Ecosystem Services 22 (2016) 73–82

Contents lists available at ScienceDirect

Ecosystem Services

journal homepage: www.elsevier.com/locate/ecoser

Integrating similarity analysis and ecosystem service value transfer: Results from a tropical coastal wetland in India

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ARTICLE INFO

Keywords:
Ecosystem services
Value transfer
Similarity analysis
Meta-regression analysis
Coastal wetland
India

ABSTRACT

Policy demand for ecosystem service values in developing countries results in a growing use of value transfer techniques, even in the absence of primary valuations from highly comparable study sites. Current techniques provide limited guidance on how to quantitatively assess the similarity between study and policy sites and control for the effect thereof on transfer accuracy. This paper proposes a methodology for the estimation of a study-policy site similarity index and explores its application to the Akkulam-Veli wetland in Kerala, India. The use of empirical similarity weights in a meta-analytical transfer yields a narrower prediction interval for the policy site value estimate. Estimating the meta-regression model parameters on a subset of primary valuation studies with greater similarity to the policy site application is found to increase value transfer accuracy. The need for further systematic testing and potential implications of the proposed approach for value transfer practitioners are highlighted.

1. Introduction

The economic valuation of ecosystem services (ES) is broadly accepted as a useful tool to inform development- and conservation-related decisions on the wider societal implications of our collective choices regarding the management of natural resources and the environment. Although various primary valuation techniques are available in the toolbox of environmental economists, environmental managers and decision-makers often rely on secondary ES valuations (i.e., value transfer) as a second-best assessment of ecosystem benefits. Value transfer refers to the procedure of drawing inferences on the unobserved monetary value of ecosystem goods or services in a policy site by borrowing existing valuation estimates from comparable study sites. Though widely used in developed countries, secondary valuation techniques are particularly relevant in the context of developing countries, where the lack of ES valuation expertise and the financial resources necessary for a primary valuation study are often limiting factors (Chaikumbung et al., 2016).

One of the key concerns of the value transfer analyst is the selection of the most appropriate study site, or sites in the case of multi-study site transfer based for instance on meta-regression analysis. The consensus among value transfer practitioners is that the more similar the original data estimates are to the intended policy site application, the more accurate the transfer will be (Rosenberger and Phipps, 2007). Johnston (2007) denotes this consensus as "similarity hypothesis". Several studies have testified to the empirical influence of site similarity on the reliability of value transfer estimates – see Rosenberger (2015) for an overview. The value transfer literature, however, currently lacks a set of standardized, quantitative tools to characterize such similarity (or dissimilarity) and take it into account in the derivation of value estimates for the policy site. Indeed in the context of meta-analytical value transfer, analysts generally aim to be as comprehensive as possible in the selection of studies to be included in the meta-database, since excluding a study is equivalent to applying a zero weight to the information in the study (Bergstrom and Taylor, 2006). While some authors point out the need to perform a systematic similarity analysis when selecting individual studies (van den Bergh et al., 1997), such recommendation is limited to the data collection phase and, in any case, is hardly reflected in the ES value transfer literature where the selection of the most similar study site(s) is generally left to subjective expert judgment. This practice has the potential to introduce a researcher bias in the analysis. Some authors have argued in favor of making "the inevitably subjective nature of benefit transfer more transparent" by acknowledging the explicit role of the analyst's sub-

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http://dx.doi.org/10.1016/j.ecoser.2016.09.014
Received 5 April 2016; Received in revised form 18 September 2016; Accepted 21 September 2016
2212-0416/

jective beliefs in a Bayesian value transfer paradigm (Phaneuf and van Houtven, 2015).

The present paper has two main objectives. First, it aims at defining a study-policy site general similarity index and showing how it can be integrated in a value transfer exercise. We demonstrate how a similarity index can be used to: (1) rank study site estimates based on an objective measure of their similarity to the intended policy site application; and (2) estimate the effect that relying on such similarity criterion has on the empirical transfer estimates obtained with different value transfer techniques. In particular, we assess how restricting the database of primary valuation studies based on the similarity with the policy site may affect the meta-analytical value transfer estimates. Moreover, we explore the use of empirical-similarity-weighted regression (Galbraith and Lieberman, 2013) as a potential alternative to more common meta-regression techniques when value transfer is the intended application of the results.

Second, we investigate the Akkulam-Veli (AV) wetland in Kerala, India as a case-study application for testing the aforementioned value transfer techniques and with the aim to provide a first estimate of the economic benefits provided by this endangered coastal tropical wetland ecosystem. Although wetlands are widely acknowledged as highly productive ecosystems capturing and processing energy to provide food for living organisms and sustain a number of vital ecological functions and economic services (Mitsch et al., 2015), many wetlands worldwide are at risk of degradation and conversion into other land uses because policy makers', planners' and other stakeholders' decisions do not accurately reflect the range of goods and services provided by them and their value to society (de Groot et al., 2006). Especially in tropical wetlands, many of the subsistence uses of wetland resources are not marketed and are thus often ignored in development decisions (Chaikumbung et al., 2016).

In India, only a fairly limited number of wetland ecosystem service valuation studies are available to date (see Table 1 for an overview of valuations in coastal wetlands), in spite of the wealth and diversity of its wetland habitats and the considerable stress they experience from urbanization, industrialization and agricultural intensification (Parikh and Datye, 2003; Bassi et al., 2014). Kerala state on the southwestern coast of India (see Fig. 1) has the largest proportion of land area classified as wetlands amongst all Indian states and displays an extensive network of backwaters, estuaries and lakes (Parikh and Datye, 2003). The AV wetland is located in a densely populated urban area in proximity to Kerala's state capital and largest city Thiruvananthapuram. The AV wetland has historically played an important economic, social and ecological role in the region (Chandran and Gowda, 2014; Indugeetha and Sunil, 2014) and has been the object of extensive investigation by environmental scientists. The AV wetland is currently threatened by severe pollution threats from municipal sources and other economic activities taking place in its drainage basin (Navami and Jaya, 2013; Sheela et al., 2010a, 2012a). Among the identified threats one may include eutrophication (Sajinkumar et al., 2015; Sheela et al., 2010b) and heavy metal enrichment (Sheela et al., 2012b; Swarnalatha et al., 2013a). The introduction of more sustainable environmental management practices in the AV wetland is considered urgent and essential for the conserva-

Table 1
Value estimates of ecosystem goods and services provided by coastal wetlands in India.

State	Site name	Wetland type	Valuation method[a]	Economic value[b]	Reference
Gujarat	All mangroves	Mangrove	VT	i. 953 US$/ha/year for carbon sequestration ii. 1,285 US$/ha for erosion control	Hirwai and Goswami (2007)
Karnataka	Kumpta Taluk	Mangrove	CVM	11,549 US$/ha/year for fish nursery, erosion & pest control	Stone et al. (2008)
Kerala	Ashtamudi estuary	Mangrove	CVM, NFI, RC, TCM	i. 134 US$/ha/year for option value ii. 900 US$/ha/year for commercial fishing iii. 20.4 US$/ha/year for recreation iv. 40.9 US$/ha/year for shrimp nursery	Anoop and Suryaprakash (2008a, 2008b)
Kerala	Ernakulam and Kannur	Mangrove	CVM	148 US$/household/year for conservation	Hema and Devi (2015)
Kerala	Kochin backwater	Lagoon	MP	i. 150 US$/ha/year for agriculture ii. 8,720 US$/ha/year for fishery & aquaculture iii. 141 US$/ha/year for tourism	Thomson (2001)
Kerala	Kol wetland	Brackish marsh	CVM	181 US$/ha for improved management	Binilkumar and Ramanathan (2009)
Kerala	Kol wetland	Brackish marsh	VT	16,077 US$/ha/year of total economic value	Raj and Azeez (2009)
Kerala	Valapattanam, Vellikkeel, Kavvayi	Mangrove	VT	11,123 US$/ha/year of total economic value	Khaleel (2012)
Kerala	Vembanad estuary	Lagoon	NFI	4,495 US$/household/year for prawn fishing	Jeena (2002)
Odisha	Bhitarkanika Conservation Area	Mangrove	MP, RC	i. 13.4 US$/household/year for fuel wood ii. 73.8 US$/household/year for subsistence fishing iii. 28.2 US$/household/year for timber & materials iv. 255 US$/ha for nutrient retention v. 995 US$/ha/year for storm protection	Badola and Hussain (2005); Hussain and Badola (2008, 2010)
Odisha	Chilika lake	Lagoon	CVM, TCM, MP	i. 1,825 US$/ha/year for tourism ii. 601 US$/ha/year for fisheries iii. 671 US$/ha/year for recreation	Kumar (2013)
Odisha	Jagatsinghpur and Kendrapada	Mangrove	ADC	236 US$/ha for protection during 1999 cyclone	Das and Crepin (2013)
Tamil Nadu	Pitchavaram Mangrove Forest	Mangrove	CVM	131 US$/person/year for conservation	Sathya and Sekar (2012)
West Bengal	Sundarban Tiger Reserve	Mangrove	CVM	1.8 US$/person for maintenance & restoration	Ekka and Pandit (2012)

Notes:
[a] VT=value transfer, CVM=contingent valuation method, NFI=net factor income, RP=replacement cost, MP=market prices, TCM=travel cost method, ADC=avoided damage cost;
[b] All values are expressed in US$ (2013, PPP).

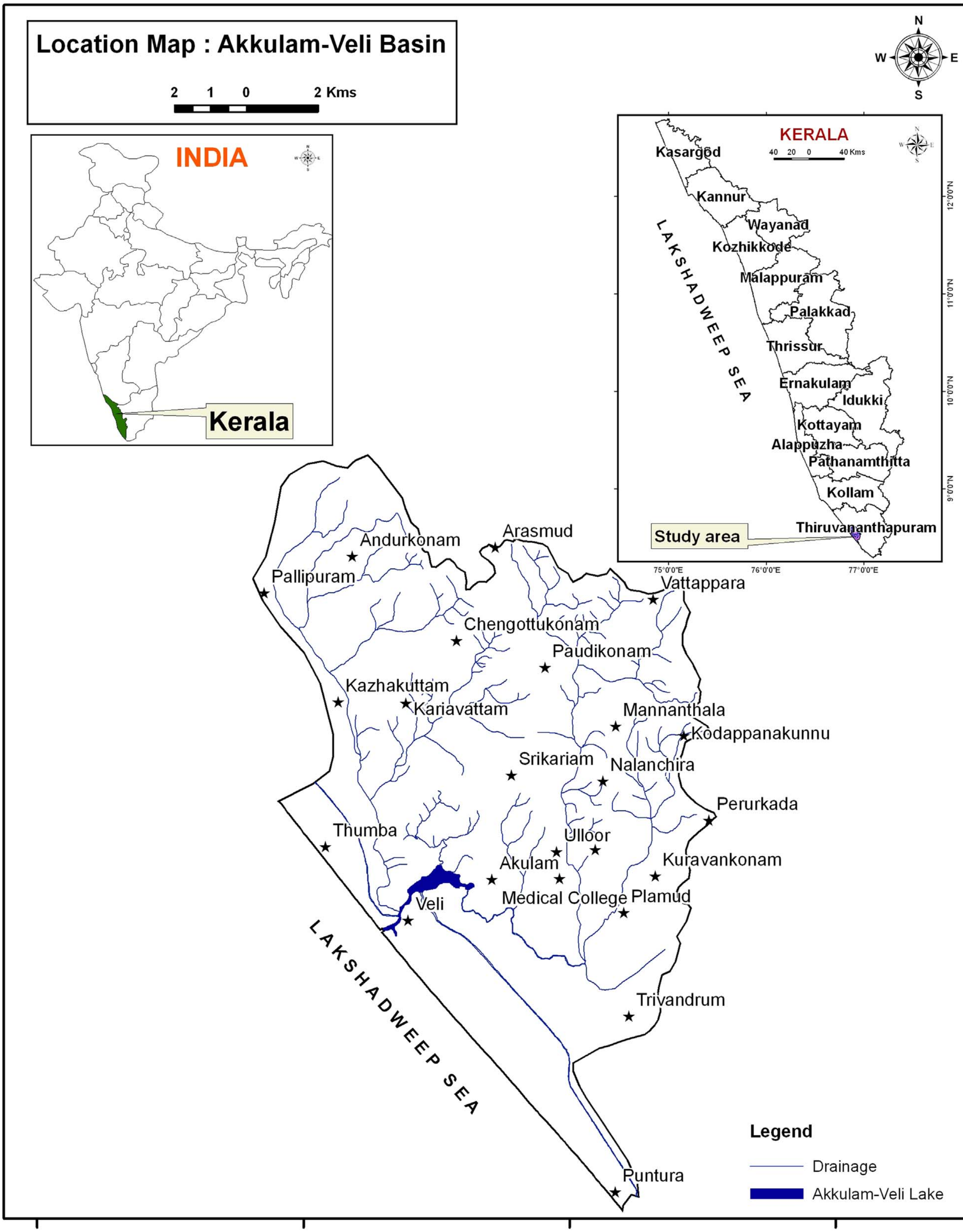

Fig. 1. Map of the Akkulam-Veli lake in Kerala, India.

tion of this stressed ecological system (Sajinkumar et al., 2015; Sheela et al., 2011a, 2014a; Swarnalatha et al., 2013b, 2013c)..

The remainder of this paper is organized as follows. Section 2.1 describes the proposed study-policy site similarity index and how it can be applied in the context of single- and multi-study site value transfer. Section 2.2 introduces the main characteristics of the AV wetland case-study site and the rationale for identification and valuation of its ecosystem services. Section 2.3 elaborates on the empirical application of the value transfer methodology to the AV wetland in India. Section 3 presents the empirical results of the study and the value transfer estimates. Section 4 concludes.

2. Material and methods

2.1. Developing a site similarity index for value transfer

Broadly speaking, ES value transfer techniques can be classified into two categories: (1) those that build on the results from a single study site; and (2) those that aim at synthesizing results from multiple study sites (Brouwer, 2000). The former is known as unit value transfer and generally relies upon expert judgment to identify the most appropriate study site and apply value correction factors to the study site estimate to control for differences in per capita income, price levels, and cultural aspects (Brander, 2014; Hynes et al., 2013; Colombo and Hanley, 2008).

Among the latter techniques, meta-analysis uses regression-based techniques to characterize the relationships between a series of moderator variables and the values observed in a large set of study sites. The unobserved value in the policy site is inferred from evaluating the meta-regression function with the estimated parameters and the variable levels associated with the policy site(s). The number of meta-analytical transfers of ES values has risen substantially in recent years, including various applications to wetland ecosystems (Nelson and Kennedy, 2009; Chaikumbung et al., 2016). The bulk of this literature is constituted by non-structural models that do not explicitly formulate a utility function and rely on empirical regressions against study-, site-, and context-specific characteristics (Bergstrom and Taylor, 2006).

The literature on meta-analytical value transfer has extensively focused on issues such as the requirements for utility-theoretical welfare consistency in primary valuation studies (Johnston and Moeltner, 2014; Smith and Pattanayak, 2002) and the use of weights to control for effect size variance and panel stratification (Bergstrom and Taylor, 2006), but does not provide systematic guidance regarding the empirical effect of applying more or less stringent similarity rules between study and policy sites. In a different economic valuation context, the use of empirical similarity measures for similarity-weighted averaging or empirical-similarity-weighted regressions has however been proposed for a range of applications including hedonic pricing of real estate and works of art (Gilboa et al., 2006; Galbraith and Lieberman, 2013).

Meta-regression models of ES values typically include a mixture of dichotomous, qualitative and quantitative variables to capture site, study and context-specific characteristics of primary valuations. Euclidean distances, which are commonly used to calculate distances for variables measured on ratio scale, are thus not directly applicable and need to be complemented with distance measures that are appropriate for other scales of measure, including nominal and ordinal (Mooi and Sarstedt, 2011).

Measures of distance between data points are routinely used in data mining and knowledge discovery tasks (Boriah et al., 2008). In cluster analysis, they are used to classify objects in a set into separate groups with different characteristics. Such algorithms rely on the characterization of each of the objects through a series of appropriately selected clustering variables, and combine such information into a single numeric value, which specifies how distant (dissimilar) pairs of objects are. A cluster analysis technique that is widely used for such purpose is Gower's composite indicator (Gower, 1971). Appropriately extended, Gower's index can be used to combine different measures of distance for mixed nominal, ratio and ordinal data into a single coefficient of (dis)similarity (Podani, 1999).

Gower's similarity index is calculated in the present study based on the formulation given by Podani (1999), which is implemented in the FD package (*gowdis* function) in the R environment (R Development Core Team, 2014; Laliberté and Shipley, 2015). Given a matrix of n objects (rows) – representing the policy site and n−1 study sites – and m variables (columns) – representing the site and context-specific variables of the meta-regression model, Gower's similarity index S_{jk} between objects j and k is computed as:

$$S_{jk}=\frac{\sum_{i=1}^{n}\delta_{ijk}s_{ijk}}{\sum_{i=1}^{n}\delta_{ijk}} \quad (1)$$

where s_{ijk} is the partial similarity of variable i for the j-k pair; the parameter δ_{ijk} allows for the specification of different weights for each j-k pair, including a zero weight when comparison is not possible due to missing data. In the present study, the function is evaluated with equal weights and there are no missing scores. Values of S_{jk} may range between 0 and 1, where 0 indicates highest dissimilarity and 1 indicates perfect similarity.

Partial similarity (s_{ijk}) is calculated using different distance measures according to the variables' scale of measure. For binary and nominal variables:

$$s_{ijk}=0 \; if \; x_{ij}\neq x_{ik} \; \text{and} \; s_{ijk}=1 \; if \; x_{ij}=x_{ik} \quad (2)$$

where x_{ij} and x_{ik} denote the values of variable x_i for observations j and k. For variables measured on interval and ratio scale (e.g., continuous variables), s_{ijk} is calculated as:

$$s_{ijk}=1-\frac{|x_{ij}-x_{ik}|}{R_i} \quad (3)$$

where $R_i=x_{i,\,max}-x_{i,\,min}$ is the range of variable i in the sample, which ensures that the distance measure ranges between 0 and 1. For ordinal variables, Podani (1999) proposed the following procedure:

$$s_{ijk}=1-\frac{|r_{ij}-r_{ik}|-(T_{ij}-1)/2-(T_{ik}-1)/2}{r_{i,max}-r_{i,min}-(T_{i,max}-1)/2-(T_{i,min}-1)/2} \quad (4)$$

where T_{ij} and T_{ik} are, respectively, the number of objects which have the same rank score for variable i as object j and object k (including j and k themselves); $r_{i,\,max}$ and $r_{i.min}$ are, respectively, the maximum and minimum ranks for variable i; $T_{i,\,max}$ and $T_{i,\,min}$ are, respectively, the number of objects with the maximum and minimum rank. Due to its flexibility to accommodate different types of variables in a single similarity measure, Gower's index with Podani's extension is used in this paper as an objective measure of distance between study and policy sites based on a series of moderator variables that will be identified in Section 4.

2.2. Case-study site: the Akkulam-Veli wetland in India

The AV lake (8°31′14″N–8°31′52″N; 76°53′12″E–76°54′6″E) is a tropical coastal wetland located in the northwestern portion of Thiruvananthapuram along the southwestern coast of India (Fig. 1). It has an area of about 76 ha and is linearly perpendicular to the shore with its seaward part abutting the shoreline and it is separated from the shore during non-rainy season. For most part of the year, it remains separated from the sea by a sand bar. The wetland is partially divided into two by the existence of a bridge of the National Highway 66 bypass road across its length. The western part, which lies towards the sea, forms the Veli wetland and the eastern part, starting from the bridge, forms the Akkulam wetland. The lake enjoys a tropical humid climate with an average rainfall of 1823.7 mm, relative humidity of 76.2% and an average temperature of about 27.5 °C.

The AV wetland bears resemblance to a coastal lagoon, in which a shallow coastal water body is separated from the ocean by a sand barrier and connected intermittently to the ocean by the breakage of the sand bar during rain events. The low flushing rate because of its restricted exchange with the ocean contributes to its high productivity as well as accumulation of water pollutants. High nutrient concentrations in the Veli lake have resulted in eutrophication of the upper reservoir and consequent stress on the local mangrove forest (Navami and Jaya, 2013). The lake ecosystem supports a variety of habitats including numerous fish species, mangroves and seagrasses. Previous research suggested that the AV wetland is a source of valuable ecosystem goods and services, but no systematic classification has been performed and no monetary estimate of their values is currently available (, 2012b and 2013).

2.3. Value transfer methodology

A growing number of ES valuations are currently available for wetlands in India (Hadker et al., 1997; Parikh and Datye, 2003; Vijayan and Job, 2015). Table 1 summarizes the studies pertaining to coastal wetlands as identified in the present study. Of the 17 studies in Table 1, eight are focusing on coastal wetlands in the state of Kerala while the remaining ones pertain to wetlands located in five of the eight other coastal states of India (Gujarat, Karnataka, Odisha, Tamil Nadu and West Bengal). Insofar as wetland typology is concerned, the available studies are mainly focusing on large mangrove ecosystems. Most studies (14 out of 17) perform primary valuations using a range of market and non-market techniques. Estimates of per-hectare value flows in Table 1 range between 20.4 US$/ha/year for recreation in the Ashtamudi estuary and 16,077 US$/ha/year for the total economic value of the Kol wetland. The mean and median value estimate for individual coastal wetland sites in India are 3,384 (±5,263) and 785 US$/ha/year, respectively. All values in Table 1 are expressed in US$ (2013) and adjusted for Purchasing Power Parity (PPP).

Given the relative small number of local primary valuation studies, we rely in this study on international value transfer using a published meta-analytical regression model of the values of coastal wetlands (Camacho-Valdez et al., 2013). The original database is extended to include ES values of coastal wetlands in India from Table 1. Estimates derived from value transfers or that could not be expressed in the US $/ha/year metric were not included in the extended database, which encompasses 160 value observations from 60 studies. Table 2 summarizes the main characteristics of the database and identifies the site-, study- and context-specific moderator variables of the meta-regression model. The reader may refer to Camacho-Valdez et al. (2013) for additional details on the database and selection of the moderator variables.

All the variables in the meta-regression model are used to calculate the vector of extended Gower similarity indexes with exception of the study-specific variables (i.e., valuation method, publication year, and publication type), which are not applicable to the policy site. The correlation between pairs of variables is calculated in order to ensure that highly correlated variables do not overly influence the estimated similarity index.

In order to investigate how the inclusion of the similarity index affects the predicted values for the AV wetland, we consider value transfer estimates obtained with three different approaches. First, an adjusted unit value transfer exercise is performed. The similarity index is used to identify the most suitable study site observation for the transfer and adjustment factors are applied to control for difference in income and purchasing power between the study and policy site (Brander, 2014).

Second, a non-structural utility linear theoretic model is estimated with the ordinary least squares (OLS) method and heteroskedasticity-robust, Huber-White standard errors (SE). The model is estimated with the mixed step-wise selection technique (James et al., 2013). At each step, a best subset selection approach with exhaustive search is implemented to identify the model with the smallest residual sum of squares for the specified number of predictors. The process is stopped when no more statistically significant variables can be added. Variables whose coefficients drop below the 20% significance level are removed. Eq. (5) shows the model.

$$\ln(y_i)=\alpha_0+\sum_{k=1}^{m}\alpha_k x_{i,k}+\varepsilon_i \tag{5}$$

Table 2
Overview of the database of coastal wetland values and moderator variables used in the meta-regression model.

Category	Variable	Measurement level (unit)	0Summary[a]
Study (X_V)	Valuation method[b]	Categorical	
	- contingent valuation		18/160
	- travel cost		10/160
	- replacement cost		32/160
	- net factor income		16/160
	- production function		15/160
	- market prices		71/160
	- choice experiment		4/160
	Years since first valuation[c]	Ordinal	22.4 (8.9)
	Peer-reviewed publication[d]	Binary	51/160
Site (X_S)	Wetland type	Categorical	
	- saltmarsh		32/160
	- mangrove		74/160
	- lagoon (omitted)		10/160
	- riverine wetland		44/160
	Wetland size	Continuous (hectares, ln)	9.7 (2.6)
	Ecosystem service	Categorical	
	- flood control and storm buffering		25/160
	- water supply		11/160
	- water quality improvement		12/160
	- commercial fishing and hunting		58/160
	- recreational fishing		7/160
	- recreational hunting		13/160
	- harvesting of natural materials		36/160
	- fuel wood collection		21/160
	- non-consumptive recreation		20/160
	- amenity and aesthetics		6/160
	- natural habitat and biodiversity		16/160
Context (X_C)	GDP per capita[e]	Continuous (PPP-adjusted 2003 US$/year, ln)	8.8 (1.2)
	Population density[f]	Continuous (inhab/km^2, ln)	13.2 (1.6)

Notes: n=60;
[a] For binary and categorical variables, frequency of occurrence; for continuous variables, mean and standard deviation;
[b] Since individual observations may pertain to more than one valuation method or ecosystem service, their number does not add up to 160 and no omitted variable is defined;
[c] Variable included to test for value changes over time;
[d] Variable included to test for publication bias in the valuation literature;
[e] Evaluated at country level, state level for the US;
[f] In year 2000 and within 50 km distance from the valued site (CIESIN, Gridded Population of the World v.2, sedac.ciesin.columbia.edu/plue/gpw).

where $\ln(y_i)$ is the natural logarithm of the value expressed in PPP-adjusted units of 2013 US$ per hectare per year; the subscript i is an index for the n observations; $\alpha_1,\ldots,\alpha_m$ are unknown coefficients of the m study-, site- and context-specific moderator variables $x_1,\ldots,x_m$; and ε is the error term. To assess how the inclusion of less similar study site estimates in the pool of primary studies affects the value transfer estimates for the AV wetland, additional value transfer estimates are produced after the model coefficients are re-estimated with a progressively smaller database of primary valuations, where the least similar observation is removed at each step. Following general rules of thumb for multiple linear regression, the procedure is continued until a minimum number of observations per predictor ratio of 15 is reached (Núñez et al., 2011).

Third, we estimate a weighted least squares model, where the set of weights is represented by the set of similarity indexes (empirical-similarity-weighted model, ESW), normalized between 0 and 1. With the exception of the set of weights, the model specification and regressors selection technique are consistent with what described for the OLS with robust SE regression model.

Standard diagnostic tests are performed to test normality and homoscedasticity of the regression residuals (Shapiro-Wilk and Breusch-Pagan tests), presence of outliers (Bonferroni test), and multicollinearity (Variance Inflation Factor). All statistical tests and regressions are implemented in the R environment (R version 3.1.2; R Development Core Team, 2014).

The results of the meta-regressions are used to estimate the value of ecosystem services provided by the AV wetland site by applying the best-fit regression function and coefficients in combination with the local values of the moderator variables at the policy site. For the set of methodological explanatory variables, the data sample mean was used in the transfer function (Stapler and Johnston, 2009; Ghermandi and Nunes, 2013). Prediction intervals for the value transfer estimates are calculated with the predict method for linear model fits in the "stats" package in R.

Lacking a primary valuation estimate from the AV wetland, we evaluate the accuracy of the value transfer estimates on the available primary valuations of Indian coastal wetlands from Table 1 as a test of the reliability of the value transfer (Brander et al., 2006; Lindhjem and Navrud, 2008). We investigate three different scale-independent accuracy measures: the Mean Absolute Percentage Error (MAPE), the Geometric Mean Absolute Percentage Error (GMAPE) and the Mean Absolute Scaled Error (MASE) (Ghermandi and Nunes, 2013). In addition, the Mean Absolute Error (MAE) is calculated as a scale-dependent summary measure of forecast accuracy. Out-of-sample forecasts for each observation from India are obtained with the $n-1$ data splitting technique, which consists in generating the value transfer model parameters based on a subset of the database that omits the observation under investigation. The baseline forecast method used in the calculation of the MASE is the unadjusted average unit value of all domestic observations from India. Lindhjem and Navrud (2008) found this method to produce lower transfer errors than meta-analysis in an international value transfer exercise. Observations from Table 1 that were obtained with value transfer techniques were excluded from this analysis.

3. Results

3.1. Identification of ecosystem services of AV wetland

The AV wetland has been identified as a source of provisioning, regulating and cultural benefits for the local and regional population (Table 3).

Insofar as provisioning services are concerned, the AV wetland plays an important role as a source of freshwater for the recharge of groundwater aquifers and the proper functioning of the hydrologic cycle. During periods of low stream flow or low lake water levels, the slow discharge of groundwater often helps maintain minimum water levels. The wetland also prevents the intrusion of seawater into the aquifers. The water supply service provided by the AV wetland is limited by the fact that the water in the western section of the wetland (i.e., the Veli lake) is brackish, due to the periodical opening of the sand bar that separates it from seawater during periods of heavy rain, and by the water pollution level that the lake is currently experiencing.

Commercial and artisanal fishing in the wetland focuses on *Etroplus suratensis*, a species that is highly valuable in the market. Recent decreases in catches, however, have become a source of great concern for local fishermen. Other economically valuable fishes such as *Wallago attu*, *Clarias batrachus*, once common in the lake, and endemic species such as *Amblypharyngodon melettinus* were not observed by Regi and Bijukumar (2012) during a fish diversity monitoring study. *Anabus testudinius*, *Hetero pneustes fossilis* and *Anguilla bicolor bicolor* are present but uncommon (Regi and Bijukumar, 2012).

The AV wetland provides valuable regulating services. It mitigates coastal pollution by preventing untreated or poorly treated urban wastewater to directly reach the sea and the nearby beaches. In spite of the establishment of a sewage treatment plant in Thiruvananthapuram in 2013, a large amount of the city's municipal wastewater enters the wetland untreated through a system of drains due to deficiencies in the sewage collection system, which include the lack of maintenance and inadequacy of the old sewer system in the city center (Sheela et al., 2013, 2014a). This leads to ecological deterioration of the lake in the form of hyper-eutrophication, with excessive growth of water hyacinth (*Eichhornia crassipes*), and a drop in the concentration of dissolved oxygen in the upstream portion of the wetland (Akkulam). The wetland plays an additional role in protecting coastal waters during rain weather, by trapping sediments, nutrients and heavy metals from runoff of its catchment basin.

The wetland reduces the frequency and intensity of floods in the upstream watershed and protects shoreline soils from the erosive forces of waves and currents. Because of the increasing tendency of filling up low-lying marsh areas, the flood-absorbing capacity of the upstream urban area has reduced considerably. With the increase in population and high demand of land, urban wetlands are being converted to public housing and industrial purposes. The Akkulam wetland acts as a natural flood moderation zone for rainwater that is collected in the city into the Kannamoola and flows into the wetland before reaching the Arabian sea. The AV wetland holds excess storm water runoff and then releases it to the sea when its absorption capacity has been exceeded. The soil acts as a sponge holding much more water than other soil types. The wetland plants act as a buffer zone by dissipating the water's energy and providing stability by binding the soil with their extensive root systems.

Cultural services are provided by the wetland through the support of tourism and recreational activities and the protection of a natural habitat and biodiversity. Of two recreational boat clubs once in operation, only the one in the downstream section (Veli) of the wetland system is currently open to visitors. The upstream one in the Akkulam

Table 3
Principal ecosystem services provided by the Akkulam-Veli wetland in India.

Category	Ecosystem service	Description
Provisioning	Water supply	Source of freshwater through recharge of groundwater aquifers.
	Commercial and artisanal fishing	Local fishermen catch commercial species such as *Etroplus suratensis*, but populations are in decline.
Regulating	Water quality improvement	Protection of coastal ecosystems from pollution from poorly treated municipal wastewater and stormwater.
	Flood control and storm buffering	Minimization of flooding in the upstream watershed by buffering of excess runoff water from urban area.
	Carbon sequestration	Accumulation of carbon in sediments. No quantitative measurement currently exists.
Cultural	Tourism and recreation	Active boat club in Veli section. Boat club in Akkulam section was closed down due to eutrophication.
	Natural habitat and biodiversity	Habitat for 35 fish species, including one endangered and four vulnerable species. Stopover of migratory birds.

reservoir was closed due to the eutrophication problems experienced in this section of the wetland.

Thirty-five species of both freshwater and seawater fish were recorded in the Veli wetland. The exotic Mozambique tilapia (*Oreochromis mossambicus*) is the dominant species in the wetland, followed by the Pearl spot (*Etroplus suratensis*). Pollution from different sources, heavy eutrophication and dominance of exotic fish species are the main factors affecting ichthyofaunal density in the wetland (Regi and Bijukumar, 2012). The only identified endangered species is the short fin eel (*Anguilla bicolor bicolor*). Four species are classified as vulnerable and seven are under low risk. The wetland is also a stopover location for migratory birds. The spot-billed pelican, a near-threatened species in the IUCN Red List (http://www.iucnredlist.org) was observed at Akkulam wetland in 2013, while the largest populations of migratory birds observed in the wetland in the same year consisted of wood sandpipers and Asiatic golden plovers (Narendran, 2013).

3.2. Econometric results and value transfer estimates

The results obtained with the different specifications of the meta-regression model are presented in Table 4.

The econometric results from the two meta-regression models are consistent in terms of sign, significance and size of the coefficients, and model explanatory power. The diagnostic tests do not indicate particular issues with normality of the residuals, heteroskedasticity or multicollinearity. Both models identify eight statistically significant regressors. The commercial fishing and hunting variable is found significant and positive in the OLS model but not in the ESW model. Conversely, the variable for harvesting of natural materials (which identifies wetland services such as the collection of building and construction material, hay or medicinal plants) is found significant and negative in the ESW but not in the OLS model. The signs of the continuous variables are consistent with the findings of previous wetland ES value meta-analyses (Chaikumbung et al., 2016) and indicate that values tend to increase with GDP per capita and population density, while there are decreasing returns to scale related to wetland size (Brander et al., 2006). Among ecosystem services, commercial fishing and hunting, amenity and aesthetics are more highly valued than harvesting of natural materials and fuel wood collection.

Table 4
Econometric results of the meta-regression of the values of ecosystem services provided by coastal wetlands.

Variable	OLS with robust SE			ESW model		
	Coeff.		SE	Coeff.		SE
Constant	−6.572	***	1.722	−6.202	***	2.276
Travel cost	−1.443	**	0.677	−1.759	***	0.655
Production function	−1.581	**	0.640	−1.259	**	0.630
Wetland size	−0.261	***	0.057	−0.284	***	0.067
Commercial fishing and hunting	0.657	**	0.332			
Harvesting of natural materials				−0.956	**	0.457
Fuel wood	−1.085	**	0.458	−1.058	*	0.599
Amenity and aesthetics	1.792	***	0.530	1.824	**	0.726
GDP per capita	1.045	***	0.144	1.103	***	0.154
Population density	0.402	***	0.101	0.383	***	0.067
R-square	0.493			0.496		
Adjusted R-square	0.466			0.469		
Residual standard error	2.035			1.545		
F-statistic (p-value)	18.13 (< 0.001)***			18.23 (< 0.001)***		
Shapiro-Wilk test (p-value)	0.989 (0.268)			0.988 (0.176)		
Breusch-Pagan test (p-value)	0.347 (0.556)			2.177 (0.140)		
Largest studentized residual (Bonferroni p)	2.849 (0.792)			3.011 (0.481)		
Maximum VIF	1.217			1.211		

Notes: n=158, after removal of two outlier observations; SE=standard error; OLS=ordinary least squares; ESW=empirical-similarity-weighted; VIF=variance inflation factor; significance is indicated with ***, **, and * for 1%, 5% and 10% statistical significance levels respectively.

Table 5
Ecosystem service value estimates for Akkulam-Veli wetland obtained with different value transfer approaches.

Value transfer methodology	ES value flow estimate (US$ 2013/ha/year, PPP)	95% prediction interval (US$ 2013/ha/year, PPP)
Adjusted unit value transfer	8,176	–
Meta-regression:		
OLS with robust SE (n=158)	8,952	[100–798,188]
ESW model (n=158)	7,577	[223–251,505]

Table 5 shows the estimated flow of ES values from the AV wetland. The estimated values range between 7,577 US$/ha/year with the ESW model and 8,952 US$/ha/year with the OLS model, corresponding to a total yearly value flow of 575,852-680,352 US$/year. The adjusted unit value transfer estimate is obtained from the Phang Nga Bay coastal wetland in Thailand (Seenprachawong, 2003), which shares with the AV wetland similar characteristics in terms of ecosystem type, GDP per capita, population density, and valued ecosystem services but is substantially larger, covering an area of about 60,000 ha.

The value transfer estimates for the AV wetland obtained with the three described approaches are fairly consistent and well within the range of values found for other coastal wetlands in India (Table 1). The robustness of the estimated AV wetland values with respect to different value transfer approaches provides support to its reliability as a first estimate of the economic benefits derived from the wetland. Nevertheless, the width of the 95% prediction intervals testifies to a high degree of remaining uncertainty in the model forecasts. Table 5 shows that the prediction interval is narrower for the ESW model than for the OLS with robust SE model.

Table 6 shows three measures of value transfer accuracy for the available primary valuations of coastal wetlands in India. Both MAPE and GMAPE indicate that the two meta-analytical value transfer models perform better than adjusted unit value transfer in out-of-sample forecasting. The OLS with robust SE and ESW models have similar performance, with a slightly better accuracy for the OLS model. As expected, the values of GMAPE are smaller than the values of MAPE, the former measure being less sensitive to outliers and less understating the forecast accuracy of the bulk of the observations (Brander et al., 2006). The MAE is lower for the two meta-analytical

Table 6
Measures of accuracy of the value transfer methodologies for out-of-sample forecasts of values of coastal wetlands in India (n=12).

Accuracy measure	Value transfer methodology		
	Adjusted unit value transfer	Meta-regression: OLS with robust SE	Meta-regression: EWS model
MAPE	10.4	2.45	2.77
GMAPE	2.81	0.72	0.88
MAE	2,907	1,781	1,833
MASE[a]	1.64	0.49	0.51

Notes:
[a] Values are calculated for n =11 observations, after removal of one outlier with disproportionate influence. MAE in US$/ha/year (2013, PPP).

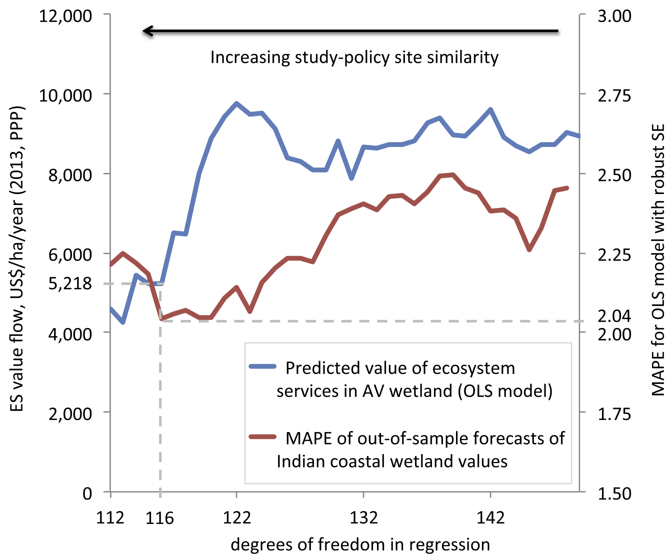

Fig. 2. Variability of predicted values in Akkulam-Veli wetland and transfer error for Indian coastal wetlands for subsamples of study site observations with increasing similarity to policy site.

transfer models than for unadjusted value transfer. The values for MASE indicate that both meta-analytical value transfer models outperform the unadjusted transfer of the mean value of domestic estimates (MASE < 1). On the contrary, adjusted unit value transfer from the database of international studies has a lower accuracy in predicting values from India than the baseline method (MASE > 1). The MAE for the unadjusted transfer of the mean value of domestic estimates is 2,227 US$/ha/year (2013, PPP).

As an additional test of the reliability of the AV wetland value transfer estimate obtained with the OLS meta-regression model and its sensitivity of the results to more or less stringent rules on similarity between policy and study site estimates, Fig. 2 shows how the AV wetland value predicted by the OLS with robust SE model is affected by progressively dropping the least similar study site observation from the regression and re-estimating the model coefficients accordingly. Within the range of observation, the value forecasts for the AV wetland obtained with the model range between 4,245 and 9,748 US$/ha/year (2013, PPP). Fig. 2 also shows the values of the MAPE accuracy measure for primary valuations of Indian coastal wetlands, as obtained for the OLS with robust SE model with the previously described out-of-sample forecast procedure. The minimum value of MAPE (=2.042) is found for the regression with 116 degrees of freedom, i.e., after the 21% of observations with the lowest similarity score to the AV wetland are dropped from the regression. The corresponding value for the AV wetland is 5,218 US$/ha/year (2013, PPP)..

3.3. Policy implications of case study results

The case study application to the Akkulam-Veli wetland in Kerala, India, shows that different value transfer techniques provide fairly robust estimates of the services that this ecosystem provides to the local and regional population. The estimated flow of ES values ranges between 7,577 and 8,952 US$/ha/year (2013, PPP), corresponding to a yearly benefits flow of 575,852-680,352 US$/year (2013, PPP). Mainstreaming such ecosystem benefits and their values can help to move forward the ongoing policy dialogue regarding the often conflicting goals of protection of the AV lake ecosystem and development of the surrounding areas.

The release of urban waste from within its catchment basin is currently the main cause of ecological deterioration in the AV wetland. Inflow of untreated sewage from the drain system has resulted in hyper-eutrophication and deterioration in water quality. Both effects conflict with the sustained provision of the identified ecosystem services. The infestation of water hyacinth has choked water ways and prevents recreation activities such as boating (in the upper reservoir), contact recreation and water sports. Water hyacinth mats also form breeding sites for mosquitoes causing various vector-borne diseases in the city, including dengue fever (Sheela et al., 2014b). Low dissolved oxygen content in the lake affects the presence of fish and other flora and fauna. Siltation of the lake has reduced the water holding capacity of the lake.

Policy guidance for defining sustainable lake management strategies can be derived from weighing the benefits of preserving (and possibly enhancing) the current provision of ecosystem services against the costs of the interventions required to prevent the inflow of untreated urban sewage. Such interventions may include the replacement of the city's old sewer system, upgrade of the current sewage pumping stations to prevent bypass of the wastewater, desiltation, removal of water hyacinth, regulate monitoring of the drains, and provision of proper sanitation for slums and houses located in proximity of the drains. Such strategies should be investigated within an Integrated Water Management approach, which should also take into account the need for improved stormwater management in the catchment and the current deficiencies in the urban waste treatment system, in the context of the current lack of adequate financial, technical, and managerial resources for the conservation of the lake and its drains.

Within this framework, a follow-up of the present study could focus on the production of spatially explicit ES value maps, with potential contributions towards: (1) visualizing the distribution patterns of ecologically important landscape elements and their overlaying with other relevant aspects and metrics; and (2) enabling decision-makers to assess the impacts and trade-offs associated with alternative policy scenarios or management plans and identify areas where investing in ES protection can enhance both human development and ecosystem conservation.

4. Discussion and conclusion

There is a growing policy and academic interest in transferring ES values from existing studies to previously unstudied policy sites. Although always to be considered a second-best strategy to a time- and location-specific primary valuation research, value transfer is particularly challenging in developing countries. In such contexts, the scarcity of financial resources and expertise often combines with the lack of primary valuations from geographically, socio-economically and ecologically comparable sites to force practitioners and researchers to choose between: (i) foregoing economic valuation entirely; (ii) transferring values from estimates obtained in different socio-economic contexts without adjustment for local characteristics; or (iii) attempting to control for specific characteristics that are expected to affect ES values in the context of international value transfer. The latter approach increasingly relies on meta-regression analysis. While the literature on meta-analytical value transfer provides guidance on how to assess and control for heterogeneity in study site valuations, there is a lack of guidance on how to quantitatively assess and treat (dis-) similarity between study and policy sites and understanding of how more or less stringent similarity thresholds may affect value transfer estimates.

This paper proposes a methodology to calculate a study-policy site similarity index and illustrates how the index can be embedded both in adjusted unit value transfer and meta-analytical value transfer techniques through an empirical case study application to a tropical coastal wetland in India. The proposed methodology makes use of tools developed in the context of similarity analysis and cluster analysis and allows to account for a range of site- and context-specific characteristics, also if measured in different scales (e.g., nominal, ordinal or ratio scale). As such it can provide a useful tool to inform the ongoing debate regarding selection effects in meta-analysis and value transfer (Rosenberger, 2015). In the present case-study application, we rely on the explanatory variables identified in a previously published meta-regression analysis of coastal wetland ecosystem services. The application of the methodology in other contexts would benefit from a set of standard rules concerning the selection of explanatory variables in ES values in meta-regression analysis, which is currently absent in the literature.

To the best of our knowledge this paper presents the first application of empirical-similarity-weighted regression in the context of a meta-analytical value transfer exercise. The inclusion of empirical-similarity weights in the regression contributes to narrow down the large uncertainty around value transfer estimates in the case study application. Testing of the meta-analytical value transfer model in the context of the available primary coastal wetland valuations from India shows that restricting the database of primary valuations based on the proposed index of study-policy site similarity results in increased value transfer accuracy, as reflected by the MAPE measure. For all considered accuracy measures, meta-analytical value transfer outperforms adjusted unit value transfer, with a conventional OLS with robust SE model performing slightly better than the empirical-similarity-weighted regression model. In the context of the present international value transfer application, adjusted unit value transfer provides less accurate estimates than the unadjusted average unit value of all domestic observations from India.

To conclude, further and more systematic testing of the need and potential benefits to account for study-policy site similarity in value transfer exercises is required to understand the extent to which the results presented in this paper are contingent upon the case study application or have more general validity. While we recognize a number of limitations in the use of value transfer techniques for policy guidance, the intention of this paper is to move the debate forward towards meeting the demand for more accurate and policy-relevant value transfer applications, particularly in the context of data-scarce developing countries.

Acknowledgments

The authors thank Dr. Paulo A.L.D. Nunes at the Ecosystem Services Economics Unit of the United Nations Environment Programme for his valuable comments at various stages of the preparation of this manuscript.

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