Benefits from water ecosystem services in Africa and adaptation to climate change.

Pettinotti L., de Ayala A., Ojea E.

Authors: Laetitia Pettinotti, Basque Centre for Climate Change, Spain laetitia.pettinotti@bc3research.org, corresponding author.

Amaia de Ayala, Basque Centre for Climate Change, Spain.

Elena Ojea, Future Oceans Lab, Universidade de Vigo, Spain.

Abstract: The present study collects original monetary estimates for ecosystem service benefits on the African continent from 36 available valuation studies. A database of 178 monetary estimates is constructed to conduct a meta-analysis that digs into what factors drive water ecosystem services values in Africa for the first time. We find that the service type, biome, author affiliation and other socioeconomic variables are significant in explaining benefits from water services. In order to understand the importance that benefits from ecosystem services have for climate change adaptation, we explore the relationship between these benefits and the countries vulnerability and readiness to climate change. We find that countries face synergies in terms of how valuable their ecosystem services are and their potential adaptation capacity. More vulnerable countries are associated with lower benefits from ecosystem services, especially regarding provisioning and regulating services. On contrast, countries with a higher adaptation potential are associated with higher ecosystem services values. These results highlight the important role of ecosystem services and their benefits in climate change vulnerability and adaptation.

Keywords: Adaptation; Africa; Ecosystem Services; Meta-analysis; Valuation; Vulnerability; Water.

JEL classification: N57: Africa • Oceania. O13: Agriculture • Natural Resources • Energy • Environment • Other Primary Products. Q57: Ecological Economics: Ecosystem Services • Biodiversity Conservation • Bioeconomics • Industrial Ecology. Q54: Climate • Natural Disasters • Global Warming

1 Introduction

The concept of ecosystem services (ESs), understood as the contribution of the benefits derived passively or actively from ecosystems towards current and future human well-being (Fisher et al., 2009), has gained increasing recognition in the last decade. Mainstreamed by the Millennium Ecosystem Assessment (MA) Program (2005), ESs were at the focus of the UNEP led study on The Economics of Ecosystems and Biodiversity (TEEB, see de Groot et al., 2012), and are still evolving under the currently developing Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) initiative (Díaz et al., 2015). The conservation and improvement of ecosystems has been identified as a central challenge to sustaining livelihoods for the XXIst century (Gleik et al., 2003; Guerry et al., 2015), and research programs and conservation initiatives have been launched at local, national and international levels (Díaz et al., 2015). In this context, research to synthetize existing evidence and provide policy guidance regarding the potential of ESs for climate change adaptation is of prime importance.

The present paper focuses on water ESs in Africa in the context of climate change adaptation. Water ESs can be understood as “the benefits to people produced by terrestrial ecosystems effects on freshwater” (Brauman et al. 2007), in other words, the services provided by watersheds in the maintenance of water flow and quality, biomass productivity and landscapes. We look at water ESs as a typology of services highly relevant for livelihoods globally. Previous research has paid a lot of attention to this type of ESs in other regions mainly due to the development of Payment for Ecosystem Services (Lele, 2009). In this paper, we change the focus to ESs research on the African continent, for three main reasons: 1. freshwater systems are pivotal to the delivery of ESs’ crucial to millions of livelihoods (WWAP, 2016); 2. the African continent presents in general a high climate change vulnerability which exacerbates the need for immediate policy solutions (World Bank, 2007) which could rely on ecosystems-based adaptation (Jones et al., 2012), and; 3. African water ESs continue to be inadequately investigated with very poor coverage (Lele, 2009).

The maintenance and delivery of water ESs is critical in Africa, where 600 million people are projected to be under water stress by the 2050s[a] (IPCC, 2007), 90% of agriculture relies on rainfall, and hydropower is the main source of electricity contributing 20.5% to the total energy mix of Sub-Saharan Africa in 2013 (IEA Statistics, 2017; World Water Assessment Programme, 2016). While many African countries have abundant freshwater resources, the final benefits to livelihoods are compromised by the lack of water storage and distribution systems (Green et al., 2015). Water services are also affected by very high variability of all climate and water resources characteristics, which are exacerbated by climate change (Faramarzi et al., 2013; IPCC, 2014). Understanding the benefits of water services delivery through economic valuation (for details on ESs valuation methods see de Groot et al., 2012; Pascual et al., 2010) and the factors that affect these economic benefits can provide guidance for water resources management and climate change adaptation.

Africa is not the continent with the largest ES valuation literature. Only 19% of the valuation studies referenced in the TEEB are located in Africa. Most studies are located in the Americas (33%) and Asia (26%) (based on the TEEB database manual by Mc Vittie and Hussain, 2013). Moreover, the valuation literature in Africa is geographically disparate: Southern and Eastern Africa gather the highest number of studies while North, West and central sub-Saharan Africa go under-represented (based on our findings and Mc Vittie and Hussain, 2013). Valuation studies on water ESs in Africa represent 28% of all water ESs valuation studies globally (Mc Vittie and Hussain, 2013). The most frequently valued water-related ESs are raw material and food provision, mainly due to two different reasons: 1. these services are relatively easy to value using the direct market pricing method (Van der Ploeg et al., 2010) and; 2. dependence on

---

[a] Water stress defined by IPCC (2007) as a combination of water availability, accessibility and demand.

provisioning services is high in African developing countries, hence an early focus on estimating values for this type of service (Egoh et al., 2012; Mc Vittie and Hussain, 2013). Indeed, ESs' consumptive outputs (e.g. crops, fuelwood etc.) tangibly contribute to subsistence livelihoods and complement the household income thus participating in poverty alleviation and reducing vulnerability (Egoh et al., 2012; Suich et al., 2015).

The role of ESs in reducing vulnerability and in contributing to adaptation is particularly important in the face of climate change (Munang et al., 2013). Adaptation to climate change can be rooted in ESs sustainability - known as 'ecosystem based adaptation' - and is expected to provide cost-effective adaptation resulting in resilient socio-ecological systems (Jones et al., 2012). Early evidence on ecosystem based adaption supports this is the case (Doswald et al., 2014). However, little is known yet on the linkages between adaptation and the value of ESs at a regional scale.

This paper synthesises water ESs values elicited for Africa in the last three decades using meta-analysis methodology. Meta-analysis – the analysis of analyses as defined by (Glass, 1976) - has been increasingly used in the field of environmental valuation (Brander et al., 2006; Ghermandi et al., 2008) as it allows for a rigorous testing of a central tendency across a large number of studies while controlling for the effect of several parameters (Nelson and Kennedy, 2009). In this context, we perform a meta-analysis for water ESs values to: 1) provide a quantitative answer for what factors drive water ESs values in Africa and; 2) understand the relationship between climate change adaptation and the benefits obtained from ESs. Understanding what drives the value of water ESs in Africa and the potential trade-offs or synergies with adaptation will help designing and implementing policies in line with the ecosystem based adaptation approach.

Next section introduces the methods, outlines the data selection, standardization and coding carried out in order to perform the meta-regression. Section 3 presents the model specification and section 4 its associated results. Last section (**Error! Reference source not found.**) discusses the result implications and concludes.

2 Methodology

2.1 Existing meta-analyses of water ESs

Studies aimed at understanding the benefits from ESs have so far conducted meta-analyses focused on one ecosystem type, such as coral reefs (Brander et al., 2007; Ghermandi and Nunes, 2013), coastal and marine ecosystems (Liu and Stern, 2008), wetlands (Brander et al., 2006; Brouwer et al., 1999; Chaikumbung et al., 2016; Ghermandi et al., 2008; Woodward and Wui, 2001), forests (Barrio and Loureiro, 2010; Ojea et al., 2016), or mangroves (Brander et al., 2012). Other studies focus on one or a bundle of ESs for a specific ecosystem, such as recreational services from forests (Ojea et al., 2015; Zandersen and Tol, 2009); water ESs from forests (Ojea et al., 2015; Ojea and Martin-Ortega, 2015); regulating services from wetlands (Brander et al., 2013) and non-carbon services from forests (Ojea et al., 2016). Even if most of these studies do not define themselves as focusing on water ES, most of them do as per Brauman et al. (2007) definition (see section 1). The geographic coverage of these meta-analyses is slightly biased towards North America, especially if the study is focused on wetlands (Ghermandi et al., 2008). Most studies have adopted a global coverage while a few have specifically focussed on developing or emerging economies (wetlands in developing countries in Chaikumbung et al., 2016; water and recreation services from forests in central America in Ojea et al., 2015; and water services from forests in central and south America in Ojea and Martin-Ortega, 2015.

The present work is, to our knowledge, the first meta-analysis study on the economic valuation of water ESs specifically on the African continent. For this, an original dataset is constructed based on secondary data from published literature, gathering information on the ES, its value, and additional socioeconomic variables following our conceptual framework (section 2.2). A meta analytical model is estimated (section 3.2) to explain the observed variations in economic values while controlling for a set of study and context characteristics (Stanley et al., 2013).

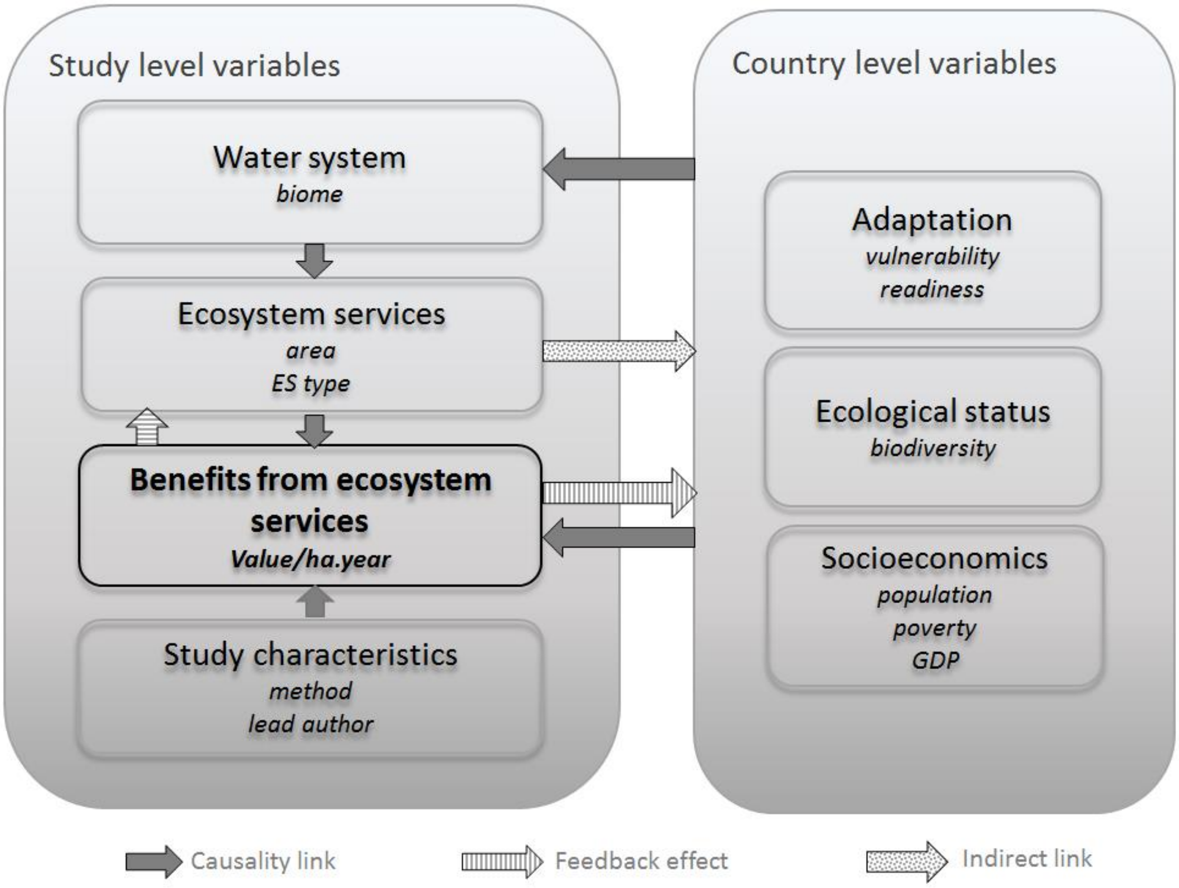
2.2 Conceptual framework

The construction of the data set for the meta-analysis is guided by the conceptualisation presented in the framework below (Figure 1), which we adapted to our case study from TEEB (de Groot et al., 2012). The water system (the biome) supports the delivery of ESs (categorized as surface area of production[b] and type of ESs), which yields a benefit to people that can be measured in monetary terms (and could potentially depend on the valuation methodology used and the authors' familiarity with the case study area). This monetary or economic value is also dependent on the wider context where it occurs and will be influenced by some context variables on a larger scale, including socio economic and demographic factors (e.g. population, GDP, education level), biodiversity richness, and climate change adaptation and vulnerability. At the same time, it also impacts on the water system. In turn, the ESs economic value can have a feedback effect on the delivery of ESs (depletion, for example) as well as on the context (e.g. reduced poverty).

---

[b] Standardization by production unit area is necessary to allow comparability across estimates.

Figure 1: Conceptual framework for the meta-analysis



Previous meta-analytical approaches for ESs support this framework. These studies include variables related to the context, the study and the ecosystem, that are impacting the economic values of the water related ESs (dependent variable) (Brander et al., 2013; Chaikumbung et al., 2016; Ojea et al., 2010; Ojea and Martin-Ortega, 2015). Moreover, the framework accounts for feedback loops and interactions among the different components of the complex social-ecological system. The next sub section details the selection process for the dependent variable. The full list of variables and their summary statistics are presented in Table 1. Moreover, a detailed definition of each variable is given in Appendix 1.

2.3 Database building

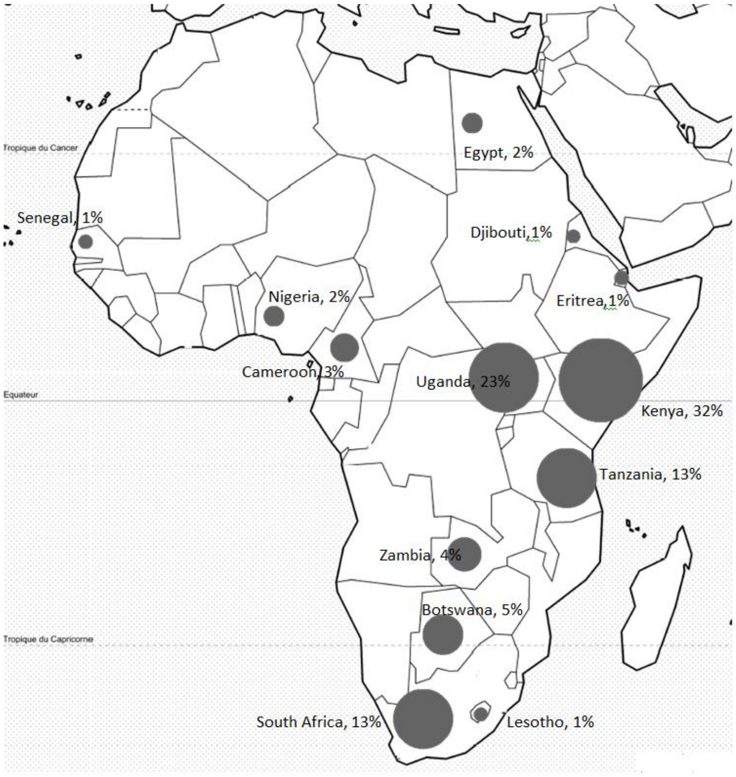
A peer reviewed literature search was conducted through electronic journal databases such as EVRI, SCIENCEDIRECT, Springer link during the months of March to August 2014 using different combinations of the keywords “Economic Valuation”, “Africa”, “Valuation”, “Ecosystem” and “Ecosystem service”, among others. The grey literature was screened as well using web-based search engines with the same keywords. This was to avoid publication bias and reflect that some ESs valuation studies are intended for policy makers and might not be published as journal papers (Ghermandi et al., 2008; Ojea and Martin-Ortega, 2015). Backward literature search was also performed. The global TEEB valuation database by Van der Ploeg et al. (2010) was screened as it gathers a comprehensive collection of valuation data for water updated to 2010. 36 data points drawn from 12 studies were extracted from this database.

The valuation of water ESs constituted the main criterion for inclusion of a study in the dataset. On a second screening, studies were selected if containing primary valuation data that was explicitly associated to a given service, for a given ecosystem type and elicited with a clearly laid out valuation method. Third, a monetary value per hectare per year unit was adopted. If the data was not readily available in this unit, only values which could be recalculated to the standard unit with information presented within the studies were included. Care was taken to avoid double counting by only reporting disaggregated primary data. As a result, 36 studies out of the 72 derived from the search were not included due to qualitative valuations, data incompleteness or to the impossibility to convert the value to the standard unit.

All observations were standardised for comparability to 2014 international USD using the World Bank purchasing power parity dataset. This is standard procedure due to the various time period reported and to adjust for the different currencies, income and consumption levels between African countries (Brander et al., 2006; Ojea and Martin-Ortega, 2015; Woodward and Wui, 2001).

The semi-systematic search resulted in an original dataset of 178 ESs value observations drawn from 36 studies dating from 1982 onward and spanning 13 countries (see Figure 2). Data is distributed across Kenya, 32% of the observed values, representing 16% of the studies; Uganda, 23% of total data points representing 27% of included studies; and Tanzania and South Africa, 12% of the reported values, respectively representing 8 and 18% of all studies. East Africa makes up more than half the data points. Other countries provided 19% of data points representing 29% of the studies.

Figure 2: Geographic distribution of the ESs value observations



On average, each study provided 5 observations with one outlier study containing 20 observations (Emerton, 2014) and 10 studies providing a single one (e.g. Naidoo and Adamowicz, 2005; Turpie and Joubert, 2001). A list of the studies included for the analysis is available in Appendix 2.

3 Model and specification

3.1 Explanatory Variables

We shall distinguish between study-specific variables that are obtained from the original studies and context variables that are excerpted from global datasets for development and natural indices databases. Description, sourcing and summary statistics of all variables used in the model are available in Table 1.

Table 1: Variable description and summary statistics

Variable	Type	Description	Variable name	Coding	Number of observations	Mean (Std. Dev.)	Range [Min; Max]
Dependent variable							
lnVAL	Numeral	Natural logarithm of the ES value in international $/ha.year (2014 value)			178	3.84 (3.00)	[-4.35; 11.35]
Explanatory variables							
Study variables							
BIO	Dummy	Type of biome where the service is provided	BIO1	Inland wetlands (=1)	64	0.36 (0.48)	[0; 1]
			BIO2	Coastal wetlands (=1)	45	0.25 (0.44)	[0; 1]
			BIO3	Freshwater[c] (=1)	20	0.11 (0.32)	[0; 1]
			BIO4	Woodlands (=1)	14	0.08 (0.23)	[0; 1]
			BIO5	Tropical forest (=1)	27	0.15 (0.36)	[0; 1]
			BIO6	Grasslands (=1)	8	0.04 (0.21)	[0; 1]
SERV	Dummy	Type of ecosystem service as per the TEEB classification	SERV1	Provisioning (=1)	113	0.63 (0.48)	[0; 1]
			SERV2	Regulating (=1)	35	0.18 (0.39)	[0; 1]
			SERV3	Habitat (=1)	15	0.08 (0.28)	[0; 1]
			SERV4	Cultural (=1)	18	0.10 (0.30)	[0; 1]
logHA	Numeral	Log of the surface area of the ES in hectares	logHA		178	10.35 (3.60)	[-.47[d]; 18.19]
METD	Dummy	Original valuation method used in the primary valuation	METD1	Direct market price (=1)	127	0.72 (0.45)	[0; 1]
			METD2	Cost based methods (=1)	28	0.16 (0.37)	[0; 1]
			METD3	Factor income (=1)	3	0.02 (0.13)	[0; 1]

---

[c] Freshwater biomes include rivers, lakes and floodplain in line with the categorisation of the TEEB (2010)

[d] The negative values are due to the <1ha figures for certain ES.

			METD4	Contingent valuation (=1)	17	0.10 (0.30)	[0; 1]
			METD5	Travel cost (=1)	2	0.01 (0.11)	[0; 1]
LEAD	Dummy	Whether the lead author of the study is based in a local or international institution located in Africa.	LEAD	First author based in Africa (=1) other (=0)	178	0.80 (0.40)	[0; 1]
Context variables							
Socio economic and demographic							
PMRY_ENROL	Numeral	Primary school enrolment rate, both sexes, in percentage (World Bank, 2015)			177	102.94 (17.13)	[30.61; 131.27]
GDP	Numeral	GDP per capita in thousands of 2014 PPP USD (World Bank, 2015)			178	3.30 (3.27)	[0.61; 1.23]
POP_R	Numeral	Percentage of rural population (World Bank, 2015)			178	74.86 (12.00)	[23.56; 88.17]
POVTY_R	Numeral	Rural poverty headcount ratio at national poverty line in percentage (World Bank, 2015)			175	50.17 (19.09)	[22.4; 92.2]
Biodiversity							
GEF	Numeral	Composite index by the Global Environmental Facility of relative biodiversity potential for each country. (Global Environmental Facility, 2015)			178	9.37 (6.67)	[0.31; 23.52]
Climate change							
VUL	Numeral	Composite index scoring the vulnerability of each country to climate change. (Notre Dame University, Canada, 2016)			178	1.01 (0.024)	[0.98; 1.11]
READ	Numeral	Composite index scoring the readiness of a country to leverage investment in climate change adaptation policies. (Notre Dame University, Canada, 2016)			178	0.99 (0.06)	[0.88; 1.09]

Study-specific variables include the methodology applied in the original valuation exercise and other characteristics of the case studies. Biome (*BIO*) can be an inland wetland, a coastal wetland, freshwater, woodlands, tropical forest, or grassland, based on what is defined in the original publication. Ecosystem service (*SERV*) is classified following the MA and TEEB categorisation into provisioning, regulating, habitat/supporting and cultural services. The valuation method (*METD*) can be direct market pricing, cost based methods, factor income and production function, contingent valuation or travel cost. The surface area is included in hectares (*logHA*) and refers to the area of the ESs provision. Finally, information on the authors is collected to identify any "authorship effect" (Brouwer et al., 1999) related to the lead author's affiliation to an institution or an international organisation based in Africa (*LEAD*).

Context variables related to development, biodiversity and adaptation to climate change are also expected to influence the value of water ESs (Ghermandi et al., 2008) and were included in our database. First, socio-economic and demographic variables such as GDP per capita (*GDP*), education level (*PMRY_ENROL*), population (*POP_R*) and poverty (*POVTY_R*). Second, a variable reflecting the biodiversity status of a country is also included with the biodiversity richness indicator (*GEF*) (Ojea et al., 2010). Third, climate change indices developed by Notre Dame University[e] for vulnerability to climate change and readiness to adapt are also considered (*VUL* and *READ*). Each index considers several dimensions of vulnerability and readiness (see Appendix 1). We use the adjusted to GDP indices that measure the actual performance of the country compared to its expected performance given its GDP. Care was taken when selecting the variables to minimize potential collinearity[f]. The tests for collinearity produced a diagnostic of no correlation problem as the Variance Inflation Factors (VIF) returned values

---

[e] ND Gain country index http://index.gain.org/

[f] For example the adjusted for GDP ND gain indices were selected rather than the non-adjusted one to limit collinearity.

lower than 10 for all variables[g] (Ojea et al., 2010). A detailed explanation on the context variables and their sources is also available in Appendix 1, and correlation for each variable is available in Appendix 2.

3.2 Model specification

The dependent variable in the models ($\ln y_{in}$) is a vector of the water ESs monetary values converted to 2014 international US$ per hectare per year using the PPP index of World Bank (2015), and is expressed in logarithmic terms (see Table 1) following the result of the Box-Cox test (Ojea et al., 2010; Ojea and Loureiro, 2011)[h]. Semi-logarithmic regression is a common functional form in meta-analyses (Barrio and Loureiro, 2010; Brander et al., 2007; Johnston et al., 2005; Lindhjem, 2007; Liu and Stern, 2008; Richardson and Loomis, 2009; Rolfe and Brouwer, 2012; Woodward and Wui, 2001). The explicit specification of the meta-regression model can be described as follows:

$$\ln y_{i,j} = \alpha + X_{s,i,j}\beta_s + X_{c,i,j}\beta_c + \varepsilon_i + u_j, \tag{1}$$

where i denotes each specific study $(i = 1, 2, ..., N)$, j refers to the value estimate reported in the study $(j = 1, 2, ..., M_i)$, α is the usual constant term or intercept and the β vectors are the coefficients to be estimated in the meta-analysis. Each β coefficient is associated to a type of explanatory variable: either study specific (X_s) or context specific (X_c) (see Table 1). Where each study i provides a single estimate j, then $M_i = 1$ and ε_i collapses into u_j. However, where a study gives more than one value estimate, it is necessary to account for the common error across estimates (u_j) and the individual-specific effect or panel error within a study (ε_i).

---

[g] Mean VIF of 2.78 ranging from 1.50 to 5.12.

[h] The Box-Cox test resulted in a value of – 298.2 (χ^2 = 90.26) hence the null hypothesis of no difference between semi-log and linear model was rejected at a 1% significance level (i.e., models are significantly different at 99% confidence level).

3.3 Model estimation

There are several approaches to estimating this model depending on assumptions regarding the error variance-covariance matrix (Lindhjem, 2007). Table 2 presents the variety of estimators used in recent meta-analysis literature in environmental economics. They include Weighted Least Squares (WLS), Generalized Least Squares (GLS), explicit specifications of panel models with fixed or random effects, and Ordinary Least Squares (OLS) usually applied with Huber-White adjusted standard errors clustered by study. This last estimator has been most commonly used in the relevant literature (see Table 2). Meta-regression models dealing specifically with data heterogeneity, heteroscedasticity and correlated observations are described in Nelson and Kennedy (2009).

Table 2: Models estimated in meta-analysis studies

Estimation technique	**Study**
OLS	Brander et al., 2012; Ghermandi et al., 2008; Lindhjem, 2007; Liu and Stern, 2008; Loomis and White, 1996; Ojea et al., 2016, 2010; Richardson and Loomis, 2009; Shrestha and Loomis, 2001
OLS with Huber–White adjusted SE	Barrio and Loureiro, 2010; Brander et al., 2006; Ghermandi and Nunes, 2013; Johnston et al., 2003; Lindhjem, 2007; Woodward and Wui, 2001; Zandersen and Tol, 2009
Weighed OLS with Huber White	Ghermandi and Nunes, 2013
Multi-level OLS	Bateman and Jones, 2003; Brander et al., 2007; Brouwer et al., 1999; Ghermandi et al., 2008; Johnston et al., 2003
GLS	Ojea et al., 2015; Ojea and Loureiro, 2011
Fixed GLS	Ojea and Martin-Ortega, 2015
RE GLS	Chaikumbung et al., 2016; Ojea and Loureiro, 2011
GLS cluster SE	Chaikumbung et al., 2016
Weighed GLS with cluster SE	Chaikumbung et al., 2016; Johnston et al., 2003

Note: some studies estimate more than one model and hence are reported multiple times. Generalized Least Square (GLS), Ordinary Least Squares (OLS), Fixed Effects (FE), Random Effects (RE), Standard Errors (SE).

Since most studies in the database report more than one monetary value estimate (a panel of observations), estimates from the same study are likely to be correlated, and therefore the meta-regression specification defined in (1) was estimated with data-panel structure following recommended practice (Nelson and Kennedy, 2009)[i].

Finally, the Hausman test was used to determine the appropriate fixed or random effects panel data model. This procedure tests whether a significant correlation between unobserved individual-specific random effects (ε_i) and the explanatory variables (X_i) exists (see Cameron and Trivedi, 2009, chapter 8; Wooldridge, 2002, chapter 10). The Hausman specification test resulted in a χ^2 value of 11.46 with Prob.> χ^2 = 0.32, yielding to not reject the null hypothesis of non-correlation at 5% significance level, and therefore supporting the random effects model. Cluster-robust standard errors were specified to control for heteroscedasticity (Nelson and Kennedy, 2009).

4 Results

To better explain the variations in the value observations and check for the stability of the results obtained, a baseline model (Model 1) and an extended model (Model 2) with a focus on climate change vulnerability and adaptation are estimated. In addition, cross-products of variables are computed to further interpret the results (section 4.2).

4.1 Baseline and extended models

Both models are random effects panel data models with cluster-robust standard errors and are estimated in STATA (V.14.1)[j]. The two models perform well with reasonable R square for this type of

---

[i] As pointed out by Nelson and Kennedy (2009), when estimates from the same study are likely to be correlated (correlated effect-size estimates), hierarchical / multilevel, panel data, clustering software or even OLS with robust standard errors should be used, and researchers can apply whichever is most convenient.

[j] A GLS model corrected for heteroscedasticity and an OLS with Huber-White standard errors were also estimated and similar results were obtained (in terms of coefficients significance and behavior).

study[k]. The estimated coefficients along with their standard errors and 95% confidence intervals are presented in Table 3:.

Table 3: Meta-analysis regression model 1 and 2

	Model 1		**Model 2**	
Variable	**Coefficient (Std. Error)**	**95% CI**	**Coefficient (Std. Error)**	**95% CI**
BIO3	-1.086** (0.376)	[--1.822 -.349]	- 1.023** (0.337)	[-1.684 -.363]
SERV1	-1.481* (0.859)	[-3.165 .204]	-1.461* (0.868)	[-3.163 .241]
SERV2	-.166 (0.713)	[-1.564 1.232]	-.215 (0.727)	[-1.639 1.210]
SERV3	-1.668* (0.951)	[-3.531 .196]	-1.810** (0.914)	[-3.603 -.019]
logHA	-.357*** (0.084)	[-.523 -.192]	-.295*** (0.083)	[-.458 -.133]
METD123	-.617 (0.852)	[-2.288 1.053]	-.587 (0.859)	[-2.271 1.097]
LEAD	1.949** (0.817)	[.349 3.550]	2.044** (0.749)	[.575 3.512]
PMRY_ENROL	-.035 (0.031)	[-.096 .027]	-.0342 (0.026)	[-.085 .017]
GDP	.311* (0.189)	[-.060 .681]	.367** (0.143)	[.087 .648]
POP_R	.039 (0.044)	[-.048 .126]	.0482 (0.040)	[-.029 .126]
POVTY_R	-.040** (0.017)	[-.074 -.007]	-.044*** (0.014)	[-.071 -.018]
GEF	-.019 (0.075)	[-.166 .128]	-.139* (0.074)	[-.284 .005]
VUL			-46.302*** (12.166)	[-70.147 -22.458]
READ			12.971** (6.840)	[-.435 26.377]
Constant	9.985** (3.930)	[2.282 17.688]	43.281** (15.353)	[13.191 73.371]
Observations	174		174	
Groups	34		34	
R-sq:	0.3917		0.4818	

Note:

***, **, *: Significance at the 1%, 5% and 10% levels, respectively.

Other combinations of variables were tried but gave no significant result

CI: Confidence Interval

---

[k] The overall R-sq is in line with previous published work using the same model (Mattmann et al., 2016) as well as with other model results (Brander et al., 2012, 2006; Brouwer et al., 1999; Chaikumbung et al., 2016; Ghermandi et al., 2008; Ojea et al., 2010, 2015; Shrestha and Loomis, 2001; Woodward and Wui, 2001).

The coefficients for the dummy variables can be interpreted as constant proportional changes given an absolute change in the variable.

For the study characteristics, the freshwater ecosystems (*BIO3*) resulted into a negative and significant coefficient indicating that freshwater ecosystems have in general, lower ESs benefits than other types of biomes in the dataset (grasslands, wetlands and woodlands, among others). Provisioning (*SERV1*) and habitat services (*SERV3*) display significant negative coefficient estimates, with respect to cultural services as the omitted variable (*SERV4*). This result indicates that provisioning and habitat services are, in general, related to lower ESs benefits as compared to cultural services. One explanation could be that revenues from international tourism can be substantially larger than the economic value derived from provisioning goods, as obtained in other analyses (UNEP, 2010). But this potential effect calls for the need to understand who the users of the ecosystem services are, so that policy decisions affect targeted populations. Unfortunately, this has not been possible in our analysis. Another potential explanation lies in the use of the market price valuation method, which in the literature is recognized for providing slightly lower estimates than other methodologies (e.g. Brander et al., 2006).

The surface area is also negative and significant, showing that, on average, the larger the area where the ES is produced, the lower the benefit per hectare. This tendency is in line with other studies on environmental valuation and is due to decreasing marginal returns with size (Brander et al., 2006; Chaikumbung et al., 2016; Ghermandi et al., 2008).

The affiliation of the lead author of the study (*LEAD*) has a significant and positive impact on the values, which indicates that, on average, valuation studies led by a researcher based on the African continent tend to provide higher benefit estimates. One reason behind this could be that local researchers design studies that are more likely to capture total ESs values, but further analysis on the effect of the lead author is needed to understand what particular factors are driving this finding.

Regarding the valuation method of the primary studies, market-based valuation methods (*METD123*) seems not to be significantly different from non-market methodologies in our dataset. However, environmental valuation literature generally shows higher values with non-market valuation techniques than with market-based valuation methods (Brander et al., 2006).

ES values greatly differ depending on context characteristics such as GDP, poverty and climate change indices. *GDP* per capita is positively related with the benefits from ESs, albeit for a very low effect. The rural poverty measure (*POVTY_R*) has, on average, a significant negative effect on water ESs benefits. Possible explanations for this includes that a higher poverty rate in a rural setting translates into a higher reliance on natural resources, which subjected to heightened human pressure degrade and provide services of lesser value (either due to lower quality or quantity). This is a two-way effect and the opposite argument could also be made, as having low ESs values leads to greater poverty rates. Primary education enrolment (*PMRY_ENROL*) and percentage of rural population (*POP_R*) are on average not significant in either model.

Model 2 results are very similar to model 1 with the exception of the biodiversity indicator (GEF) that becomes statistically significant. The negative coefficient for *GEF* suggests that there is a trade-off between a country's biodiversity potential and ESs benefits. Phelps et al. (2012) suggest that there may be important trade-offs between biodiversity conservation and regulating services such as carbon uptake by forests. We will investigate this hypothesis later in section 4.2 to examine if this negative sign can be associated with regulating services.

Model 2 also shows that vulnerability to climate change of a given country (*VUL*) results into a significant negative estimate. As vulnerability to climate change is higher in a country, the ESs benefits are lower. This result illustrates the relationship between ESs benefits and vulnerability to climate change. It is to be noted that GDP and vulnerability levels are positively correlated[l], confirming that less developed countries are more vulnerable to climate change. Higher vulnerability lowers ESs benefits, what may indicate the importance of highly valued ESs for adaptation. A feedback loop pattern could be at play: an increased vulnerability can in part be due to a degradation of ecosystems, and a heightened degradation could lead to a reinforced vulnerability.

In agreement to the findings on vulnerability, readiness to adapt to climate change index (*READ*) displays, on average, a positive relationship with ESs benefits. This suggests that when institutions are more able to leverage finance for climate change adaptation and implement adaptation policies at country level, the values associated with ESs in that country are also higher. This result is also in line with previous literature showing for some cases (not at the country level) that promoting ESs can be a cost-effective adaptation measure (Ecosystem-based adaptation) (Doswald et al., 2014; Jones et al., 2012; Munang et al., 2013).

4.2 Interactions

Cross-effects between multiple variables allow to further explore the results of the meta-models and understand the interactions between variables (Ghermandi et al., 2008). A few interactions were investigated (see Table 4) to: 1. check the interplay between biodiversity levels and the different types of ESs (GEFSERV2); 2. explore the authorship effect with the methodologies (LEADMETD123 and LEADMETD45); 3. further investigate vulnerability and ESs types (VULSER1 and VULSERV2) and 4. examine effects of GDP on vulnerability to climate change (VULGDP). Results are available in Table 5 only for the significant cross effects.

---

[l] VUL and GDP correlation coefficient corresponds to 0.159 at the 5% level

Table 4: Cross products

Name of cross product	Coefficient (Std. Error)
GEFSERV2	0.131 ** (0.061)
LEADMETD123	-4.475*** (0.976)
LEADMETD45	4.475*** (0.976)
VULSERV1	- 41.666 ** (16.835)
VULSERV2	- 73.602 *** (16.586)
VULGDP	-9.121 *** (3.588)

Note: ***, **, *: Significance at the 1%, 5% and 10% levels, respectively.

Interacting *GEF* with the type of ESs aims at understanding the linkages between biodiversity potential and ESs type. The interaction between *GEF* and ESs type is only significant for regulating services and is positive (*GEFSERV2* in Table 4). The cross effect refines our understanding of the impact of potential biodiversity on ESs values. Indeed, one more point in the GEF index translates into a higher value for regulating ES. The literature states that biodiversity levels impact the delivery of regulating services (Cardinale et al., 2012; Harrison et al., 2014). In our case, potential biodiversity is aligned with regulating services and we do not find a trade-off as seen in other approaches (Phelps et al., 2012). In the general result in Table 3, the *GEF* biodiversity index variable is based on the relative number of species and their threat status per eco region present in a given country (Pandey et al., 2006). Now, scientific evidence indicates that the biodiversity dimension that underpins ESs delivery is the species biotic integrity – species composition, relative abundance, functional organization and species number – rather than the number of species present in a given area (Díaz et al., 2006). This could explain why a higher biodiversity (as measured by the *GEF* index as number of species) does not automatically translate into higher estimates but into an incremental decrease in ESs benefits. We also know that this trade-off is not happening with regulating services specifically but further analysis would be needed to understand better these results.

The cross-effect of the author's institution (*LEAD*) and the valuation method (*METD213* and *METD45*) further explains the authorship effect. When the lead author is based in an institution located Africa and uses market based valuation methods), the ESs benefits obtained are lower (*LEADMETD123* in Table 4). One reason for this can be the access and understanding of more reliable market data, at a finer scale that may avoid over estimation bias. Of course, this interpretation comes with caution as it is unclear whether this explanation applies if the researchers based in Africa works on a country different from the one where they do the research. Inversely, if the lead author uses non-market based methods, the values of the ESs benefits are higher (*LEADMETD45* in Table 4). This interaction may be behind the positive effect of *LEAD* author variable in the first model estimation results and the non-significance of variables regarding the method (see Table 3).

The interaction between the vulnerability index and the type of service further informs us about the importance of the different benefits from ESs on adaptation to climate change. More vulnerable countries have lower benefits from provisioning and regulating ESs (VULSERV2 in Table 4). This is due to the fact that more vulnerable countries have lower GDP, as the negative coefficient for the cross effect between the vulnerability index and the GDP (VULGDP) shows (Table 4). This result reinforces the role of provisioning and regulating ESs in reducing climate vulnerability and provides evidence for understanding the role of ESs in climate change adaptation in less developed countries.

5 Conclusions

We conducted a meta-analysis on benefits from water ESs in Africa. We related benefits from water ESs to climate change adaptation by introducing vulnerability to climate change and adaptation readiness indices in the analysis. We find that water ESs provide different benefits depending on the type of service, biome, lead author’s affiliation and socioeconomic factors such as GDP per capita and rural poverty ratio, as well as a country’s vulnerability and readiness to adapt to climate change.

The present work is novel for two main reasons: 1. we address a meta-analysis on water ESs valuation for African case studies for the first time, and; 2. we link water ESs benefits to climate change vulnerability and readiness to adapt indices at the national scale finding evidence that can support the case for ecosystem-based adaptation.

The analysis highlights the importance of the location of the lead author institution; the interlinks between a country’s development status and the value of water ESs; and the relation between water ESs benefits and climate change adaptation in African countries. We find that poverty and vulnerability are directly linked to low water ESs benefits, while readiness to adapt is directly related to high water ESs benefits. These results are crucial for adaptation planning in the region and reinforce current policy and research recommendations in adapting to climate change.

Further research should address what drives ecosystem services at the local scales, by combining benefits with spatial information that can explain variation at a finer scale. This was not possible for exploring adaptation and vulnerability to climate change, but may be a good approach for understanding the specific location of the service users and providers, the area of the ecosystems that is producing the services and potential seasonal variations in the service provision that may have an effect on their value.

Appendices

Appendix 1 – List of variables

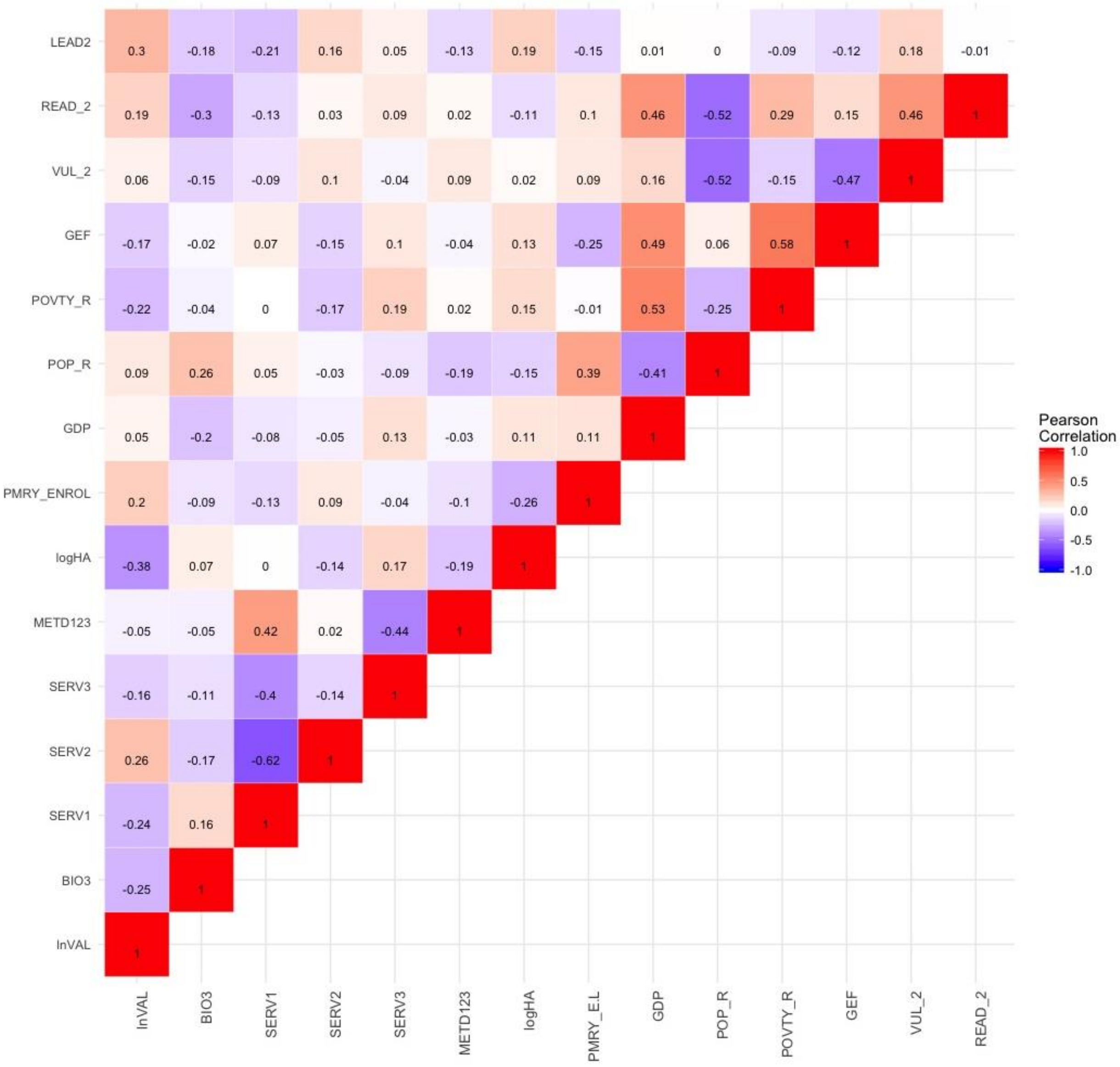
ACRONYM	VARIABLE	DESCRIPTION	UNIT	TYPE
VAL	**VALUE**	ES value in 2014 purchasing power parity (PPP) $ per hectare (ha) and year	2014 PPP $ per ha and year	Quantitative
	ECOLOGICAL VARIABLES			
BIO	**BIOME**	Type of biome in which the service is provided	n.a.	Qualitative
SERV	**SERVICE**	Type of ecosystem service considered as per the TEEB classification in 4 categories Source: http://www.teebweb.org/resources/ecosystem-services/	n.a.	Qualitative
	STUDY VARIABLES			
METD	**METHOD**	Original valuation method used for obtaining the value estimate of the ES. Note: Benefit transfer valuation method was replaced by the original valuation method of the original study for Seyam et al., (2001) and Turpie et al.,(2000).	n.a.	Qualitative
HA	**SURFACE AREA IN HA**	Surface area in hectares where the ESs is delivered	Hectares	Quantitative
LEAD	**LEAD**	Whether the lead of the paper (first author) is affiliated to either an organisation located in Africa, either an international organisation with offices in Africa at the time of publication.	n.a.	Qualitative
	SOCIO ECONOMIC INDICATORS			

PMRY_ENROL	**GROSS ENROLMENT RATIO, PRIMARY BOTH SEXES, PERCENTAGE**	Total enrolment in primary education, regardless of age, expressed as a percentage of the population of official primary education age. The ratio can exceed 100% due to the inclusion of over-aged and under-aged students because of early or late school entrance and grade repetition. Note: Data is not always available for the study year. When this was the case the closest year with data available was entered. Source: World Bank indicator, can be accessed at http://data.worldbank.org/indicator/SE.SEC.ENRR/countries	Percentage	Quantitative
GDP	**GDP PER CAPITA IN THOUSANDS OF 2014 PPP $**	GDP per capita based on purchasing power parity (PPP).. Data are in current international dollars based on the 2011 ICP round. Note: For year 1982 in Zambia, data was not available in 2014 PPP. The current 2014 USD data was taken from the World Bank. Current 2014 USD is equivalent to PPP 2014 USD. Source: World Bank indicator, can be accessed at http://data.worldbank.org/indicator/NY.GDP.PCAP.PP.CD	2014 PPP USD	Quantitative
POP_R	**PERCENTAGE OF RURAL POPULATION**	Rural population refers to people living in rural areas as defined by national statistical offices. It is calculated as the difference between total population and urban population. Aggregation of urban and rural population may not add up to total population because of different country coverages. Source: World Bank indicator, can be accessed at http://data.worldbank.org/indicator/SP.RUR.TOTL.ZS	Percentage	Quantitative
	VULNERABILITY/ ESs RELIANCE INDICATORS			
	POVERTY INDICATOR			
POVTY_R	**RURAL POVERTY HEADCOUNT RATIO AT NATIONAL POVERTY LINE IN PERCENTAGE**	Rural poverty headcount ratio is the percentage of the rural population living below the national poverty lines. Source: World Bank indicator, can be accessed at http://data.worldbank.org/indicator/SI.POV.RUHC	Percentage	Quantitative
	ENVIRONMENTAL INDICATOR			

GEF	**GEF BENEFITS INDEX FOR BIODIVERSITY**	GEF benefits index for biodiversity is a composite index of relative biodiversity potential for each country based on the species represented in each country, their threat status, and the diversity of habitat types in each country. The index has been normalized so that values run from 0 (no biodiversity potential) to 100 (maximum biodiversity potential) Source: World Bank indicator, can be accessed at https://www.thegef.org/gef/sites/thegef.org/files/documents/GBI_Biodiversity_0.pdf	Index	Quantitative
	CLIMATE CHANGE INDICES			
VUL	**VULNERABILITY INDEX ADJUSTED FOR GDP**	The adjusted for GDP Notre Dame Global Adaptation Index (ND-GAIN) for vulnerability is an index assessing the vulnerability of a country by considering six life supporting sectors: food, water, health, ES, human habitat, infrastructure. Each sector is represented by six indicators that span the three cross cutting components of vulnerability: - exposure to climate related hazards; - sensitivity of that sector to climate related hazards; - adaptive capacity of the sector to cope with these impacts Index ranges from - 0.989 to 0.222. The direction of the index was reversed so that higher score indicates a better performance. We used the adjusted for GDP version of the index. Source ND-GAIN website, can be accessed at http://index.gain.org/	Index	Quantitative
READ	**READINESS INDEX ADJUSTED FOR GDP**	The adjusted for GDP Notre Dame Global Adaptation Index (ND-GAIN) for adaptation is an index measuring readiness by considering a country's ability to apply economic investments to adaptation actions. It considers three components: - economic readiness; - governance readiness; - social readiness Index ranges from -0.387 to 1.228. The direction of the index was reversed so that lower score indicates a higher performance. We used the adjusted for GDP version of the index. Source ND-GAIN website, can be accessed at http://index.gain.org/ Note: Education in the index is the enrolment rate at tertiary school level, not primary school like our variable.	Index	Quantitative

n.a: not applicable

Appendix 2 – Correlation table



	lnVAL	BIO3	SERV1	SERV2	SERV3	METD123	logHA	PMRY_E.L	GDP	POP_R	POVTY_R	GEF	VUL_2	READ_2
LEAD2	0.3	-0.18	-0.21	0.16	0.05	-0.13	0.19	-0.15	0.01	0	-0.09	-0.12	0.18	-0.01
READ_2	0.19	-0.3	-0.13	0.03	0.09	0.02	-0.11	0.1	0.46	-0.52	0.29	0.15	0.46	1
VUL_2	0.06	-0.15	-0.09	0.1	-0.04	0.09	0.02	0.09	0.16	-0.52	-0.15	-0.47	1	
GEF	-0.17	-0.02	0.07	-0.15	0.1	-0.04	0.13	-0.25	0.49	0.06	0.58	1		
POVTY_R	-0.22	-0.04	0	-0.17	0.19	0.02	0.15	-0.01	0.53	-0.25	1			
POP_R	0.09	0.26	0.05	-0.03	-0.09	-0.19	-0.15	0.39	-0.41	1				
GDP	0.05	-0.2	-0.08	-0.05	0.13	-0.03	0.11	0.11	1					
PMRY_ENROL	0.2	-0.09	-0.13	0.09	-0.04	-0.1	-0.26	1						
logHA	-0.38	0.07	0	-0.14	0.17	-0.19	1							
METD123	-0.05	-0.05	0.42	0.02	-0.44	1								
SERV3	-0.16	-0.11	-0.4	-0.14	1									
SERV2	0.26	-0.17	-0.62	1										
SERV1	-0.24	0.16	1											
BIO3	-0.25	1												
lnVAL	1													

Appendix 3 – Studies in the database

1. Acharaya, G. and Barbier E.B., 2000, Valuing groundwater recharge through agricultural production in the Hadejia-Nguru wetlands in northen Nigeria. Agricultural Economics 22(3): 247-259.

2. Adekola, O., Moradet S., de Groot R. and Grelot F., 2008, The economic and livelihood value of provisioning services of Ga-Mampa wetland, South Africa. In: 13th IWRA World Water congress, 1 - 4 September, 2008, Montpellier, France.

3. Arntzen, J., 1998, Economic valuation of communal rangelands in Botswana: a case study. IIED, London, UK.

4. Barbier, E.B., Adams W.M. and Kimmage K., 1991, Economic valuation of wetland benefits: the Hadejia-Jama floodplain, Nigeria. IIED, London, UK.

5. Emerton L, 1994, An Economic Valuation of the Costs and Benefits in the Lower Tana Catchment Resulting from Dam Construction, A Report Prepared For Acropolis Kenya Limited

6. Emerton, L., 1998, Djibouti biodiversity - economic assessment. IUCN, Gland, Switzerland.

7. Emerton L., 1999, Balancing the opportunity costs of wildlife conservation for communities around lake Mburo National Park, Uganda, Evaluating Eden Series Discussion Paper No.5

8. Emerton L., 2002, The return of the water: Restoring the Waza Logone floodplain in Cameroon, IUCN Wetlands and Water Resources Programme

9. Emerton, L (ed), 2005, Values and rewards: counting and capturing ecosystem water services for sustainable development. IUCN Water, Nature and Economics Technical Paper No. 1, IUCN — The World Conservation Union, Ecosystems and Livelihoods Group Asia.

10. Emerton, L. and A. Asrat, 1998, Eritrea biodiversity - economic assessment. IUCN, Gland, Switzerland.

11. Emerton, L., Iyango L., Luwum P. and Malinga A., 1998, The present economic value of Nakivubo Urban Wetland, Uganda. National Wetlands Conservation and Management Programme; IUCN: Biodiversity economics for Eastern Africa.

12. Emerton, L. and Muramira E., 1999, Uganda biodiversity - economic assessment. Prepared with National Environment Management Authority, Kampala. IUCN, Gland, Switzerland.

13. Hatfield R. Malleret King D., 2007, The economic value of the mountain gorilla protected forests - The Virungas and Bwindi Impenetrable National Park, IGCP

14. Hoberg J., 2011, Economic Analysis of Mangrove Forests: A case study in Gazi Bay, Kenya, UNEP report

15. Kairo J, Wanjiru C and Ochiewo J, 2009, Net Pay: Economic analysis of a Replanted Mangrove Plantation in Kenya, Journal of Sustainable Forestry, 28:3,395 — 414

16. Kakuru W., Turyahabwe N., and Mugisha J., 2013, Total Economic Value of Wetlands Products and Services in Uganda, The Scientific World Journal, Volume 2013

17. Karanja, F., Emerton L., Mafumbo J. and Kakuru W., 2001, Assessment of the economic value of pallisa district wetlands, Uganda. Biodiversity Economics for Eastern Africa & Uganda's National Wetlands Programme, IUCN Eastern Africa Programme.

18. Kipkoech A., Mogaka H., Cheboiywo J. & Kimaro D., 2011, The total economic value of Maasai Mau, Trans Mara and Eastern Mau Forest blocks of the Mau Forest, Kenya, Environmental Research and Policy Analysis

19. Lannas Kathryn S. M. and Turpie Jane K., 2009, Valuing the Provisioning Services of Wetlands: Contrasting a Rural Wetland in Lesotho with a Peri-Urban Wetland in South Africa, Ecology and Society 14(2): 19

20. Ly, O.K., Bishop J.T., Moran D. and Dansohho M., 2006, Estimating the Value of Ecotourism in the Djoudj National Bird Park in Senegal. IUCN, Gland, Switzerland, 34pp.

21. Naidoo, R. and W.L. Adamowicz (2005) Biodiversity and Nature-Based Tourism at Forest Reserves in Uganda, Environment and Development Economics 10(2): 158-178.

22. Navrud, S. and Mungatana E.D., 1994, Environmental valuation in developing countries: The recreational value of wildlife viewing. Ecological Economics 11(2): 135-151.

23. O'Farrell P.J., W.J. De Lange a, D.C. Le Maitre a, B. Reyers a, J.N. Blignaut b, S.J. Milton c, D. Atkinson d, B. Egoh e, A. Maherry a, C. Colvin a, R.M. Cowling, 2011, The possibilities and pitfalls presented by a pragmatic approach to ecosystem service valuation in an arid biodiversity hotspot, Journal of Arid Environments 75 - 612:623

24. Schaafsma, M., Morse-Jones, S., Posen, P., SwetnamR.D., Balmford, A., Bateman, I.J., Burgess, N.D., Chamshama, S.A.O., Fisher, B., Freeman, T., Geofrey, V., Green, R.E., Hepelwa, A.S., Herna´ ndez-Sirventm, A., Hess, S., Kajembe, G.C., Kayharara j, G., Kilonzo, M., Kulindwa, K, Lund, J.F., Madoffe, S.S., Mbwamboq, L., Meilby, H., Ngaga, Y.M., Theilade, I., Treue, T., van Beukering, P., Vyamana, V.G. & Turner, R.K.. 2014. The importance of local forest benefits: Economic valuation of Non-Timber Forest Products in the Eastern Arc Mountains in Tanzania. Global Environmental Change, Volume 24, Pages 295-305

25. Seyam, I.M., Hoekstra A.Y., Ngabirano G.S. and Savenije H.H.G., 2001, The value of freshwater wetlands in the Zambezi basin. Value of Water Research Report Series No. 7, IHE Delft, The Netherlands.

26. Spurgeon, J., 2002, Socio-economic assessment and economic valuation of Egypt's mangroves, FAO report

27. Turpie, J., 2000, The use and value of natural resources of the Rufiji Floodplain and Delta, Tanzania. Rufiji Environmental Management Project, Technical report No. 17.

28. Turpie, J.K. (2003) The existence value of biodiversity in South Africa: how interest, experience, knowledge, income and perceived level of threat influence local willingness to pay. Ecological Economics 46(1-2): 199-216.

29. Turpie J., 2005, The Valuation of Riparian Fisheries in Southern and Eastern Africa, Tropical river fisheries valuation: background papers to a global synthesis by Neiland, A. E.; Béné, C. 2006. Tropical river fisheries valuation: A global synthesis and critical review. Colombo, Sri Lanka: International Water Management Institute. 45 pp. (Comprehensive Assessment of Water Management in Agriculture Research Report 15)

30. Turpie, J. et al. 2010. Estimation of the Water Quality Amelioration Value of Wetlands A Case Study of the Western Cape, South Africa

31. Turpie J., Barnes J., Arntzen J., Nherera B., Lange G., Baleseng Buzwani B., 2006, Economic value of the Okavango delta, Botswana, and implications for management, Report

32. Turpie, J.K., B.J. Heydenrych and S.J. Lamberth, 2003. Economic value of terrestrial and marine biodiversity in the Cape Floristic Region: implications for defining effective and socially optimal conservation strategies. Biol. Conservation 112: 233-251.

33. Turpie, J., Joubert A., 2000, Estimating potential impacts of a change in river quality on the tourism value of Kruger National Park: An application of travel cost, contingent and conjoint valuation methods, Water SA, vol 7-3

34. Turpie, J., Smith B., Emerton L. and Barnes J., 1999, Economic value of the Zambezi Basin Wetlands. Zambezi Basin Wetlands conservation and resource utilization project. IUCN Regional Office for Southern Africa.

35. Turpie, J., Day E., Ross-Gillespie V., Louw A.., 2010, Estimation of the Water Quality Amelioration Value of Wetlands A Case Study of the Western Cape, South Africa, Environment for Development Discussion Paper Series 10-15

36. Wasswa H., Mugagga F., Kakembo V., 2013, Economic Implications of Wetland Conversion to Local People's Livelihoods: The Case of Kampala- Mukono Corridor (KMC) Wetlands in Uganda, Academia Journal of Environmental Sciences 1(4): 066-077

References

Barrio, M., Loureiro, M.L., 2010. A meta-analysis of contingent valuation forest studies. Ecol. Econ. 69, 1023–1030. doi:10.1016/j.ecolecon.2009.11.016

Bateman, I.J., Jones, A., 2003. Contrasting conventional with multi-level modeling approaches to meta-analysis: expectation consistency in UK woodland recreation values. Land Econ. 79, 235–258.

Brander, L., Brouwer, R., Wagtendonk, A., 2013. Economic valuation of regulating services provided by wetlands in agricultural landscapes: A meta-analysis. Ecol. Eng. 56, 89–96. doi:10.1016/j.ecoleng.2012.12.104

Brander, L., J. Wagtendonk, A., S. Hussain, S., McVittie, A., Verburg, P.H., de Groot, R.S., van der Ploeg, S., 2012. Ecosystem service values for mangroves in Southeast Asia: A meta-analysis and value transfer application. Ecosyst. Serv. 1, 62–69. doi:10.1016/j.ecoser.2012.06.003

Brander, L.M., Florax, R.J.G.M., Vermaat, J.E., 2006. The Empirics of Wetland Valuation: A Comprehensive Summary and a Meta-Analysis of the Literature. Environ. Resour. Econ. 33, 223–250. doi:10.1007/s10640-005-3104-4

Brander, L.M., Van Beukering, P., Cesar, H.S.J., 2007. The recreational value of coral reefs: A meta-analysis. Ecol. Econ. 63, 209–218. doi:10.1016/j.ecolecon.2006.11.002

Brauman, K.A., Daily, G.C., Duarte, T.K., Mooney, H.A., 2007. The Nature and Value of Ecosystem Services: An Overview Highlighting Hydrologic Services. Annu. Rev. Environ. Resour. 32, 67–98. doi:10.1146/annurev.energy.32.031306.102758

Brouwer, R., Langford, I.H., Bateman, I.J., Turner, R.K., 1999. A meta-analysis of wetland contingent valuation studies. Reg. Environ. Change 1, 47–57.

Cameron, C., Trivedi, P., 2009. Microeconometrics Using Stata. Stata Press Publication.

Cardinale, B.J., Duffy, J.E., Gonzalez, A., Hooper, D.U., Perrings, C., Venail, P., Narwani, A., Mace, G.M., Tilman, D., Wardle, D.A., Kinzig, A.P., Daily, G.C., Loreau, M., Grace, J.B., Larigauderie, A., Srivastava, D.S., Naeem, S., 2012. Biodiversity loss and its impact on humanity. Nature 486, 59–67. doi:10.1038/nature11148

Chaikumbung, M., Doucouliagos, H., Scarborough, H., 2016. The economic value of wetlands in developing countries: A meta-regression analysis. Ecol. Econ. 124, 164–174. doi:10.1016/j.ecolecon.2016.01.022

de Groot, R., Brander, L., van der Ploeg, S., Costanza, R., Bernard, F., Braat, L., Christie, M., Crossman, N., Ghermandi, A., Hein, L., Hussain, S., Kumar, P., McVittie, A., Portela, R., Rodriguez, L.C., ten Brink, P., van Beukering, P., 2012. Global estimates of the value of ecosystems and their services in monetary units. Ecosyst. Serv. 1, 50–61. doi:10.1016/j.ecoser.2012.07.005

Díaz, S., Demissew, S., Carabias, J., Joly, C., Lonsdale, M., Ash, N., Larigauderie, A., Adhikari, J.R., Arico, S., Báldi, A., others, 2015. The IPBES Conceptual Framework—connecting nature and people. Curr. Opin. Environ. Sustain. 14, 1–16.

Díaz, S., Fargione, J., Chapin III, F.S., Tilman, D., 2006. Biodiversity loss threatens human well-being. PLoS Biol 4, e277.

Doswald, N., Munroe, R., Roe, D., Giuliani, A., Castelli, I., Stephens, J., Möller, I., Spencer, T., Vira, B., Reid, H., 2014. Effectiveness of ecosystem-based approaches for adaptation: review of the evidence-base. Clim. Dev. 6, 185–201. doi:10.1080/17565529.2013.867247

Egoh, B.N., O'Farrell, P.J., Charef, A., Josephine Gurney, L., Koellner, T., Nibam Abi, H., Egoh, M., Willemen, L., 2012. An African account of ecosystem service provision: Use, threats and policy options for sustainable livelihoods. Ecosyst. Serv. 2, 71–81. doi:10.1016/j.ecoser.2012.09.004

Emerton, L., 2014. Valuing and investing in ecosystems as development infrastructure: economic analysis of options for climate-compatible development in coastal zones of Kenya & Sri Lanka, iCoast report. LTS International, Edinburgh, UK.

Faramarzi, M., Abbaspour, K.C., Ashraf Vaghefi, S., Farzaneh, M.R., Zehnder, A.J.B., Srinivasan, R., Yang, H., 2013. Modeling impacts of climate change on freshwater availability in Africa. J. Hydrol. 480, 85–101. doi:10.1016/j.jhydrol.2012.12.016

Fisher, B., Turner, R.K., Morling, P., 2009. Defining and classifying ecosystem services for decision making. Ecol. Econ. 68, 643–653. doi:10.1016/j.ecolecon.2008.09.014

Ghermandi, A., Nunes, P.A.L.D., 2013. A global map of coastal recreation values: Results from a spatially explicit meta-analysis. Ecol. Econ. 86, 1–15. doi:10.1016/j.ecolecon.2012.11.006

Ghermandi, A., Van den Bergh, J.C., Brander, L.M., De Groot, H.L., Nunes, P.A., 2008. The economic value of wetland conservation and creation: A meta-analysis.

Glass, G., 1976. Primary, Secondary, and Meta-Analysis of research. Am. Educ. Res. Assoc. 5, 3–8.

Green, P.A., Vörösmarty, C.J., Harrison, I., Farrell, T., Sáenz, L., Fekete, B.M., 2015. Freshwater ecosystem services supporting humans: Pivoting from water crisis to water solutions. Glob. Environ. Change 34, 108–118. doi:10.1016/j.gloenvcha.2015.06.007

Guerry, A.D., Polasky, S., Lubchenco, J., Chaplin-Kramer, R., Daily, G.C., Griffin, R., Ruckelshaus, M., Bateman, I.J., Duraiappah, A., Elmqvist, T., Feldman, M.W., Folke, C., Hoekstra, J., Kareiva, P.M., Keeler, B.L., Li, S., McKenzie, E., Ouyang, Z., Reyers, B., Ricketts, T.H., Rockström, J., Tallis, H., Vira, B., 2015. Natural capital and ecosystem services informing decisions: From promise to practice. Proc. Natl. Acad. Sci. 112, 7348–7355. doi:10.1073/pnas.1503751112

Harrison, P.A., Berry, P.M., Simpson, G., Haslett, J.R., Blicharska, M., Bucur, M., Dunford, R., Egoh, B., Garcia-Llorente, M., Geamănă, N., Geertsema, W., Lommelen, E., Meiresonne, L., Turkelboom, F., 2014. Linkages between biodiversity attributes and ecosystem services: A systematic review. Ecosyst. Serv. 9, 191–203. doi:10.1016/j.ecoser.2014.05.006

IEA Statistics, 2017. Electricity production from hydroelectric sources [WWW Document]. World Bank.

Intergovernmental Panel on Climate Change (Ed.), 2007. Climate change 2007: the physical science basis: contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge ; New York.

IPCC (Ed.), 2014. Climate change 2014: impacts, adaptation, and vulnerability: Working Group II contribution to the fifth assessment report of the Intergovernmental Panel on Climate Change. Cambridge University Press, New York, NY.

Johnston, R.J., Besedin, E.Y., Iovanna, R., Miller, C.J., Wardwell, R.F., Ranson, M.H., 2005. Systematic Variation in Willingness to Pay for Aquatic Resource Improvements and Implications for Benefit Transfer: A Meta-Analysis. Can. J. Agric. Econ. Can. Agroeconomie 53, 221–248. doi:10.1111/j.1744-7976.2005.04018.x

Johnston, R.J., Besedin, E.Y., Wardwell, R.F., 2003. Modeling relationships between use and nonuse values for surface water quality: A meta-analysis: NONUSE VALUE META-ANALYSIS. Water Resour. Res. 39, n/a-n/a. doi:10.1029/2003WR002649

Jones, H.P., Hole, D.G., Zavaleta, E.S., 2012. Harnessing nature to help people adapt to climate change. Nat. Clim. Change 2, 504–509. doi:10.1038/nclimate1463

Lele, S., 2009. Watershed services of tropical forests: from hydrology to economic valuation to integrated analysis. Curr. Opin. Environ. Sustain. 1, 148–155. doi:10.1016/j.cosust.2009.10.007

Lindhjem, H., 2007. 20 years of stated preference valuation of non-timber benefits from Fennoscandian forests: A meta-analysis. J. For. Econ. 12, 251–277. doi:10.1016/j.jfe.2006.09.003

Liu, S., Stern, D.I., 2008. A meta-analysis of contingent valuation studies in coastal and near-shore marine ecosystems.

Mattmann, M., Logar, I., Brouwer, R., 2016. Wind power externalities: A meta-analysis. Ecol. Econ. 127, 23–36. doi:10.1016/j.ecolecon.2016.04.005

Mc Vittie, A., Hussain, S., 2013a. TEEB valuation database manual.

Mc Vittie, A., Hussain, S., 2013b. TEEB valuation database manual.

Millennium Ecosystem Assessment (Program) (Ed.), 2005. Ecosystems and human well-being: synthesis. Island Press, Washington, DC.

Munang, R., Thiaw, I., Alverson, K., Liu, J., Han, Z., 2013. The role of ecosystem services in climate change adaptation and disaster risk reduction. Curr. Opin. Environ. Sustain. 5, 47–52. doi:10.1016/j.cosust.2013.02.002

Naidoo, R., Adamowicz, W.L., 2005. Biodiversity and nature-based tourism at forest reserves in Uganda. Environ. Dev. Econ. 10, 159–178. doi:10.1017/S1355770X0400186X

Nelson, J.P., Kennedy, P.E., 2009. The Use (and Abuse) of Meta-Analysis in Environmental and Natural Resource Economics: An Assessment. Environ. Resour. Econ. 42, 345–377. doi:10.1007/s10640-008-9253-5

Ojea, E., Loureiro, M.L., 2011. Identifying the scope effect on a meta-analysis of biodiversity valuation studies. Resour. Energy Econ. 33, 706–724. doi:10.1016/j.reseneeco.2011.03.002

Ojea, E., Loureiro, M.L., Alló, M., Barrio, M., 2016. Ecosystem Services and REDD: Estimating the Benefits of Non-Carbon Services in Worldwide Forests. World Dev. 78, 246–261. doi:10.1016/j.worlddev.2015.10.002

Ojea, E., Martin-Ortega, J., 2015. Understanding the economic value of water ecosystem services from tropical forests: A systematic review for South and Central America. J. For. Econ. 21, 97–106. doi:10.1016/j.jfe.2015.02.001

Ojea, E., Nunes, P.A.L.D., Loureiro, M.L., 2010. Mapping Biodiversity Indicators and Assessing Biodiversity Values in Global Forests. Environ. Resour. Econ. 47, 329–347. doi:10.1007/s10640-010-9381-6

Ojea, E., Zamora, J.C., Martin-Ortega, J., Imbach, P., 2015. Climate change economic impacts on water and recreation services in Central American forests. Clim. Change Impacts Trop. For. Cent. Am. Ecosyst. Serv. Perspect. 113.

Pandey, D.K., Buys, P., Chomitz, K., Wheeler, D., 2006. Biodiversity Conservation Indicators: New Tools for Priority Setting at the Global Environment Facility.

Pascual, U., Muradian, R., Brander, L., Gómez-Baggethun, E., Martín-López, B., Verma, M., Armsworth, P., Christie, M., Cornelissen, H., Eppink, F., others, 2010. The economics of valuing ecosystem services and biodiversity. TEEB–Ecological Econ. Found.

Richardson, L., Loomis, J., 2009. The total economic value of threatened, endangered and rare species: An updated meta-analysis. Ecol. Econ. 68, 1535–1548. doi:10.1016/j.ecolecon.2008.10.016

Rolfe, J., Brouwer, R., 2012. Design effects in a meta-analysis of river health choice experiments in Australia. J. Choice Model. 5, 81–97. doi:10.1016/S1755-5345(13)70053-8

Shrestha, R.K., Loomis, J.B., 2001. Testing a meta-analysis model for benefit transfer in international outdoor recreation. Ecol. Econ. 39, 67–83.

Stanley, T.D., Doucouliagos, H., Giles, M., Heckemeyer, J.H., Johnston, R.J., Laroche, P., Nelson, J.P., Paldam, M., Poot, J., Pugh, G., Rosenberger, R.S., Rost, K., 2013. Meta-analysis of economics research reporting guidelines: reporting guidelines for meta-regression analysis in economics. J. Econ. Surv. 27, 390–394. doi:10.1111/joes.12008

Suich, H., Howe, C., Mace, G., 2015. Ecosystem services and poverty alleviation: A review of the empirical links. Ecosyst. Serv. 12, 137–147. doi:10.1016/j.ecoser.2015.02.005

Turpie, J., Joubert, A., 2001. Estimating potential impacts of a change in river quality on the tourism value of Kruger National Park: an application of travel cost, contingent, and conjoint valuation methods. Water Sa 27, 387–398.

UNEP (Ed.), 2010. Mainstreaming the economics of nature: a synthesis of the approach, conclusions and recommendations of teeb, The economics of ecosystems & biodiversity. UNEP, Geneva.

Van der Ploeg, Wang, Gebre Weldmichael, de Groot, 2010. The TEEB Valuation Database – a searchable database of 1310 estimates of monetary values of ecosystem services.

Woodward, R.T., Wui, Y.-S., 2001. The economic value of wetland services: a meta-analysis. Ecol. Econ. 37, 257–270.

Wooldridge, J., 2002. Econometric analysis of cross section and panel data. The MIT Press.

World Bank, 2007. Africa Development Indicators 2007: Spreading and Sustaining Growth in Africa. The World Bank.

World Water Assessment Programme, 2016. Water and jobs (The United Nations World Water Development Report 2016: Water and Jobs). UNESCO, Paris.

Zandersen, M., Tol, R.S.J., 2009. A meta-analysis of forest recreation values in Europe. J. For. Econ. 15, 109–130. doi:10.1016/j.jfe.2008.03.006