Exploring diversity: a meta-analysis of wetland conservation and creation

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Abstract: The rationale for conservation and creation of wetlands is bounded by the recognition of both their ecological and economic values. This paper examines the welfare impacts of goods and services provided by wetlands. We collected 353 observations on the economic value of natural and man-made wetlands from 155 studies worldwide. The resulting database is less biased towards North America than previous reviews of the literature. The relative importance of characteristics of the valuation study, of the wetland site and of the socio-economic and geographical context is estimated by means of a meta-regression of wetland values. Water quality improvement, provision of amenity and biodiversity enhancement are the most highly valued wetland services. The relevance of the socio-economic and geographical context clearly emerges from the analysis and, in particular, the proximity to other wetland sites is negatively correlated with values. An analysis of the effect of environmental stress on wetland value shows that the latter increases with stress from human development activities and uses.

Keywords: economic valuation, constructed ecosystems, man-made wetlands, wetland values

1. Introduction

Wetlands are among world's most productive ecosystems and host a large amount of biological diversity. Countless species of birds, mammals, reptiles, amphibians, fish and invertebrate species depend on water and vegetation in the wetlands for survival. In recent years, the need for conservation of natural wetlands for their ecological value is increasingly coupled with the recognition that wetlands provide services and goods that are important welfare constituents. This has led in 1971 to the creation of the Convention on Wetlands of International Importance – the Ramsar Convention. More recently, the Millennium Ecosystem Assessment (2005) concluded that the ecosystem services provided by wetlands are extremely valuable to people worldwide.

In spite of the growing efforts in conservation, wetland ecosystems are under threat in many regions of the world. Policy and decision making often fail to fully account for the contribution of wetlands to environment sustainability and for human welfare. Many of the economic values are often overlooked due to their public good character or market failures resulting from undefined property rights in or near the wetland area.

Acknowledgement of the economic services provided by wetlands has also led to an increased effort in the creation of wetlands. Treatment wetlands are constructed with the primary goal of increasing the quality of the inflowing water, but this is often coupled to the provision of ancillary benefits, notably the creation of a natural environment and the provision of opportunities for wetland recreational activities (Knight et al., 2001).

The number of studies aimed at estimating the value of wetlands has constantly grown over the last decades since the first valuation study was performed by Hammack and Brown (1974). The most extensive review of wetland valuation studies so far was conducted by Brander et al. (2006), who performed one of the three existing meta-analyses of wetlands. The first of these is Brouwer et al. (1999), who analyzed the results of contingent valuation method (CVM) studies of temperate climate zone wetlands. The definition of wetlands used in this study is very broad and the meta-analysis includes a number of valuation estimates for open water (rivers and lakes). The focus of this meta-analysis on estimates from CVM studies in developed countries, mainly the United States, narrows the sample size to 92 value observations from 30 studies. Woodward and Wui (2001) similarly restricted their meta-analysis to include only valuation studies for North American and European wetlands. They used a narrower definition of wetland than Brouwer et al. (1999) and included wetland values obtained with valuation techniques other than CVM. The resulting data set contains 65 value observations taken from 39 studies. Brander et al. (2006) assembled a dataset of 215 value observations from 80 studies. This analysis includes studies from temperate and tropical regions, for all wetland types (including mangroves), and for a broader set of wetland functions and valuation methodologies. An important element of this meta-analysis is the inclusion of socio-economic variables in the form of GDP per capita and population density. In spite of the broad scope of the study, the authors observe that the geographical distribution of the available studies was significantly biased by the practice and availability of natural resource valuation studies rather than by the distribution of wetlands. Studies from North America accounted for half of the total number of observations.

Building on the lessons of the previous studies, the present article provides an original contribution to the assessment and explanation of wetland values using statistical meta-analysis. The database used for the analysis contains by far the largest number of wetland valuation studies used in a study of this kind: 353 independent observations derived from 155 studies. The average and maximum number of observations per study are 2.3 and 7 respectively. With respect to previous meta-analyses, there is an extension of the geographical coverage of the studies, which is less biased towards developed Western countries. In particular, the number of new studies from North America, where wetland valuation was first widely used, decreased in recent years, while there is a clear increase in the number of studies from Africa, Asia and Europe. One additional contribution of the present study is the inclusion of substitute wetland sites as an important explanatory variable of wetland values. Estimated wetland values are shown to significantly decrease when substitute sites are present in the vicinity of the valued wetland. Furthermore, the present study is the first to include man-made wetlands in the analysis. The presence of human pressures on the wetlands, which acts as a proxy for the ecological integrity of the wetlands, is taken into account in the meta-analysis by means of an index of environmental stress.

The organization of the remainder of this article is as follows. In Section 2 we briefly discuss the economic services and goods provided by wetlands, distinguishing between economic services and goods on one hand and ecological and physical functions on the other. The valuation methods that are most often used in the literature to estimate the economic value of such services and goods are introduced. The need for standardization of the findings of the empirical studies is underlined and the procedure followed in this study described. In Section 3, an overview is given of the data set and descriptive statistics are presented. Section 4 performs a meta-regression and interprets the results obtained. Section 5 concludes and summarizes the main findings of the study.

2. Wetland values and valuation methods

The first issue that every meta-analysis of wetland values must address is to provide its definition of wetland. There is in fact no definition that can be adopted straightforwardly and a different perspective on what should be considered a wetland can lead to very different choices of studies to include in the analysis. The most widely and internationally accepted definition is the one given by the Ramsar Convention, which defines wetlands as the "areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static of flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres". Depending on interpretation, this very inclusive definition encompasses a large number of ecosystem types and can potentially be assumed to comprise all areas of rice cultivation, coral reefs, sea-grass beds and most rivers and shallow lakes (Scott and Jones, 1995). In this study we adopt a somewhat strict interpretation of the Ramsar definition, in which we explicitly exclude from the analysis valuations of coral reefs, sea-grass beds, rivers, lakes and rice cultivation areas.

Wetlands provide a number of economic services and goods that are of value to humans. The economic services of wetlands are derived from, but should not be confused with, their ecological and physical functions. The range of services provided by wetlands is partly related to direct geophysical processes, such as sediment retention and the provision of flood and storm buffering capacity, but it extends to wider climatologic, biological, and socio-cultural functions, including impacts on local and global climate change and stabilization, preservation of biodiversity, and the provision of natural environmental amenities. Wetlands provide ecological processes enabling the extraction of goods and services in the form of natural resources such as water, fish and other edible animals, wood, and energy, in addition they provide the natural surroundings for recreational activities.

It is beyond the scope of this article to enter the discussion about the classification of wetland functions and services, which has been the object of a large number of studies (de Groot, 1992; Barbier, 1997). It will suffice to say that wetland values have generally been classified on the basis of the underlying wetland functions (Barbier, 2007), the characteristics of use and non-use values (Barbier, 1997; Tomasin, 1991), the provision of intermediate, final or future goods and services (Scodari, 1994; Leschine, 1997), or private versus public or social values (Bennett and Whitten, 1998). In this paper, we follow the approach proposed in the Millennium Ecosystem Assessment (2005), which is based on classification of ecosystem services into the categories of supporting, provisioning, regulating and cultural services. Table 1 illustrates the main ecological and physical functions of wetlands together with the corresponding services and expected impacts on human welfare.

A wide array of market and non-market methods has been used for the assessment of the different values of wetlands. Table 1 reports the most common methods found in the literature, which are: CVM, hedonic pricing (HP), travel cost method (TCM), market prices, net factor income (NFI), production function, replacement cost, opportunity cost and choice experiment.

Table 1. Principal wetland functions and related economic services

Wetland functions	Wetland services		Valuation methods
Overall natural environment	Amenity/aesthetics	Cultural	HP, CVM
	Non-consumptive recreational activities	Cultural	CVM, TCM
	Appreciation of uniqueness to culture/heritage	Cultural	CVM
	Educational	Cultural	CVM
Habitat and nursery for plant and animal species	Recreational fishing and hunting	Cultural	CVM, TCM
	Biodiversity	Supporting	CVM, contingent choice method
	Support of pollinators	Supporting	-
	Commercial fishing and hunting	Provisioning	Market prices, NFI
	Harvesting of natural materials	Provisioning	Market prices, NFI
	Fuel wood	Provisioning	Market prices, NFI
Hydrological regime	Surface and groundwater supply	Provisioning	Production function, NFI, replacement cost
	Flood control and storm buffering	Regulating	Replacement cost, production function, opportunity cost
	Sediment retention	Regulating	Replacement cost, production function
	Water quality improvement	Regulating	CVM, replacement cost
Interactions with atmosphere	Micro-climate stabilization	Regulating	Production function
	Regulation of greenhouse gases	Regulating	Replacement cost

HP = hedonic pricing; CVM = contingent valuation method; TCM = travel cost method; NFI = net factor income
Adapted from de Groot et al. (2006) and Brander et al. (2006)

To allow a comparison between wetland values that have been calculated in different years and expressed in different currencies and metrics (e.g., WTP per household per year, capitalized values, marginal value per acre, etc), standardization to common metric and currency is needed. Willingness to pay (WTP) per household per year cannot be used as a common metric since several of the valuation methods used in the literature (e.g., NFI, opportunity cost, replacement cost and market prices) do not produce WTP per person estimates, while WTP per person can be converted to a value per hectare per year if the relevant population is known. Thus, we standardized values to 2003 US$ per hectare per year, following Woodward and Wui (2001) and Brander et al. (2006). Values referring to different years were standardized using appropriate deflator factors from the World Bank Millennium Development Indicators (WDI, 2006), while differences in purchase power among the countries were accounted for by the Purchase Power Parity index provided by the Penn World Table (Heston et al., 2006).

3. The database: descriptive statistics

The data set used by Brander et al. (2006) provided the starting point for the analysis. The original data set is significantly enlarged with new observations from the most recently published studies and efforts were also made to include studies that are not published in the English language. In total, the data set contains 353 observations from 155 studies. Such a large number of observations makes the database used in this study by far the largest data set used in a meta-analysis of wetland values.

All five continents are represented. The largest number of observations is derived from North American studies (123), but a significant fraction comes from Asia (75), Europe (73) and Africa (49). South America (17) and Australasia (16) are less well represented. The database is significantly less biased towards North American studies than those used in the previous meta-analyses. In particular, the inclusion of the most recent observations allows to identify a significant shift in the geographical distribution of the valuation studies in the last years. While the oldest wetland valuation studies pertained to North America, a great enlargement of the geographical scope has subsequently occurred. Figure 1 illustrates how the number of observations from North America constantly decreased over the last fifteen years, while the number of European, Asiatic and African observations increased over the same period of time.

A relevant contribution of the present study is that the analysis is not limited to natural wetlands but valuation results from man-made wetlands are also included, a total of 35 observations. Man-made wetlands are created with the aim of (i) mitigating the destruction of natural wetland habitats with artificial ones, which are meant to mimic the foregone ecological and economic values of the lost ecosystem, or (ii) to improve water quality (Kadlec and Knight, 1996). In this case we talk of constructed treatment wetlands. In spite of their single principal objective of water quality improvement, constructed treatment wetlands are often explicitly designed to perform other wetland functions and provide services such as biodiversity increase and opportunities for recreational activities (Knight et al., 2001).

Man-made wetlands were excluded from the previous meta-analyses of wetlands. A review of the literature concerning the comparison of natural and man-made wetlands shows, however, that man-made wetlands express similar functions as natural wetlands, although the level of provision may be lower than that of undisturbed reference wetlands and resemble that of degraded natural wetlands (Campbell et al., 2002; Brooks et al., 2004; Balcombe, 2005; Confer and Niering, 1992; Spieles and Mitsch, 2000). This potentially limited functionality of man-made wetlands is traceable to the presence of higher pressure due to human activities. The impacts of human activities on wetlands can manifest themselves, for instance, in extended or reduced hydroperiods (Boers et al., 2006; Mitsch and Gosselink, 2000), wetland isolation (Kadlec and Knight, 1996; Matthews et al., 2005) and poor influent water quality (Spieles and Mitsch, 2000; Kadlec and Knight, 1996). The presence of pressure is accounted for in the meta-regression by including an index of human pressures on the wetlands (see Section 4).

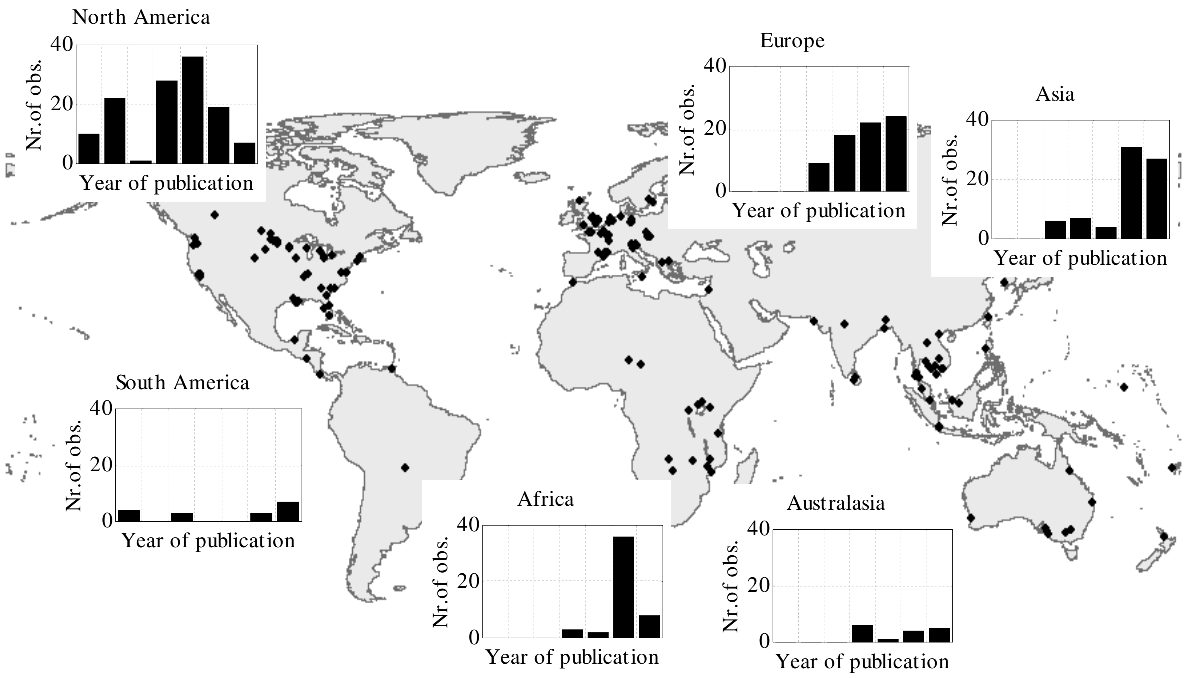

Figure 1. Year of publication (intervals of five years, from 1972 to 2007) and geographical location of the observations in the database.

The wetlands in the database are classified according to the basic hierarchical unit of the *Classification of Wetlands and Deepwater Habitats of the United States* (Cowardin et al., 1979), which identifies five basic wetland systems: marine, estuarine, riverine, lacustrine and palustrine. Due to a lack of information about hydrological conditions and vegetation in many of the wetland sites included in the database, it was not possible to apply to full extent neither the Cowardin nor the Ramsar classification, which is nowadays, the most widely accepted international wetland classification scheme. As large wetlands may include areas with very different characteristics, the same observation may be classified under two or more wetland systems. The distribution of wetland observations in the data set is quite balanced among the five categories. Most of the wetlands in the database are freshwater riverine (128) or palustrine (125) wetlands. A large number of observations concerns estuaries (107), while slightly fewer observations are available for lacustrine (95) and marine (84) wetland ecosystems.

The large diversity of the wetland sites included in the data set is also reflected by their size. Most of the wetlands for which value estimates are available are medium to large size wetland areas. Examples of large valued sites, covering hundreds of thousands of hectares are the coastal wetlands of Louisiana (Gosselink et al., 1974), the Pantanal (Shrestha et al., 2002), the Everglades (Milon et al., 1999), the Sundarban in Bangladesh (Ahmad, 1984) and the Danube floodplain (Gren et al., 1995). In some cases aggregate values are estimated for all wetlands located within a certain administrative region, such as Minnesota (Sip, 1998), South Dakota (Johnson, 1984), New South Wales (Streever et al., 1998) or all mangrove wetlands in Indonesia (Burbridge and Koesoebiono, 1984). Although the majority of the valuation studies so far has comprehensively focused on large sites, small wetlands are also represented. Some examples are small wetlands in the North Dakota prairie (Leitch and Hovde, 1996), in Louisiana (Breaux et al., 1995), Italy (Marangon et al., 2002) and England (Ledoux, 2003). All these wetlands are below hundred hectares in size. Although there is no clear *a priori* expectation of the influence of wetland size on its value, the previous meta-analyses agree on the relevance of size as a significant factor to explain the variability of wetland values.

The wetland services included in the database are those illustrated in Table 1 with the exception of educational services, support of pollinators, sediment retention, micro-climate stabilization and regulation of greenhouse gases for which we could not find any observation that could be used in the analysis. In total, 11 wetland services are included in the data set: flood control and storm buffering (49 observations), surface and groundwater supply (34), water quality improvement (43), commercial fishing and hunting (89), recreational hunting (64), recreational fishing (57), harvesting of natural materials (62), fuel wood (30), amenity/aesthetics (40), non-consumptive recreational activities (79) and biodiversity (41).

Environmental valuation studies carried out at different geographical sites and involving populations with different socio-economic characteristics and consumer preferences typically produce different outcomes (Brouwer, 2000). In the case of wetlands, the variety of geographical and socio-economic characteristics is reflected also in the identification of relevant services and goods and in the choice of valuation methods to be applied. In this study we found, for instance, that valuation studies of the recreational hunting service tend to be concentrated in North America, while provision of materials and fuelwood are valued in South America, Asia and Africa more often than in North America and Europe. The existence of such correlations between the objects of the valuation and the socio-economic and geographic context of the study adds to the complexity of the interpretation of the diversity of wetlands values. The socio-economic characteristics of the population residing in the vicinity of the wetlands in the database are expected to vary dramatically across different observations. This is partially reflected by the large variations in average real GDP per capita – available at country level and state level (for the US) – which ranges from 616 US$ 2003 per person year in Cambodia to 47,547 UD$ 2003 per person per year in Massachusetts, US. Similarly the number of people residing in the regional surrounding of the wetland and the presence of other wetland area in the proximity of the valued site varies greatly.

Figure 2 provides some summary descriptive statistics of the variability in wetland size and in the socio-economic and geographical context, as expressed by the real GDP per capita, the total population and the total area of wetlands in a 100 km radius around the centre of each valued wetland. In Figure 2, the variables are plotted against the wetland value, expressed in 2003 US$. Positive correlation with the wetland value are found for GDP per capita and total population, negative for wetland size and wetland area within a 100 km radius. As indicated by the low values of the R^2, however, none of the variables can explain much of the variability in the values.

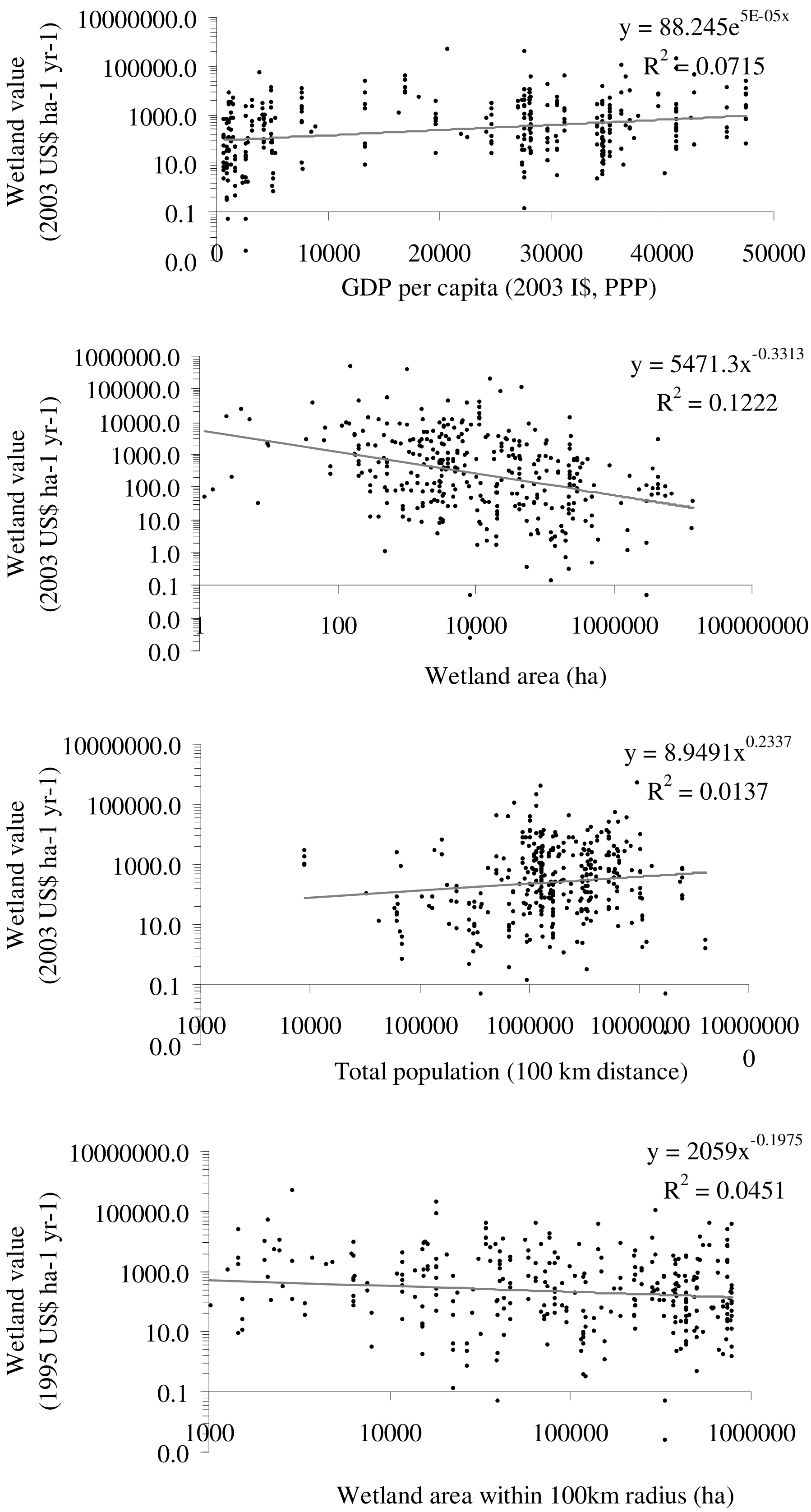

Figure 2. Wetland value in 2003 US$ ha-1 year-1 plotted against real GDP per capita, wetland size, total population in a 100 km from the wetland centre, total area of wetlands in a 100 km radius from the city centre

4. Meta-regression

The summary statistics described in the previous section provide only a very partial explanation of the relative importance of specific factors in determining wetland values, which is not surprising since bivariate analysis cannot take into account the interactions between multiple explanatory variables. The purpose of this section is to allow for such interactions by estimating a meta-analytical regression model of wetland values.

The dependent variable (y) in the meta-regression equation is the vector of the natural logarithm of the wetland values expressed in 2003 US$ per hectare per year. The independent, explanatory variables are grouped in three categories, namely characteristics of (i) the valuation study X_S, (ii) the valued wetland X_W and (iii) the socio-economic and geographical context X_C. Table 2 provides a list of the explanatory variables used in each group along with the unit in which they are measured. The estimated regression model, in matrix notation, is the following:

$$\ln(y_i) = a + b_S X_{Si} + b_W X_{Wi} + b_C X_{Ci} + u_i$$

where the subscript i assumes values from 1 to 353 (number of observations), a is the constant term, b_s, b_w *and* b_c are the vectors containing the coefficients of the explanatory variables and u is the vector of residuals, which we assume well behaving.

Table 2. Explanatory variables used in the meta-regression

Group of variables	Variables	Unit
X_S (study characteristics)	Valuation method	Group of 8 dummies
	Comprehensive/partial valuation	Dummy
X_W (wetland characteristics)	Wetland size	Natural logarithm of area in ha
	Wetland services	Group of 11 dummies
	Wetland type	Group of 5 dummies
	Degree of pressure	Continuous index (from 0 to 3)
X_C (context characteristics)	Real GDP per capita	Natural logarithm of GDP in 2003 US$ person^{-1} year^{-1}
	Population in 100 km radius	Natural logarithm of population
	Proximity to other wetlands (100 km radius)	Natural logarithm of wetland area in ha within the specified radius

The valuation methods considered in the analysis reflect the most commonly used methods already presented in Table 1. With respect to other meta-analyses we introduced the contingent choice method, for which we collected 9 observations. The 11 wetland services considered are those described in Section 2.

With respect to previous meta-analyses of wetlands, we introduced several new explanatory variables. Among the study characteristics, the dummy 'comprehensive/partial valuation' accounts for whether or not all the components of a specific wetland service are covered. A specific wetland may produce a value, for instance, for the service 'commercial fishing and hunting' through different components (e.g. hunting, fishing of crabs and fishing of shrimps), but the valuation study may estimate only one of these (for instance crab fishing), typically due to lack of data for the other components. In such a case the dummy 'comprehensive/partial valuation' assumes the value 0 (37 observations), while it assumes the value 1 otherwise (316).

As one of the wetland characteristics, we introduced an index representing the degree of pressure exerted by human activities on the wetland. This is a composite index that takes into account, with equal weights, the presence of alterations in the natural hydrologic regime of the wetland (as induced, for instance, by the construction of dikes to regulate the water level in the wetland), the density of urban and agricultural area in the immediate surroundings of the wetland, and the status of protection of the site – Ramsar site, national park, nature reserve or no protection measure. The index assumes as a highest value 3 for the least impacted wetlands and a value 0 for the most heavily impacted ones. As wetland ecological conditions and biodiversity are expected to respond to the presence of stressors, the index of pressure may be interpreted as a broad, landscape assessment of wetland condition (Fennessy et al., 2004). In Figure 3, we plot the biodiversity at species level against the index of pressure in the wetlands and for the species for which this information is available. The index is positively correlated with the number of species of fish and mammals present in the wetlands. The correlation with amphibians/reptiles species and bird species is low and not statistically significant. For bird species, this may be due to the fact that they are less sensitive to the ecological conditions in the wetlands due to their higher mobility.

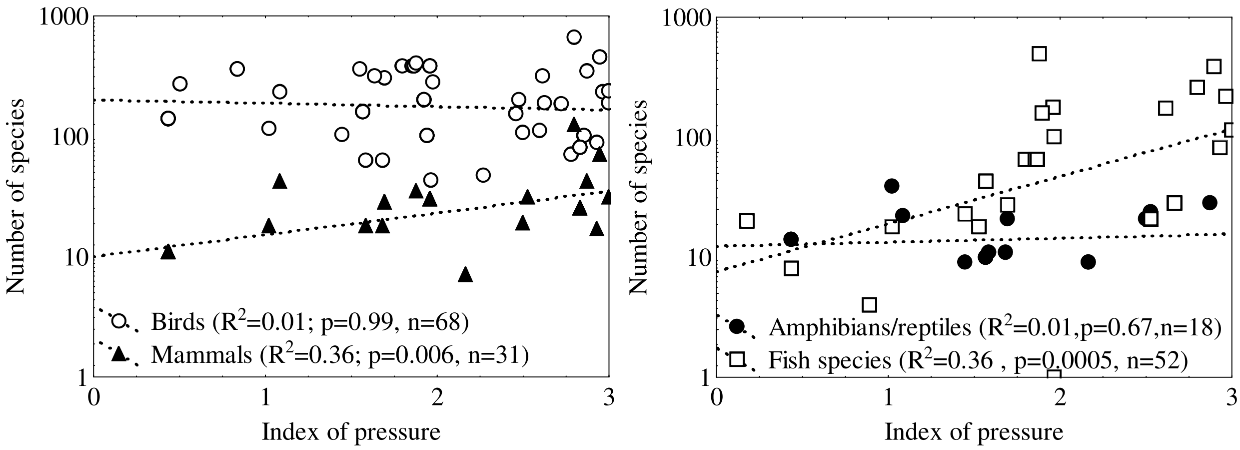

Figure 3. Index of pressure plotted against the animal biodiversity in the wetlands at species level (n=number of observations)

To assess whether the proximity to other wetland sites has an influence on the value of a wetland, we introduced as one context variable the area of wetlands located within a radius of 100 km from the wetland centre. Information about the distribution and sizes of wetlands in the proximity of the valued site was obtained performing a GIS analysis using the Global Lakes and Wetlands Database (Lehner and Döll, 2004). This variable accounts for the uniqueness of a wetland environment and may help explaining the influence of people's perceptions and preferences due to the presence of other wetland sites that can act as a substitute for some of the wetland services provided.

The results obtained with ordinary least squares are presented in Table 3. The values of R^2 (=0.44) and adjusted R^2 (=0.39) are reasonably high. In this (largely) 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 explanatory variables expressed as logarithms, the coefficients represent elasticities, that is, the percentage change in the dependent variable given a (small) percentage change in the explanatory variable.

Among the study characteristics, the dummy variable 'comprehensive/partial valuation' turns out to be highly statistically significant and its coefficient is positive and relatively large. This confirms that the studies performing only partial valuations produced significantly lower values than the comprehensive ones. The coefficients of the valuation methods are not statistically significant with the exception of hedonic pricing. The coefficient is significant and highly negative. The number of studies applying this method is however very small (5 observations).

Table 3. Meta-regression results

	Variable	Coefficient	Std. Error
	(Constant)	-1.663	2.095
Study variables	Contingent valuation method	-0.255	0.668
	Hedonic pricing	-2.176*	1.250
	Travel cost method	-0.834	0.656
	Replacement cost	-0.326	0.664
	Net factor income	-0.245	0.627
	Production function	-0.370	0.649
	Market prices	-0.178	0.571
	Opportunity cost	-1.196	1.275
	Choice experiment	0.186	0.979
	Comprehensive	1.569***	0.410
Wetland variables	Wetland size (ln)	-0.320***	0.053
	Flood and storm protection	-0.084	0.396
	Surface and groundwater supply	-0.039	0.469
	Water quality improvement	0.897*	0.462
	Commercial fishing and hunting	0.459	0.316
	Recreational hunting	-1.293***	0.396
	Recreational fishing	0.592	0.401
	Harvesting of natural materials	-0.075	0.350
	Fuelwood	-1.722***	0.470
	Non-consumptive recreational activities	0.056	0.396
	Amenity/aesthetics	1.038**	0.488
	Biodiversity enhancement	0.699	0.440
	Estuarine	0.497	0.339
	Marine	0.874***	0.339
	Riverine	0.732**	0.306
	Palustrine	-0.178	0.305
	Lacustrine	1.024***	0.333
	Degree of pressure	-0.181	0.166
Context variables	Real GDP per capita (ln)	0.571***	0.120
	Population in 100 km radius (ln)	0.449***	0.097
	Area of wetlands in 100 km radius (ln)	-0.267***	0.059

OLS results. Significance is indicated with ***, ** and * for 1, 5 and 10% statistical significance levels respectively.

Several variables capturing wetland characteristics turn out to be statistically significant. The negative coefficient of wetland size indicates decreasing returns to scale, which confirms the results obtained by Woodward and Wui (2001) and Brander et al. (2006). The type of wetland also significantly affects the value. Palustrine wetlands produce the lowest values compared to the other four kinds of wetlands, whose coefficients are all positive. Among wetland functions, the coefficients of hunting and fuel wood are largely negative, while the coefficients of water quality improvement and amenity/aesthetics are positive.

Surprisingly, the coefficient of the index of environmental pressure is negative, though not statistically significant. This seems to indicate that a higher pressure of human activities on the wetland produces higher values. Possible explanations for this are that human activities contribute to translate potential uses into values or that human interventions in a wetland often aim at improving the level of provision of specific wetland services, such as water quality improvement in the case of treatment wetlands. A somewhat comparable result is reported by Brander et al. (2006), who found lower values for Ramsar sites. It is clear, however, that a higher pressure of human activities in a wetland raises questions about the temporal sustainability of wetland values. Regrettably, this issue cannot be addressed with the temporal snapshots of values that can be inferred from the valuation studies.

All three context variables appear to be highly statistically significant. Wetland values are positively related both to GDP per capita and to the population living in a 100 km radius from the centre of the wetland. On the other hand, there is a negative relationship between the proximity of other wetlands and the value of the wetland, which might indicate the presence of substitution effects at least for some of the wetland services.

As a second step of the meta-analysis, we used a multi-level model (MLM) to relax the assumption of independent observations and examine hierarchies within the data, such as similarity of estimates produced by the same author or in the same geographic region. The estimated model is:

$$\ln(y_{ij}) = \alpha + \beta_S X_{Sij} + \beta_W X_{Wij} + \beta_C X_{Cij} + u_j + e_{ij}$$

where the subscript i assumes values from 1 to 353 (number of observations) and subscript j takes values from 1 to the number of authors or geographic regions; α is the constant term; X_S, X_W and X_C are variables respectively capturing characteristics of the study, wetland and context; β_S, β_W and β_C are vectors containing the coefficients of the respective explanatory variables; u_j is a vector of residuals at the second (author/region) level; e_{ij} is a vector of residuals at the first (observation) level. In this equation, both u_j and e_{ij} are random quantities with means equal to zero. We assume that these variables are uncorrelated and also that they follow a Normal distribution. We consider 6 regions in the analysis: Africa, Asia, Australasia, Europe, North America and South America.

We examine the influence of authorship effects and of the geographic regions on estimated values using a likelihood ratio test, for which the null hypothesis is that the variance of the residuals u (σ^2_u) is equal to zero. We compare the above estimated model with a model where σ^2_u is constrained to equal zero, i.e. a single level model.

The value of the likelihood ratio statistic is 1566.401 – 1477.539 = 88.862. Comparing this to a chi-squared distribution with 1 degree of freedom, we conclude that there are real differences between the mean value estimates produced by different authors. In other words, value estimates from a particular author tend to be more similar than estimates drawn from different authors. This result contrasts with that of Bateman and Jones (2003), who find no evidence of authorship effects in their meta-analysis of woodland recreation values in the UK. On the other hand, the contribution of the geographic regions to explain the residuals at the second level is insignificant, which supports our decision not to include them in the first meta-regression.

5. Conclusions

The present study has provided the most comprehensive review of wetland valuation studies so far and contributes to the identification of the main determinants of wetland values. The data set includes 353 observations from wetland sites worldwide, which were derived from 155 studies. The location of the valued sites reflects the shift in the geographical scope of valuation studies in the last decade. With respect to previous literature reviews and meta-analyses of wetland values, the data set is much less biased towards North America and includes a large number of studies from other regions, in particular from Europe, Asia and Africa. For the first time, man-made wetlands are included in the analysis.

A meta-regression was performed to identify and estimate the relative importance of the determinants of wetland values. The regression function includes variables that reflect characteristics of the valuation study, the wetland site and the socio-economic and geographical context.

The importance of the wetland type and size, and of the function valued, is confirmed by the statistically significant coefficients found for related explanatory variables. *Ceteris paribus*, palustrine wetlands produce lower values than other wetland types, while water quality improvement and the provision of amenity are the most highly valued services. With respect to wetland size, decreasing returns to scale are identified.

The socio-economic and geographical context is similarly relevant in explaining the variability of wetland values. Both GDP per capita and population residing within a 100 km radius from the wetland centre were found to be positively and significantly correlated with the wetland value. On the other hand, an important contribution of this paper is to show that the proximity of other wetlands negatively affects the value of the site. This is likely to be linked to the fact that nearby wetlands may act as substitute sites for at least some of the services valued. Authorship effect may also contribute to explain differences in wetland value estimates.

References

Ahmad I.U. Some aspects of economic resources of Sundarban mangrove forest of Bangladesh. In: Proceedings of the Asian symposium on mangrove environment research and management, Soepadmo and Macintosh (eds.), 1984.

Balcombe C.K., Anderson J.T., Fortney R.J. and Kordek W.S. Wildlife use of mitigation and reference wetlands in West Virginia. Ecol Eng 25(2005):85–99.

Barbier, E. B., Acreman M. and Knowler D. Economic Valuation of Wetlands: A Guide for Policy Makers and Planners. Gland, Switzerland.: Ramsar Convention Bureau, 1997.

Barbier, E. B. Valuing ecosystem services. Economic policy 22(49)(2006).

Boers A.M., Veltman R.L.D. and Zedler J.B. Typha×glauca dominance and extended hydroperiod constrain restoration of wetland diversity. Ecol Eng 29(3)(2007):232-244.

Brander L.M., Florax R.J.G.M. and Vermaat J.E. The empirics of wetland valuation: a comprehensive summary and a meta-analysis of the literature. Environ Resource Econ 33(2006):223-250.

Breaux, A., Farber S.C. and Day J. Using Natural Coastal Wetlands Systems for Wastewater Treatment: An Economic Benefit Analysis. J Enviro Manage 44(1995):285–291.

Brooks R.P., Wardrop D.H., Cole C.A. and Campbell D.A. Are we purveyors of wetland homogeneity? A model of degradation and restoration to improve wetland mitigation performance. Ecol Eng 24 (2005):331–340.

Brouwer R., Langford I.J., Bateman T.C., Crowards T.C. and Turner R.K. A meta-analysis of wetland contingent valuation studies. Regional Environmental Change 1(1999):47-57.

Brouwer, R. Environmental value transfer: state of the art and future prospects. Ecolog Econ 32(2000): 137–152.

Burbridge P.R. and Koesoebiono H. Management of mangrove exploitation in Indonesia. In: Proceedings of the Asian symposium on mangrove environment research and management, Soepadmo and Macintosh (eds.), 1984.

Campbell D.A., Cole C.A. and Brooks R.P. A comparison of created and natural wetlands in Pennsylvania, USA. Wetlands Ecology and Management 10(2002):41–49.

Confer S.R. and Niering W.A. Comparison of created and natural freshwater emergent wetlands in Connecticut (USA). Wetlands Ecology and Management vol. 2 (3) (1992):143-156.

Cowardin, L. M., Carter V., Golet F. C. and LaRoe E. T. Classification of wetlands and deepwater habitats of the United States. U. S. Department of the Interior, Fish and Wildlife Service, Washington, D.C, 1979.

Fennessy M.S., Jacobs A.D. and Kentula M.E. Review of rapid methods for assessing wetland conditions. US EPA Report EPA/620/R-04/009, 2004.

Gosselink G.J., Odum E.P. and Pope R.M. The value of the tidal marsh. Center for Wetland Resources, Louisiana State University, 1974.

Gren I.M. Costs and benefits of restoring wetlands: two Swedish case studies. Ecol Eng 4 (1995): 153-162.

Groot de R., Stuip M., Finlayson M. and Davidson N. Valuing wetlands. Guidance for valuing the benefits derived from wetland ecosystem services. RAMSAR Technical Report No.3. CBD Technical Series No.27, 2006.

Groot de R. S. Functions of nature: Evaluation of nature in environmental planning, management and decision making. Wolters-Noordhoff, Amsterdam, The Netherlands, 1992.

Hammack, J. and Brown G.M., Waterfowl and wetlands: toward a bio-economic analysis. Washington, D.C.: Resources for the Future, John Hopkins University Press, 1974.

Heston A., Summers R. and Aten B., Penn World Table Version 6.2, Center for International Comparisons of Production, Income and Prices at the University of Pennsylvania, September 2006.

Johnson C.J. An economic valuation of South Dakota wetlands as a recreation resource for resident hunters. M.Sc. Thesis. South Dakota State University, 1984.

Kadlec R.H. and Knight R.L. Treatment wetlands. CRC Press Boca Raton USA, 1996. ISBN 0873719301.

Knight R.L. Clarke R.J.Jr., Bastian R.K. Surface flow (SF) treatment wetlands as a habitat for wildlife and humans. Wat Sci Tech 44(11-12) (2001):27-37.

Ledoux L. Wetland valuation: state of the art and opportunities for further development. CSERGE Working Paper PA 04-01. Proceedings of a Workshop, 2003.

Lehner, B. and Döll P. Development and validation of a global database of lakes, reservoirs and wetlands. Journal of Hydrol 296 (1-4) (2004): 1-22.
Leitch, J. A. and Hovde B. Empirical valuation of prairie potholes: five case studies. Great Plains Research 6(1996): 25–39.
Leschine T.M., Wellman K.F. and Green T.H. The economic value of wetlands: wetlands' role in flood protection in Western Washington. Ecology Publication no. 97-100, Washington State Department of Ecology, 1997.
Marangon F., Tempesta T. and Visintin F. Turismo e attività ricreative nelle aree protette italiane: un quadro conoscitivo ancora inadeguato. Paper presented at: II Conferenza Nazionale delle Aree Naturali Protette, 2002.
Matthews J.W., Tessene P.A., Wiesbrook S.M. and Zercher B.W. Effect of area and isolation on species richness and indices of floristic quality in Illinois, USA wetlands. Wetlands 25 (3) (2005): 607–615.
Millennium Ecosystem Assessment. Ecosystem and human well-being: synthesis. Island Press. Washington, DC, (2005).
Milon J.W. and Scrogin D. Latent preferences and valuation of wetland ecosystem restoration. Ecolog Econ 56 (2006): 162– 175.
Mitsch W.J. and Gosselink J.G. Wetlands. John Wiley and Sons Inc., 920pp, 2000. ISBN 0 471 29232X.
Scott D.A. and Jones T.A. Classification and inventory of wetlands: a global overview. Vegetatio 118 (1995): 3-16.
Sip R.L. Leitch J.A. and Meyer A.J. An economic assessment of wetland mitigation in Northwest Minnesota. Agricultural Economics Report No.397, Department of Agricultural Economics, North Dakota State University, 1998.
Tomasin A. Economic valuation of the Po delta wetlands. Nota di lavoro 8.91. Milan: Fondazione Eni Enrico Mattei, 1991.
Shrestha R.K., Seidl A.F. and Moraes A.S. Value of recreational fishing in the Brazilian Pantanal: a travel cost analysis using count data models. Ecolog Econ 42 (2002):289-299.
Spieles D.J. and Mitsch W.J. Macroinvertebrate community structure in high and low nutrient constructed wetlands. Wetlands (20) (4) (2000): 716–729.
Streever W.J., Callaghan-Perry M., Searles A., Stevens T. and Svoboda P. Public attitudes and values for wetland conservation in New South Wales, Australia. Journal of Environmental Management 54 (1998): 1-14.
WDI, World Development Indicators (2006), World Bank.
Whitten S.M. and Bennett J.W. Private and social values of wetlands. Research Reports. School of Economics and Management, University College, The University of South Wales, Canberra, 1998.
Woodward R.T. and Wui Y.S. The economic value of wetland services: a meta-analysis. Ecolog Econ 37 (2001):257-270.