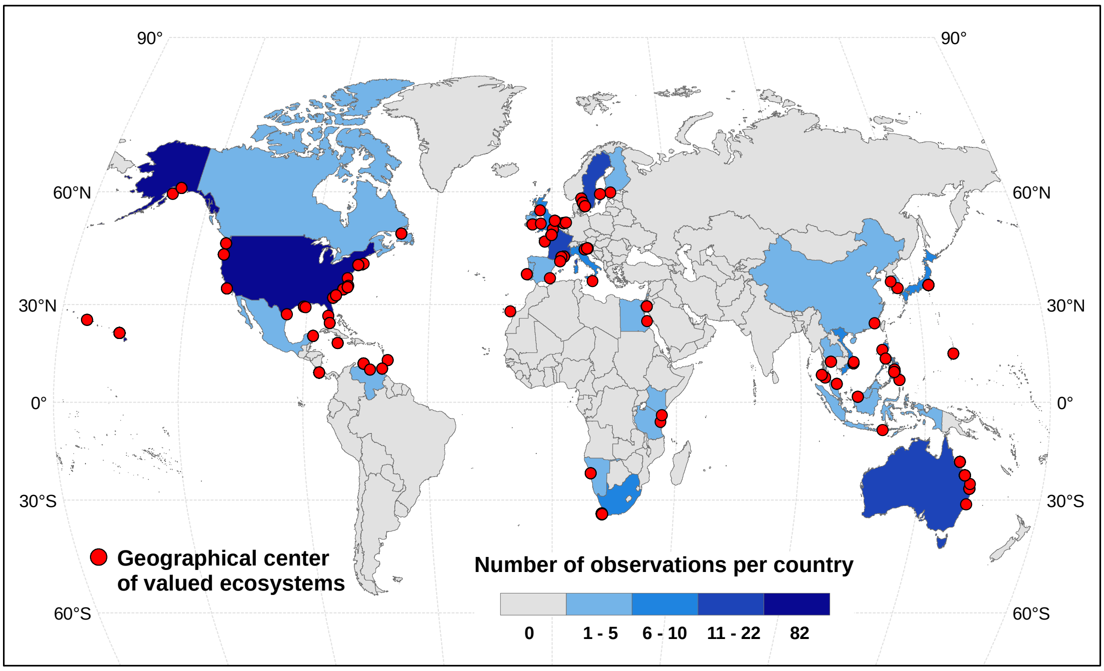

Figure 1. Geographical distribution of the valued coastal ecosystems

Table 1. Overview of studies and valued sites included in the meta-regression

Prevailing ecosystem type	Valuation method	Year of survey	Coastline length, km	Nr. of value estimates
Estuary[a]	Stated preference	2000 – 2003	12 – 1540	4
	Travel cost	1995 – 2003	12 – 1718	8
	Contingent behavior	1995	1718	1
Beach[b]	Stated preference	1991 – 2006	3 – 2268	27
	Travel cost	1992 – 2003	1 – 233	22
	Contingent behavior	1986 – 2003	20 – 233	12
Coral reef[c]	Stated preference	1996 – 2007	1 – 694	33
	Travel cost	1996 – 2005	15 – 5618	18
	Contingent behavior	2004 – 2008	678 – 5618	2
Marsh/lagoon[d]	Stated preference	1983 – 2002	2 – 53	7
	Travel cost	1992 – 2002	2 – 53	8
	Contingent behavior	1992	53	1
Mangrove[e]	Stated preference	1997	16	8
	Travel cost	1974	21	3
Other[f]	Stated preference	1994 – 2007	6 – 1171	32
	Travel cost	1981 – 2007	5 – 8322	58
	Contingent behavior	1995 – 2007	5 – 1064	9

Study references:

[a] Johnston et al. 2002; Lipton 2004; Marangon et al. 2002; Scherrer 2003; Whitehead et al. 2000

[b] Ballance et al. 2000; Bateman et al. 2001; Blackwell 2007; Chen et al. 2004; Choe et al. 1996; Dharmaratne et al. 2000; Hanley et al. 2003; Judge et al. 1995; King 1995; Kosenius 2004; Landry et al. 2003; Lee & Han 2002; Machado & Mourato 1999; McConnell 1986; Mourato et al. 2003; Nunes & van den Bergh 2004; Oh et al. 2008; Parsons et al. 2009; Pitt 1997; Saengsupavanich et al. 2008; Whitehead et al. 2008a

[c] Ahmed et al. 2007; Arin & Kramer 2002; Asafu-Adjaye & Tapsuwan 2008; Bhat 2003; Carr & Mendelsohn 2003; Casey et al. 2010; Cesar 2003; Cesar & van Beukering 2004; Dharmaratne et al. 2000; Edwards 2009; Kragt et al. 2006; Leeworthy & Bowker 1997; Nam & Son 2004; Ngazy et al. 2005; Park et al. 2002; Parsons & Thur 2008; Ransom & Mangi 2010; Reid-Grant & Bhat 2009; Seenprachawong 2003; van Beukering 2006; Wielgus et al. 2003; Yacob et al. 2009

[d] Anderson & Edwards 1986; Espinoza 2001; Klein & Bateman 1998; Marangon et al. 2002; Rudloff et al. 1997; Seguì-Amórtegui 2004; de Groot & Velthuijsen 1998

[e] Adamson-Badilla & Castillo 1998; Ramdial 1980

[f] Araña et al. 2001; Bergstrom et al. 2004; Cantrell et al. 2004; Costanza & Maxwell 1989; Curtis 2003; Eggert & Olsson 2003; Flachaire & Hollard 2006; Fleming & Cook 2007; Hausman et al. 1995; Kawabe & Oka 1996; Marikan & Radam 2006; Martínez Paz et al. 2009; Péronnet et al. 2003; Prayaga et al. 2009; Rosato & Defrancesco 2002; Rowe et al. 1985; Sandström 1998; Signorello 1998; Söderqvist & Scharin 2000; Thomas & Stratis 2002; Walpole et al. 2001; Whitehead et al. 2008b; Zeybrandt & Barnes 2001

Valued ecosystems in the data set are located in 34 countries, most observations being concentrated in North America, Europe, South-East Asia, and Australia. The USA contribute 82 observations to the data set (32% of the total). The majority of values are from sites located in the North Temperate Zone, i.e., at a latitude comprised between 23.5 and 66.5 degrees North (151 observations). A relatively large number of observations are located in the Tropical Zone, between 23.5 degrees South and 23.5 degrees North (88 observations), while only 14 observations are from the South Temperate Zone. Overall, the Southern hemisphere accounts for 14% of the observations. Besides the USA, the largest number of observations are from Australia

(22 observations), France (18 observations), and Sweden (13 observations). In the World Bank classification of economies (http://data.worldbank.org/country), eighteen countries in the dataset are high-income economies, eight upper-middle-income, five lower-middle-income, and three low-income economies (Kenya, Tanzania and Vietnam). Fourteen observations are from Small Island Developing States.

All the studies in the data set use non-market valuation techniques. Contingent valuation accounts for the largest number of observations among stated preference techniques (93 observations), but choice experiment is also represented (18 observations). Among revealed preference techniques, the travel cost method accounts for slightly less than half of the observations (117 observations). Finally, 25 values were estimated with the contingent behavior method, which combines both revealed and stated preference techniques.

Most studies examine the recreational values of a sample of the whole population of recreationists at the investigated site, irrespective of where the recreation trips have originated (e.g., whether the recreationists are local excursionists or international travelers). The sub-sample of observations exclusively pertaining to local residents counts 24 valuations, while 35 estimates were specifically derived for international tourists. Regarding the evaluated scenarios, several studies aim at determining the total annual consumer surplus (CS) from recreational activities at specific sites but most focus on the welfare impact of a change in the current level of provision of ecosystem services. This may be determined by improvement or deterioration in water quality – such as due to oil spills or algal blooms – or beach erosion.

Among ecosystem types, sandy beaches (61 observations) and coral reefs (53 observations) are valued with a higher frequency than other ecosystem types such as lagoons, coastal marshes, estuaries, mangroves, and rocky shores. A substantial number of value estimates (99 observations) refer to ecosystems that are a mosaic of different coastal biomes. These are classified as “other” in Table 1 and in the meta-regression. A considerable fraction of the observations focuses on sites that either have the status of protected area or include protected sections (114 observations). The valued sites show a large variability in size, ranging from the Prince William Sound and Kodiak Island in Alaska (Hausman et al. 1995) and the Great Barrier Reef in Australia (Carr & Mendelsohn 2003), to much smaller sites, 33 observations referring to sites with 10 km or less of coastline.

The economic values reported in the primary studies were calculated in different years and are expressed in different currencies and metrics (e.g., WTP per person per year, WTP per household per year, CS per trip, etc.). In order to compare them, the value estimates were standardized to a common metric and currency: 2003 I$ per hectare per year. The total value of the investigated ecosystems was first calculated multiplying the per-person or per-household estimates by the aggregation population reported in the primary studies (e.g., number of recreationists per year). Subsequently, a per-hectare value was calculated based on the extension of the valued ecosystems. The areal extent of the ecosystems is derived from the GIS analysis considering a swath of 2 km landwards from the shapefile. Such extent was selected compatibly with the limitations in the resolution of the GIS layers that underlie the analysis and considering that most coastal recreational activities either take place directly at the coastline or very close to it[1]. Finally, following (Ghermandi et al. 2010), values referring to years other than 2003 were deflated using the appropriate factors from the Millennium Development Indicators (World Bank 2006) and differences in purchasing power among the countries were accounted for by the Purchasing Power Parity indexes provided by the Penn World Table (Heston et al. 2006). Figure 2 presents the distribution of the standardized per-hectare values of coastal recreation.

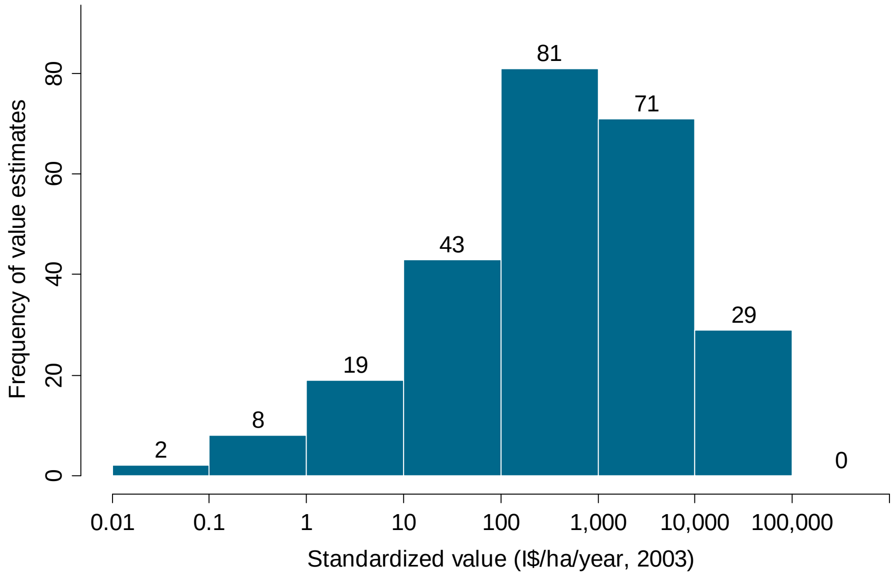

Figure 2. Frequency of standardized per-hectare value estimates

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[1] The sensitivity of the results to the choice of a different swath extension of 5 km or 10 km landwards was evaluated. Per-hectare values would decrease in proportion to the larger swath area, but the significance, sign and size of the meta-regression coefficients would scarcely be affected when compared to the 2 km swath.

The estimated values are distributed over a wide span around an average of 4,698 I$/ha/year (±11,283 I$/ha/year) and a median value of 453 I$/ha/year. The majority (60%) of the value estimates are comprised between 100 and 10,000 I$/ha/year. For the sake of comparison, in a meta-analysis of the recreational value of coral reefs, (Brander et al. 2007) found an average value of 3,726 IS$/ha/year (2000 prices), with values ranging between $0.25 and $57,470 per hectare per year.

2.2 Moderator variables selection and *a priori* expectations

To select the moderator variables to be included in the meta-regression model we were directed by the theoretical and empirical guidelines provided by the valuation literature and previous meta-analyses of ecosystem services values. We expect study-, site-, and context-specific characteristics to affect the value estimates in the primary valuation studies. The selected moderator variables are summarized in Table 2. Regarding study-specific characteristics, Bateman & Jones (2003) provide a detailed discussion of how recreational value estimates may vary according to the valuation methods and analytical techniques implemented both in stated and revealed preference methods. Among contingent valuations, open-ended elicitation formats are more liable to free-riding behavior, which may lead to understatement of the true WTP. Such value estimates are thus likely to lie below those obtained with other elicitation formats such as payment card, single- and double-bounded dichotomous choice. Unlike stated preference methods, which produce Hicksian welfare measures, travel cost method generates Marshallian CS estimates. Several studies have argued on empirical grounds that contingent valuation estimates are lower than travel cost values (see references in Bateman & Jones (2003). Moreover, among travel cost estimates we expect that zonal travel cost values will be higher than individual travel cost and random utility model estimates since zonal travel cost relies on an upward bias of travel time and distance (Bateman et al. 1999)[2].

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[2] Bateman & Jones (2003) also discuss the theoretical expectations from contingent valuation studies using iterative bidding as elicitation format and travel cost studies relying on OLS estimation techniques. Both cases are not included in the present study: the first because no estimate with iterative bidding is present in the dataset, the second because several travel cost studies in the dataset fail to satisfactorily report on the type of estimation technique used.

Table 2. Explanatory variables of the meta-regression model

Group	Variable	Units and measurement	Mean (SD)	*N*
Study (X_V)	Choice experiment	Binary	0.07 (0.26)	18
	CVM – open ended	Binary	0.12 (0.32)	30
	CVM – other elicitation format	Binary (omitted)	0.25 (0.43)	63
	TCM – individual and RUM	Binary	0.35 (0.48)	89
	TCM – zonal	Binary	0.11 (0.31)	28
	Contingent behavior	Binary	0.10 (0.30)	25
	WTP to avoid degradation	Binary	0.15 (0.36)	38
	WTP for improvement	Binary	0.32 (0.47)	82
	CS at current status	Binary (omitted)	0.53 (0.50)	133
	Unpublished	Binary	0.63 (0.48)	159
	Year of primary data	Years after first valuation (1974)	23.9 (6.52)	253
Site (X_S)	(Partially) protected area [a]	Binary	0.45 (0.50)	114
	Beach	Binary	0.24 (0.43)	61
	Reef	Binary	0.21 (0.41)	53
	Mangrove	Binary	0.04 (0.20)	11
	Lagoon or coastal marsh	Binary	0.06 (0.24)	16
	Estuary	Binary	0.05 (0.22)	13
	Other coastal ecosystem	Binary (omitted)	0.39 (0.49)	99
	Recreational fishing	Binary	0.40 (0.49)	101
	Non-extractive recreation	Binary	0.78 (0.42)	197
Context (X_C)	GDP per capita [b]	2003 US$/year (PPP, ln)	10.0 (0.81)	253
	Population density [c,d]	Inhabitants per km^2 (ln)	4.77 (1.75)	253
	Anthropogenic pressure [c,e]	Nutrients concentration (ton/km^2/year, ln)	0.41 (2.85)	253
	Marine biodiversity [c,f]	Shannon index of biodiversity	3.84 (1.64)	253
	Accessibility [g]	Travel time to nearest large city (hours, ln)	4.53 (1.04)	253
	Low human development [c,h]	Binary	0.57 (0.50)	143
	Medium human development [c,h]	Binary	0.09 (0.29)	23
	High human development [c,h]	Binary (omitted)	0.34 (0.48)	87
	Political stability [i]	Political stability index	2.92 (0.63)	253
	Degree heating months [j]	Degrees Celsius	49.4 (40.3)	253
	Max monthly precipitation [k]	mm of precipitation	1270 (634)	253

Notes: [a] Based on World Database on Protected Areas, 2009 edition (www.wdpa.org); [b] Evaluated at country level, state level for the US; [c] Within 20 km distance from the valued site; [d] CIESIN, Gridded Population of the World, v.2 (sedac.ciesin.columbia.edu/plue/gpw); [e] Source: Halpern et al. (2008); [f] Source: Ocean Biogeographic Information System, OBIS (www.iobis.org); [g] Source: European Commission, Global Accessibility Maps (bioval.jrc.ec.europa.eu/products/gam/); [h] Source: GLOBIO project (www.globio.info); [i] Source: Kaufmann et al. (2009); [j] Calculated by the authors based on data from Community Climate System Model (http://www.ccsm.ucar.edu); [k] Maximum monthly precipitation in the years 1979-1999 (http://archive.wri.org/pubs/pubs_dataset.cfm?PubID=3874).

Two dummy variables identifying choice experiment and contingent behavior estimates are included in the meta-regression model as well, although there is no clear *a priori* expectation on how such estimates will compare with other methods. In addition to method-specific variables, we included a set of binary variables to characterize the direction of the valued environmental change (i.e., either degradation or improvement) or whether the estimate refers to the total CS experienced at the current status or a WTP to maintain the current status. The extent of environmental change could not be included in quantitative terms since it is often only qualitatively described in the original studies.

A variable identifying whether the value estimates stems from a peer-reviewed publication – i.e., a scientific journal or edited book – or an unpublished report or thesis was included as well. The rationale here is to test whether the effect size measure is correlated with the publication status, thus providing empirical support for the existence of a publication bias in the valuation literature (Hoehn 2006; Woodward & Wui 2001). Finally, the number of years elapsed since the first survey in the dataset was performed in 1974 was included in order to test whether values change over time, possibly due to shifts in consumers' preferences.

Site-specific characteristics are expected to affect value estimates in a variety of ways. A binary variable is included to distinguish sites that are identified as coastal or marine protected areas in the World Database on Protected Areas (www.wdpa.org) or that include one such area. There is no clear expectation on the sign of the coefficient of such variable since while on one hand protected areas are presumably of high ecological or cultural value, the protection status of such sites may, on the other hand, limit the type and extent of permitted recreational activities. Since different ecosystem types are likely to have different attractiveness for recreational purposes, we distinguish seven ecosystem type categories: sandy beaches, coral reefs, mangroves, lagoons, coastal marshes[3], estuaries, and other coastal ecosystems. The latter mainly includes mixed coastal areas where no prevailing ecosystem type can be identified. Finally, two main types of recreational activities are considered: recreational fishing and non-extractive recreation. Since the two services are not mutually exclusive, i.e., one value observation may pertain to both service types, no reference category is defined for ecosystem services in the analysis. For this reason, the observations reported in Table 2 for the ecosystem service variables do not add up to 253.

The context characteristics accounted for in the meta-regression model reflect the level of anthropogenic pressure which they are exposed to, level of human development in the surrounding areas, their richness in marine biological diversity, climatic characteristics, and the socio-economic and demographic context in which the valued sites are located. Various studies show that high water quality is correlated to the value of the recreational experience for activities such as recreational fishing and bathing (Anderson & Edwards 1986; Choe et al. 1996; Eggert & Olsson 2003; Kawabe & Oka 1996; Whitehead et al. 2000; Huang et al. 1997; Hanley et al. 2003;

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[3] Due to the small number of value estimates available for lagoons and coastal marshes, the two ecosystem types were grouped in a single category in the meta-regression.

King 1995). The anthropogenic pressure on water quality is captured in the model by the concentration of nutrients in the surrounding of the valued site. The presence of healthy coastal habitats (Hausman et al. 1995; Sandström 1998; Söderqvist & Scharin 2000; Nunes & van den Bergh 2004; Pitt 1997; Rudloff et al. 1997; Kragt et al. 2006) and the richness and variety of living organisms (Bhat 2003; Carr & Mendelsohn 2003; Park et al. 2002) is also expected to be positively correlated with values. To capture these effects, measures of the level of human development and of marine biodiversity in and around the valued sites are included in the model. The socio-economic and demographic context is likely to play a crucial role in determining how easily accessible the recreational site is and the size of the potential market of recreationists. Greater leisure time among wealthy populations may affect values through income effects. Such potential influences of the socio-economic context are captured in the model by the population density in the surrounding of the valued sites, the travel time from the nearest city with more than 50,000 inhabitants, and the GDP per capita of the local population adjusted for differences in purchasing power across countries. A measure of political stability and absence of violence and terrorism is included as well as it may influence the attractiveness of a country's coastal area. The climatic context at the recreation sites may affect the value estimates in conflicting ways. While, on one hand, moderately warm weather conditions are generally understood to be attractive, very hot temperatures may damage the recreational experience and result in lower values. Here, we use degree heating months to characterize the climate, following (Maddison 2001) in assuming that an average temperature of 18.3 °C represents the optimum at which the amenity value of the climate is fully expressed. Since very wet climates may similarly discourage recreationists, precipitation levels are included in the model as the average rain or snowfall during the wettest month of the year calculated over the period 1979-1999[4].

2.3 A spatial explicit meta-analytical valuation method

An important trait of this study is its contribution to the field of spatial economic valuation through the explicit inclusion of spatial heterogeneity both in a meta-regression function and value transfer. Although ecosystem service flows are

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[4] Average and minimum monthly precipitation were evaluated as well but finally rejected on the ground of lower statistical significance of the respective coefficients in the regression and high correlation with the value of maximum monthly precipitation.

inherently of a spatial nature, value transfer generally fails to satisfactorily capture how differences in the socio-economic and geographic spatial context may result in different value flows in the study and policy sites (Bateman et al. 2002). Non-spatial per-hectare or per-household point estimates are assumed appropriate to characterize the entire ecosystem under consideration but fail to assess the distribution of values over the investigated natural asset (Eade & Moran 1996). Most previous attempts to incorporate GIS analysis in value transfer consist in mean or site-to-site unit value transfer methodologies which are applied to land use/land cover classes maps to spatially differentiate the provision of services and values (Troy & Wilson 2006; Bagstad et al. 2009; Liu et al. 2010; Wilson et al. 2004; Brenner et al. 2010). Lovett et al. (1997) used a more sophisticated approach for the transfer of travel cost estimates of woodland recreation involving the derivation of travel time surfaces around the valued sites, distance and travel time to substitute sites and other socio-economic variables.

This study relies on a spatial explicit characterization of the valued recreation sites for the evaluation of the explanatory variables of the meta-model. With exception of GDP per capita and political stability, all context variables are evaluated using GIS techniques within a distance of 20 km from the valued site. Buffer zones were created, which identify all the points on the map located within a distance of 20 km or less from the shapefile of the valued sites (see Figure 3). The value of the context variables is estimated as the average value within the buffer zone, with the exception of the human development variable which was calculated based on whether the majority of the cells in the buffer would pertain to low, medium or highly human developed areas. Such spatially explicit analysis constitutes a substantial improvement to the techniques that were previously used in similar studies. Only few previous meta-analyses of ecosystem service values looked at context characteristics in a spatially explicit way and those who did used much more simplified approaches. Two wetland meta-analyses by Brander et al. (2006) and Ghermandi et al. (2010) used a fixed distance from the geographic center point of the valued ecosystem – independently from its size – to determine the population density and wetlands abundance in the surrounding of the site. If applied to sites with very different areal extension as in the present study, such simplification of the geographic setting might provide a reasonable approximation of the geographical context in small sites such as Canal Novo and Isonzo estuary in Figure 3, but would largely fail to capture the spatial reality of larger sites such as, for instance, the coast of Ireland. Conversely, the characterization of context variables based on administrative divisions, such as country-wide averages, might be meaningful for extensive ecosystems but would not capture the site-specific features of small areas.

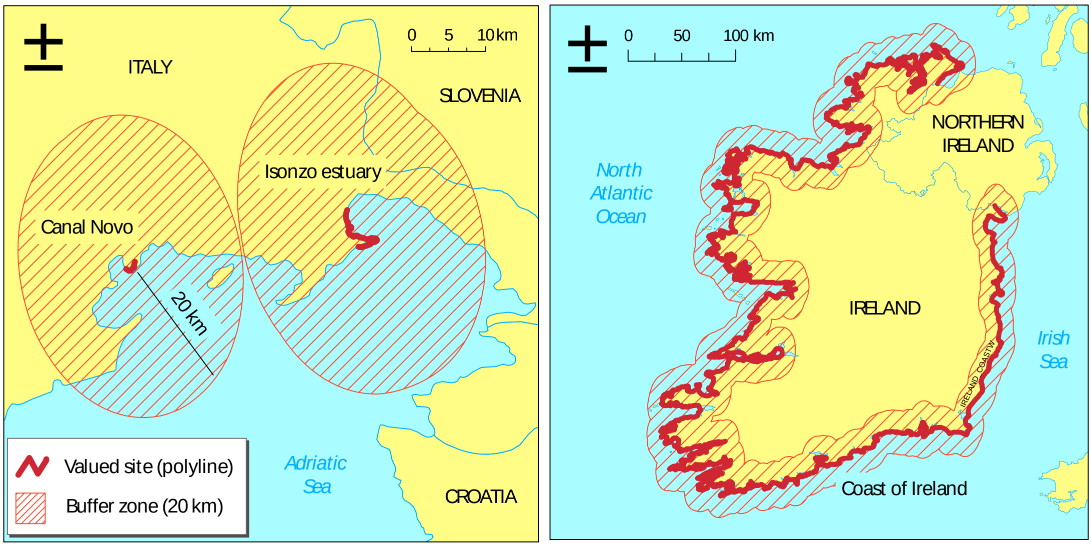

Figure 3. Shapefile and buffer zones for the characterization of the context moderator variables in two different European sites

3 Econometric specifications and regression results

3.1 The meta-regression model

The meta-analytical model for the regression of values is specified as follows:

$$\ln(y_i) = a + b_V X_{Vi} + b_S X_{Si} + b_C X_{Ci} + u_i \qquad (1)$$

where $\ln(y_i)$ is the natural logarithm of the endogenous variable measured in 2003 I$/ha/year; the subscript i is an index for the value observations; a is a constant term; b_V, b_S and b_C are vectors containing the coefficients of the explanatory variables X_V (valuation study characteristics), X_S (site characteristics), and X_C (context characteristics); u is an error term that is assumed to be well-behaved. The model is semi-logarithmic with exception of several context variables which are included as in logarithmic form (see Table 2).

To ensure that the econometric results are robust to changes in the model assumptions, four alternative specifications are considered. *Model A* includes all moderator variables and observations. The standard error is calculated with Huber-White/sandwich estimators, which are robust to modest departures from normality and homoskedasticity of residuals. All observations are assumed to be mutually independent. *Model B* relaxes the assumption on independent observations by addressing the potential correlation between multiple estimates from one study. Observations are weighted in such a way that each primary valuation study receives equal weight in the meta-regression. This allows to control that the studies producing many observations will not overly influence the results.[5] This approach was chosen over alternative techniques because it has the advantage of not discarding any observation from the complete set (Matt & Cook 1994)..*Model C* is designed to address issues with heteroskedasticity of effect-size variances, a frequent concern in the use of meta-analysis in environmental economics (Nelson & Kennedy 2009). Non-homogenous variances of value estimates may stem from the variable size of primary samples or different estimation procedures. Since variance estimates are not directly available from the primary studies in the data set, the size of the primary sample is used in *Model C* as a proxy for the variances, as suggested by various authors (see references in Nelson & Kennedy, 2009). Since not all studies in the dataset provide information on sample size, the regression was limited to 235 observations out of the original 253. Finally, *Model D* explores whether the provenience of the recreationists, mainly the distinction between local and international recreationists, affects the desirability of specific characteristics of the valued site. Despite its potential high relevance, most studies fail to appropriately report about such variable. Among the 253 observations, we find 24 that solely look at local recreationists and 35 that exclusively consider international travelers. The remaining studies either fail to report about the provenience of the interviewed sample or provide estimates for the pooled sample only. The joint effect of provenience with several moderator variables was computed by including cross-effect terms in the meta-regression.

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[5] The largest number of observations from one study in the data set is 15 (Whitehead et al. 2008a).

3.2 Estimation results

The results obtained with the different specifications of the meta-regression model are presented in Table 3. In the semi-logarithmic model, the coefficients measure the constant proportional or relative change in the dependent variable for a given absolute change in the value of the explanatory variable. For the variables expressed as logarithms, the coefficients represent elasticities, that is, the percentage change in the dependent variable given a one-percentage change in the explanatory variable. The econometric results of the four models are quite consistent in terms of sign, significance and size of the coefficients. Among study characteristics, all valuation method coefficients are significant in at least three models, with exception of “choice experiment”, which is insignificant in all models. Regarding ecosystem types, the models predict high values for coral reefs, sandy beaches and estuaries. Mangroves are highly valued in *Model D*. Context variables are found to be important determinants of value. With the exception of political stability and maximum monthly precipitation, all context variable coefficients are significant in *Models A*, *C* and *D*, with the exception of degree heating months, which is insignificant in *Model D*. Several context variables are not statistically significant in *Model B*. Although one should bear in mind that the cross-effect variables in *Model D* pertain to a small sub-sample of the whole data set, the meta-regression results suggest that resident recreationists and international travelers follow substantially different preferences in their recreational choices. While international tourists prefer recreational sites with high temperatures – possibly suggesting a “sea, sun and sand” recreational experience – the residents of coastal areas attribute a higher importance to the presence of cultural landmarks such as protected areas. Contrary to expectation, political stability plays a positive role in the value of recreation for residents but not for tourists, where the coefficient is negative. One possible explanation for this effect is that several of the observations of tourist values in low-stability countries contained in the data set refer to resorts of international importance (e.g., Riviera Maya in Mexico, Montego Bay in Jamaica, Zanzibar in Tanzania), which do not necessarily reflect the attractiveness to international tourists of other, less renowned coastal sections. We suggest that the study of differences in the preferences of local and foreign tourists is a key area for future investigation.

Table 3. Econometric results of the meta-regression of recreational values

	Model A		Model B		Model C		Model D	
Variable	Coeff.	SE	Coeff.	SE	Coeff.	SE	Coeff.	SE
Constant	-8.767 **	3.674	-3.051	6.137	-10.569 ***	3.902	-12.432 ***	3.381
Choice experiment	-0.141	0.519	-0.660	1.021	-0.575	0.504	-0.504	0.516
CV – open ended	-0.869 **	0.412	-0.876	0.842	-0.779 *	0.422	-1.089 **	0.433
TCM – zonal	2.041 ***	0.465	1.944 **	0.894	1.247 **	0.492	1.294 ***	0.435
TCM – individual & RUM	1.313 ***	0.389	1.430 *	0.752	1.113 ***	0.404	1.197 ***	0.396
Contingent behavior	-1.484 ***	0.470	-1.662	1.005	-1.723 ***	0.483	-1.558 ***	0.504
WTP to avoid degradation	0.511	0.348	0.511	0.803	0.495	0.367	0.364	0.379
WTP for improvement	1.010 ***	0.374	1.386 *	0.704	0.768 **	0.364	0.709 *	0.377
Unpublished	-1.376 ***	0.347	-1.113 **	0.510	-1.035 **	0.435	-1.518 ***	0.329
Year of primary data	0.146 ***	0.024	0.113 **	0.049	0.080 **	0.036	0.131 ***	0.024
(Partially) protected area	-0.040	0.384	0.229	0.588	-0.169	0.384	0.211	0.400
Estuary	1.560 **	0.708	0.451	1.216	1.449 **	0.709	2.115 ***	0.755
Lagoon or coastal marsh	0.243	0.428	0.086	0.968	-0.674	0.424	0.296	0.420
Mangrove	0.881	0.834	0.395	1.891	-0.193	0.977	1.494 *	0.848
Beach	2.301 ***	0.479	1.981 **	0.806	2.557 ***	0.519	2.876 ***	0.523
Reef	2.305 ***	0.492	2.781 ***	0.947	2.829 ***	0.596	2.390 ***	0.559
Recreational fishing	1.819 ***	0.443	1.482 **	0.697	1.453 ***	0.401	2.244 ***	0.425
Non-extractive recreation	3.268 ***	0.446	2.581 ***	0.885	2.319 ***	0.436	3.236 ***	0.422
GDP per capita (ln)	0.444 *	0.241	0.328	0.434	0.798 ***	0.267	0.763 ***	0.243
Political stability	0.269	0.273	0.211	0.538	0.112	0.287	0.171	0.296
Population density (ln)	0.497 ***	0.160	0.223	0.250	0.554 ***	0.176	0.521 ***	0.135
Low human development	2.305 ***	0.411	1.124	0.701	2.245 ***	0.517	2.292 ***	0.415
Medium human development	0.715	0.582	0.515	1.142	-0.239	0.674	0.600	0.590
Anthropogenic pressure (ln)	-0.268 ***	0.057	-0.265 **	0.111	-0.230 ***	0.065	-0.275 ***	0.053
Accessibility (ln)	-0.525 **	0.238	-0.777 *	0.436	-0.344	0.251	-0.441 **	0.219
Marine biodiversity	0.238 ***	0.077	0.155	0.166	0.153 *	0.088	0.186 ***	0.072
Degree heating months	-0.011 **	0.005	-0.010	0.011	-0.010 *	0.006	-0.005	0.005
Max monthly precipitation	0.000	0.000	0.000	0.001	0.001 *	0.000	0.000	0.000
Residents * deg heat months							-0.020 **	0.008
Tourists * deg heat months							0.015 **	0.007
Residents * protected area							3.456 ***	0.939
Tourists * protected area							-0.249	0.651
Residents * stability							2.122 ***	0.639
Tourists * stability							-1.595 **	0.729
Number of observations		253		79 [a]		235		253
R-square		0.728		0.597		0.658		0.767
Adjusted R-square		0.695		0.384		0.613		0.732
Root MSE		1.584		1.898		1.524		1.485
Shapiro-Wilk test, p-level		0.064		0.081		0.050		0.757
Breusch-Pagan test, prob>χ^2		0.134		0.332		0.575		0.192
Max VIF		5.47		4.50		5.95		7.34

Note: OLS estimates. Significance is indicated with ***, **, and * for 1%, 5% and 10% statistical significance levels respectively; [a] All 253 observations are retained in the regression, but weighted so that each of the 79 studies receives weight 1.

The robustness of the regression results presented in Table 3 was investigated by means of a series of diagnostic tests. The analysis of residuals by means of the Shapiro-Wilk test reveals a certain deviation from normality, which however visual inspection of the distribution of the residuals reveals not to be substantial. Diagnostic testing with the Breusch-Pagan test and variance inflation factor (VIF) does not provide any indication of either heterogeneous variance of the residuals or multicollinearity between predictor variables. The explanatory power of the models is high (adjusted R-square is equal to 0.767 and 0.728 in *Models D* and *A*, respectively), particularly for a meta-analysis with a broad scope such as the present one. Nelson & Kennedy (2009) found that the median adjusted R-square of the 140 meta-analyses they surveyed was equal to 0.44.

The estimated coefficients of the methodological variables are all significant, with exception of choice experiment, and reflect *a priori* expectations (see section 2.2), i.e., open-ended contingent valuation questionnaires produces the lowest values, followed by contingent valuation questionnaires with other elicitation formats, individual TCM and RUM, and zonal TCM. Among the considered studies, the lowest estimates are given by the contingent behavior method. The model also reveals that WTP of the respondent is higher for an environmental improvement rather than for avoiding degradation and is increasing over the years, which is consistent with the large increase in the number of visitors to coastal recreation resorts experienced in many coastal locations in recent decades. Unpublished studies and reports provide lower estimates, suggesting a publication bias and supporting the inclusion of grey literature in meta-analysis. Regarding site-specific variables, high values are found for sandy beaches, coral reefs and estuarine ecosystems. Non-extractive recreational activities (e.g., beach leisure, diving, and swimming) are more highly valued than recreational fishing. The estimated coefficient estimate for ‘marine biodiversity’ is positive and statistical significant, indicating that the recreational value of the coastal zone under consideration increases with marine biodiversity. Among context-specific variables, the coefficient of population density and travel time from the nearest large city are, as expected, respectively positive and negative, indicating that proximity to the market of potential visitors and site accessibility result in higher recreational values. The estimated coefficient for the ‘anthropogenic pressure’ variable is negative and statistically significant, indicating that an increase of one percent in this indicator is associated in *Model A* to a decrease of 26.8% in the reported recreational value. The coefficient of GDP per capita is positive and smaller than 1, indicating that income plays a role in explaining the reported values and confirming that recreational services are not to be classified as a luxury good. The model confirms the importance of the climatic conditions as drivers of the coastal recreation experience showing that lower average values are found at high temperatures.

4 Scaling up coastal recreation values

4.1 Value transfer approach

The first step in the procedure for meta-analytical value transfer and scaling up proposed in this study consists in selecting the meta-analytical transfer function among the four different specifications described in Section 3. The most promising model – i.e., the model with the best overall explanatory power and the highest consistence with the theoretical and empirical expectations – is identified and the value of the regression coefficients in equation (1) is determined accordingly.

Second, one must define the appropriate geographic scale for transferring values. *A priori*, the sole technical limitation on the geographic resolution of the GIS-based value transfer exercise is the highest resolution among the GIS layers representing spatially explicit moderator variables (i.e., about 1 km grid cell size in this study). Before selecting an appropriate scale, however, one must first question the purpose of the transfer exercise and the degree of approximation that is considered acceptable. Recreational benefits in a specific coastal site are expected to be particularly sensitive to local conditions, such as the presence of infrastructure (e.g., access roads, hotels and other accommodation, diving facilities, etc.) and the proximity of sites with similar characteristics that may act us substitutes in the provision of recreational services. Capturing such level of details is beyond the scope of the present study since it requires much more detailed layers of spatial information for the moderator regression variables and conceivably the introduction of additional ones. Acknowledging the limitations in data availability, a more appropriate objective for the transfer exercise is to investigate the distribution of values along world coasts at a lower spatial resolution. For the present study we demonstrate the application of the value transfer function to produce a raster map of coastal values with a resolution of 0.5 degrees (corresponding to about 55 km at the Equator), an extension comparable with a regional scale assessment[6]. This approach retains the strength of the GIS-based transfer technique to provide a spatial differentiation of values which is not dependent on super-imposed levels of aggregation, such as aggregation at administrative level, and at the same time is more in accordance with the level of detail in the geographical information that is available for the proposed large scope application.

After assigning the geographic scale for value transfer, each of the coastal grid cells of the raster map is treated as a policy site, to which values are transferred by estimating the value of the transfer function by means of map algebra. To achieve this, the value of the moderator variables in all coastal locations and at the required scale must be accessed. A series of layers representing each representing one of the geo-referenced variables of the equation (i.e., GDP per capita, population density, human development, anthropogenic pressure, accessibility, marine biodiversity, and degree heating months), were prepared with consistent projection, spatial resolution and extension. The original layers were re-projected in the geographic coordinate system WGS1984 and converted to raster layers with a cell dimension of 0.5 degrees.

4.2 Global map of coastal recreation values

For the purpose of transferring and scaling up values, the regression coefficients of meta-regression *Model A* were recalculated, including only the statistically significant variables in the regression. The results are shown in Table 4. The explanatory power of the model, the sign and significance of the coefficients remain unchanged with respect to the full *Model A*. In applying the calibrated transfer equation to the new policy sites, the values of spatial variables was determined based on the procedure described in Section 4.1 non-spatial variables, conservative estimates were assumed. The valuation outcome of CV studies using elicitation formats other than open-ended and the results of unpublished studies were assumed as the benchmark. The reference year for the value transfer was chosen to be 2009. Since any grid cell in the map is likely to reflect a composite of ecosystem types at the chosen geographic resolution (0.5 degrees), a mix of different ecosystem types was assumed in the transfer function. For ecosystem service types, for which we have no information at the level

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[6] This holds true at most latitudes but not near the geographic North and South Poles, where the length of a degree of longitude gradually shrinks to zero. These regions, however, are the least relevant for coastal recreation.

of the policy sites, we assume that they have the average characteristics of the study sites underlying the meta-analysis.

Table 4. Restricted meta-regression model of per-hectare recreational values

Variable	Coefficient	95% confidence interval		p-value
Constant	-7.987	-14.510	-1.465	0.017
CV – open ended	-0.944	-1.713	-0.174	0.016
TCM – zonal	1.862	1.089	2.635	0.000
TCM – individual & RUM	0.937	0.377	1.497	0.001
Contingent behavior	-1.639	-2.432	-0.847	0.000
WTP for improvement	0.863	0.326	1.400	0.002
Unpublished	-1.312	-1.870	-0.754	0.000
Year of primary data	0.144	0.106	0.182	0.000
Estuary	1.050	-0.228	2.328	0.107
Beach	1.860	1.087	2.632	0.000
Reef	1.667	0.826	2.507	0.000
Recreational fishing	1.697	0.956	2.439	0.000
Non-extractive recreation	3.387	2.585	4.188	0.000
GDP per capita (ln)	0.470	0.051	0.889	0.028
Population density (ln)	0.454	0.156	0.751	0.003
Low human development	1.972	1.367	2.577	0.000
Anthropogenic pressure (ln)	-0.239	-0.327	-0.150	0.000
Accessibility (ln)	-0.534	-0.984	-0.085	0.020
Marine biodiversity	0.290	0.144	0.437	0.000
Degree heating months	-0.008	-0.016	0.001	0.092

Note: OLS estimates with robust estimators; N = 253; R-square = 0.719; adj. R-square = 0.696; Root MSE = 1.583; Shapiro-Wilk test, p-level = 0.193; Breusch-Pagan test, prob>χ^2 = 0.280.

Figure 4 presents the global map of recreational values obtained in the value transfer and scaling up exercise. The map is composed of 234,326 grid cells, for each of which a unique value estimate was calculated based on the local context factors. All continents with the exception of Antarctica are represented. The three boxes indicate three regional maps – Australia, Middle East and East Africa, and the South of Africa – and their objectives are (1) to display the valuation results at a higher resolution, now at the regional level; (2) to demonstrate how the differences in the values of some of the explanatory variables are reflected in different outcomes of the valuation model; and, finally, (3) to show how the proposed valuation mechanism is spatially explicit and the effect size changes according to the areas under consideration.

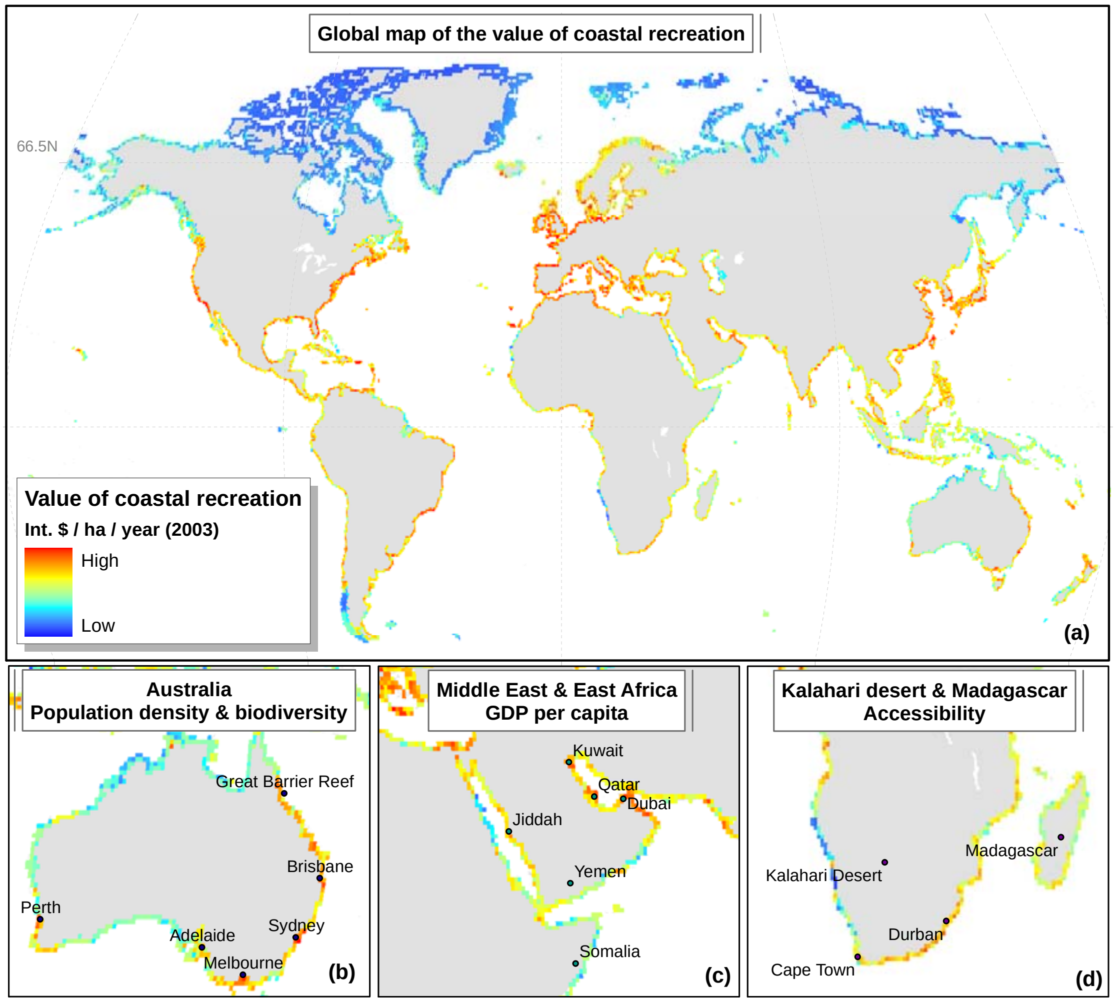

Figure 4. Global map of recreational values of coastal ecosystems

The estimated recreational values of coastal ecosystems range up to 71,112 I$/ha/year. The lowest values are found at high absolute latitudes (e.g., in the Arctic Circle, North of Canada, East Russia, South of Chile and Patagonia). The highest values are located in correspondence of large cities (e.g., Los Angeles, Caracas, Rio de Janeiro, Abidjan, Hong Kong, Taipei, Tokyo, and Sydney), particularly in European Mediterranean cities (e.g., Rome, Naples, Marseille, and Barcelona) and in Florida (e.g., Miami, Orlando, and Tampa), as well as in several tropical islands (e.g., Canary islands, Puerto Rico, and Andaman islands).

The marginal impacts of the local variations in the driving forces embedded in the valuation transfer mechanism are reflected in the value estimates of the model. This is illustrated for four different regression variables in Figure 4(b-d). Figure 4(b) highlights the differences in the predicted value along the coast of Australia. The highest values are concentrated in proximity of large cities, where population density drives the values upwards. High values are also found in the North-East coast of Australia in proximity of the Great Barrier Reef, where the value of the biodiversity index is highest. Figure 4(c) shows that substantial variation in the state and health of the economy across regions may also significantly affect recreational values. The coastal area in poor countries such as Yemen and Somalia generates substantially lower values than that of richer countries such as Kuwait and the United Arab Emirates. Again, recreational values are higher in proximity of large cities such as Jiddah in Saudi Arabia. Figure 4(d) shows the effect of different accessibility in different regions in the South of the African continent. Areas with a markedly lower accessibility, such as the coast facing the Kalahari Desert and, to a lesser extent, various parts of the island of Madagascar, have substantially lower values than other coastal areas in the region, particularly where large cities such as Cape Town and Durban are located.

4.3 Scaling up accuracy

The accuracy and reliability of value transfer depend upon how representative the dataset of study sites is of the characteristics of the set of policy sites: The greater the correspondence, or similarity, between study and policy sites, the smaller is the error in benefit transfer (Rosenberger & Stanley 2006). Although the dataset of coastal recreation provides a wide domain upon which to fit the transfer function, the variability in the explanatory variables is insufficient to cover the range of variability at the global level. This is illustrated in Figure 5, were the range in the spatial explanatory variables in the dataset is compared to the variation found in the grid cells of the world map. Values were standardized to range between 0 and 100. Coastal areas located in countries with very low GDP per capita, population density, and accessibility are not properly represented in the dataset. This implies that the map estimates should be applied with caution to remote areas such as those located at high latitudes or in the poorest countries. Similarly, sites with high accessibility and anthropogenic pressure are underrepresented, which suggests that the values of coastal recreation in areas of high urbanization and development may not be properly captured in the global map.[7]

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[7] Three different measures of model accuracy – Mean Absolute Percentage Error (MAPE), Geometric Mean Absolute Percentage Error (GMAPE), and Mean Absolute Scaled Error (MASE). The absolute

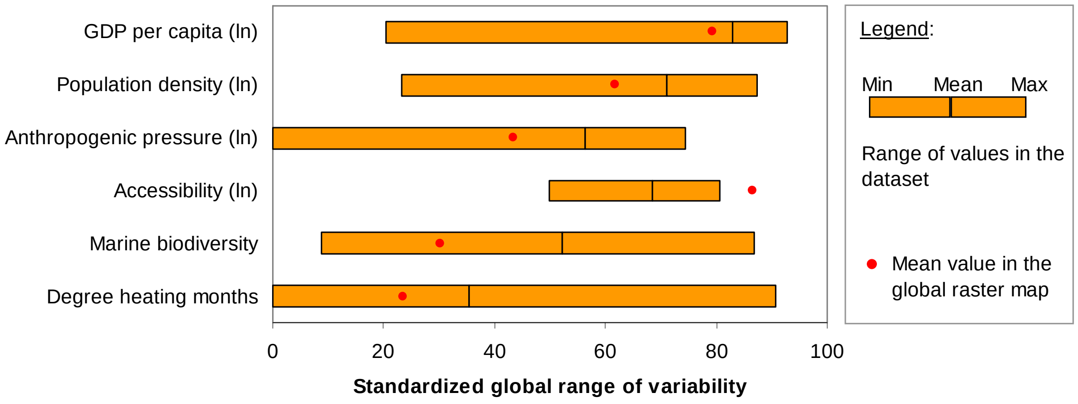

Figure 5. Standardized range of spatial variables in the dataset and world raster map

The limits of the scaling up exercise to produce the global map of coastal ecosystem service flow values should be taken into account when the mapped value estimates are used in a policy context. To highlight some of the sources of uncertainty in the mapped estimates, in Figure 6, the range in values from the primary studies for each of the study sites is compared to the corresponding values in the grid cells of the global map. On the horizontal axis, the range in the observed values captures the variation among the individual observations from the primary studies. On the vertical axis, the range in the mapped values shows the range in the values of the grid cells corresponding to each valued site.

Figure 6 does not reflect a transfer error analysis since there is no direct correspondence between study sites and grid cells due to the different geographic scale and assumptions made in the scaling up exercise (e.g., we assumed sample average values for ecosystem service types in the policy sites). The comparison helps, however, to understand which types of uncertainty affect both primary and mapped values and for which type of application the mapped values can be more useful. First, for a specific study site primary valuations may vary greatly in the primary studies. This is the case, for instance, of the Capricorn Coast in Australia, the coast of Namibia and Tokyo Bay in Japan, where values differ substantially according to

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error for out-of-sample forecast using the n-1 data splitting technique is 14% and 29% lower for the meta-analytical value transfer than for unadjusted transfer of respectively the mean value of domestic studies and the mean of all observations in the dataset. In other words, MAPE and GMAPE are substantially lower for meta-analytical value transfer than for mean value transfer. This confirms the overall good performance of the value transfer model. For more information see the Technical Annex.

different model assumptions, considered ecosystem service types or extent of change in the provision of the services.

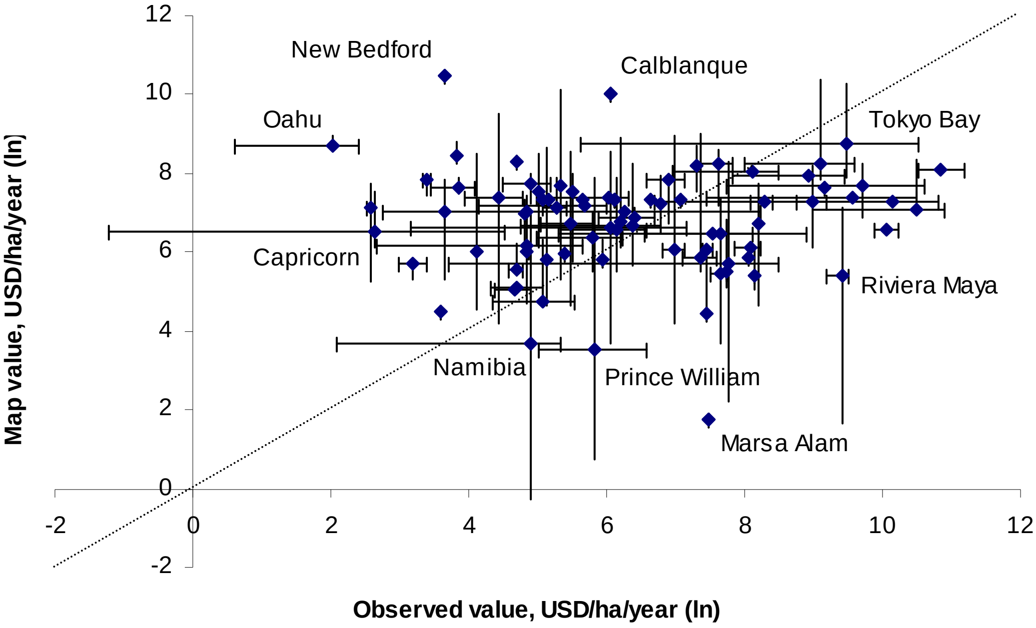

Figure 6. Comparison between primary valuations and corresponding grid cells in the global map with respective ranges of variability

Second, very site-specific values (such as those for sites with a small extension such as New Bedford, Calblanque and Marsa Alam) cannot be properly captured by the map, which rather reflects the values at a regional level. The value of small coastal areas can be substantially affected for instance by the availability of recreational infrastructure and other local variability which cannot be captured at the resolution of the global map. On the other hand, the mapped values can provide a useful breakdown of the values of larger sites, such as Prince William Sound and Riviera Maya, where the underlying geographic variability in the values is hidden by the non-spatial nature of the values reported in the primary studies.

5 Conclusions

In this study we present an integration of meta-analysis of ecosystem services valuations and GIS analysis applied to the assessment of the recreational values of coastal ecosystems. The meta-analysis relies on a dataset of 253 distinct value observations that is larger in scope and size than any that has been pulled together previously. From a methodological perspective, this study contributes to the emerging field of the spatial economic valuation of ecosystem services by fully integrating GIS tools and geo-referenced information in the meta-analytical model. GIS analysis was used at three distinct levels: (1) for the characterization of the study sites by creating shapefiles of the valued ecosystems; (2) for the determination of the value of the site- and context-specific spatial variables of the meta-regression in each of the study sites; and (3) for the prediction of recreation values at the policy site level, i.e. in each grid cell of the global recreation map. The principal objectives of the GIS analysis are twofold. First, the geographic extent of the study sites is characterized consistently across all sites. Previous studies relied on the ecosystem sizes reported by the authors of the valuation studies or on external sources to fill missing data in the primary studies. Such estimates, however, are likely determined with different precisions as they rely on different assumptions about the extension of the ecosystem and rounding offs. Second, the use of GIS allows for a spatially meaningful evaluation of the effect of spatial variables such as population density, marine biodiversity richness, anthropogenic pressure, human development, and site accessibility. With the exception of population density, all such variables are used here for the first time in a meta-analysis of ecosystem service values and found highly statistically significant. The adjusted R-square of the restricted meta-regression model used for the transfer exercise is 0.696 and ranges between 0.597 and 0.767 for the other four evaluated models. Such values are substantially higher than what found by Nelson & Kennedy (2009) as the median adjusted R-square value of the 140 meta-analyses they surveyed which equaled 0.44. The estimated coefficients were used to scale up values and produce the first global map of the economic values of coastal recreation. Unlike Lindhjem & Navrud (2008) we found evidence in support of meta-analytical value transfer in higher transfer accuracy for the meta-regression models compared to simple unit transfer methodologies.

Despite the good performance of the model, the challenges of meta-analysis and value transfer with international primary data should not be understated. One important limitation of the analysis is that it relies on a global sample values estimated within a limited sample of primary valuation studies, which may be subject to a selection bias. A selection bias arises, for instance, when ecosystems that are politically perceived more significant *a priori* are more likely selected for economic valuation or simply because the study area is close to the research group conducting the valuation study measure (Hoehn 2006; Woodward & Wui 2001). In the case of coastal recreation values, this may occur when sites perceived with high recreational values are more easily subject to an economic investigation. Having recognized the potential for a self-selection bias, the econometric valuation results of this study represent the best estimate of the spatial variability of the values of coastal recreation worldwide. Second, we believe that the current application is useful to foster the methodological debate on the significance of the use of value transfer estimates and the development of more refined, more reliable, and spatially explicit transferred values. Third, the presented value estimates with the respective spatial distribution, constitute a visual synthesis of scientific knowledge and provide valuable indicators of the social dimension of coastal areas. Fourth, the underlying econometric estimates will help us to assist in the identification of weaker and stronger determinants of recreational value within each spatial dimension. Therefore, these results can play a practical tool that can buttress the policy process in setting its priorities for the conservation of coastal areas and therefore compliment other existing information such as the well known IUCN and/or the UN-WCMC criteria in classifying marine coastal areas, in which a social economic dimension is typically absent.

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Technical Annex

The accuracy of the meta-analytical model forecasts are evaluated based on three different measures. The Mean Absolute Percentage Error (MAPE) is a commonly used summary measure, which is defined as $\sum_{i=1}^{N} \left| (\hat{y}_i - y_i) / y_i \right| \Big/ N$, where $\hat{y}_i$ and y_i are, respectively, the predicted and the observed value, and N is the number of observations. MAPE is scale-independent and allows for comparison of forecast performance across different datasets but has a limit in its sensitivity to outliers (Coleman & Swanson 2007). The right-skewed asymmetry in the distribution of absolute (percentage) errors makes them prone to understating the forecast accuracy of the bulk of the observations and is often circumvented by reporting MAPE values after outliers are removed (see for instance Brander et al., 2006).

Two accuracy measures that are not subject to the shortcomings of MAPE are the Geometric Mean Absolute Percentage Error (GMAPE) and the Mean Absolute Scaled Error (MASE). GMAPE is defined as $\prod_{i=1}^{N} \left| (\hat{y}_i - y_i) / y_i \right|^{1/N}$. For log-normal distributions, it is an intuitively understandable accuracy measure which is not sensitive to the direction of error.

MASE is the mean absolute value of scaled errors. The scaled error is a relative measure that compares the model forecast error with the in-sample mean absolute error committed using a baseline forecast method (Hyndman & Koehler 2006). Here, we assume the transfer of the unadjusted average unit value of all domestic observations as the baseline method. This method was found by Lindhjem & Navrud (2008) to produce lower transfer errors than meta-analysis in an international value transfer exercise. The scaled error is thus defined as $\dfrac{\hat{y}_i - y_i}{\frac{1}{N}\sum_{i=1}^{N} \left| \bar{y}_i - y_i \right|}$, where $\bar{y}_i$ is the arithmetic mean of the value estimates from the country where observation i is located. A value of MASE lower (higher) than unity indicates that the meta-analytical model is more (less) accurate than the baseline method. To guarantee a certain degree of variation in the domestic estimates, for the calculation of the error we consider only the 23 countries in the dataset with three or more observations.

Table A1 shows the values of the selected summary measures of accuracy for the model specification in Table 4. Both within and out-of-sample error is presented. In-sample errors are calculated for each observation based on the residuals of the regression model on the parameters calibrated on the entire set of observations. Out-of-sample forecasts are produced relying on the *N*–1 data splitting technique, which consists in generating parameters estimates with *N*–1 observations and forecasting the omitted observation. Out-of-sample forecast error has been proposed as a test of the reliability of benefit transfer techniques (Brander et al. 2006; Lindhjem & Navrud 2008). Figure A1 shows the distribution of out-of-sample forecasts compared to the observed values and the relative values of absolute error in I$/ha/year for all observations.

Table A1: Measures of accuracy of the meta-analytical model for within and out-of-sample forecasts

Accuracy measure	Forecast error	
	In-sample	Out-of-sample
MAPE (log-model)	29.5[a]	32.1[a]
GMAPE (log-model)	16.8	18.2
MASE	0.77	0.74

Note: [a] The value is calculated for N = 252 observations after excluding one outlier with disproportionate influence.

The error analysis confirms the generally good forecast performance of the model. The value of MAPE for within sample forecasts is 29.5% when calculated eliminating one outlying observation from Prayaga et al. (2009) with value close to zero and large absolute percentage error. Including such observation in the calculation would increase the value of MAPE to 42.8%, confirming the sensitivity of this summary measure to extreme scores. The value of MAPE is lower than what found by Brander et al. (2006) in a meta-analysis of wetland studies (MAPE = 58% after removing one outlier). GMAPE produces a measure that is much less susceptible to the extreme value from the Prayaga et al. (2009) study, estimating the mean in-sample error for the entire dataset to 16.8%, a value that is very close to the median absolute percentage error (18.4%). As expected the forecast performance of the model decreases slightly for out-of-sample predictions, the value of MAPE and GMAPE increasing respectively to 32.1% and 18.2%. Both for within sample and out-of-sample predictions, the absolute percentage error is dependent from the size of the predicted value, higher errors occurring for values that are close to zero. For in-sample forecasts, the average percentage errors in the lowest and highest quartiles of the value series are respectively 64.1% and 15.7% and the correlation coefficient for value size and absolute percentage error is -0.60 (p-value < 0.001).

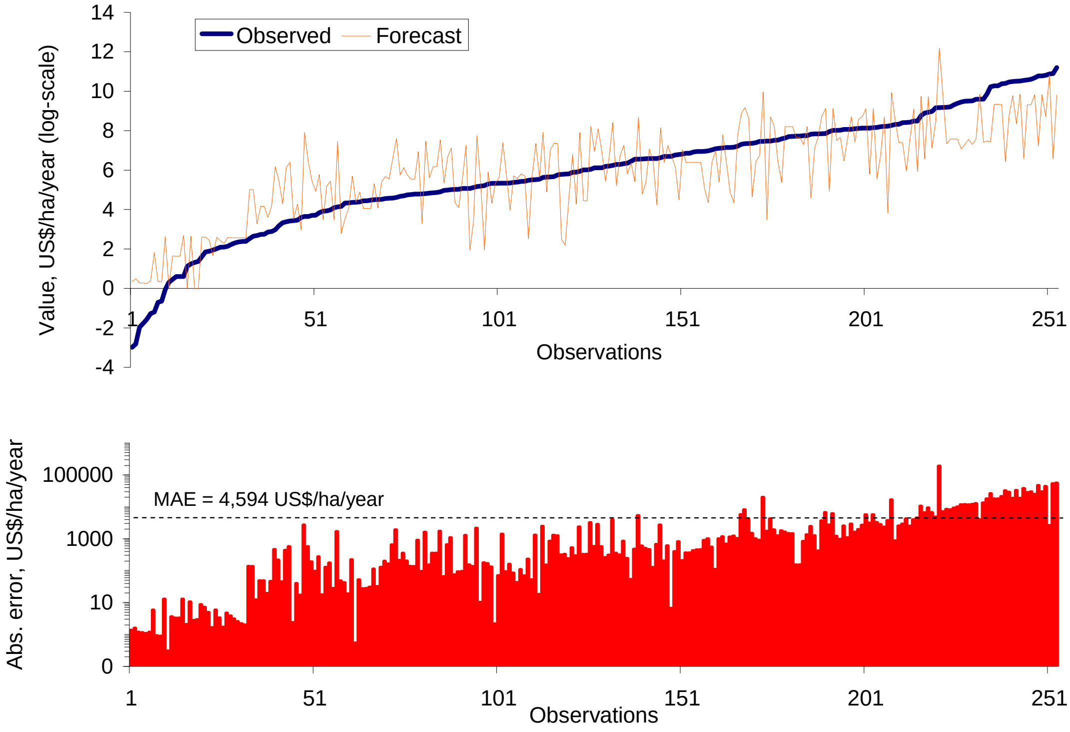

Figure A1: Model accuracy for out-of-sample forecasts

Regarding the sign of the forecast error, Figure A1 shows that the model tends to over-predict low values and under-predict high values, confirming what observed by Brander et al. (2006). In absolute terms, the average errors for within and out-of-sample sample forecasts are respectively 4,084 I$/ha/year and 4,594 I$/ha/year. The median errors are respectively 431 I$/ha/year and 497 I$/ha/year. Absolute errors are positively correlated with values (correlation coefficient = 0.50, p-level < 0.001).

The value of MASE is lower than unity indicating that the meta-analytical transfer performs on average better than the unadjusted transfer of the mean value of domestic estimates. Such result contradicts the finding of Lindhjem & Navrud (2008), who questioned that meta-analytical value transfer is more reliable in international value transfer exercises. Following Brouwer & Bateman (2005), we interpret this result as suggesting that meta-analytical value function transfer outperforms mean value transfer when transferring across dissimilar contexts since it is capable to partially adjust for the differences. MASE is lower for out-of-sample forecasts (MASE = 0.74) than for within sample predictions (MASE = 0.77) indicating that the better performance of meta-analytical value transfer is more marked in conditions that are more similar to real transfer exercises. The average absolute errors in the domestic mean value transfer are 4,887 I$/ha/year and 5,332 I$/ha/year respectively for within and out-of-sample forecasts. MAPE and GMAPE are very large for the domestic mean value transfer due to substantial percentage errors in low value forecasts. Both meta-analytical value transfer and domestic mean value transfer outperform the simple transfer of the mean value of the estimates in the dataset, which would lead to an absolute error of 6,527 I$/ha/year for out-of-sample forecasts.