VU University Amsterdam

Natural Capital Accounting and Valuation of Ecosystem Services

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Outline presentation

- Choices (DG ENV project TEEB synthesis in Europe)
- Example 1: Integrated Environmental-Economic Accounting
- Example 2: Ecosystem Services Valuation

<u>Choice level 1</u>: what do you want to achieve?

↓

<u>Choice level 2</u>: what are the relevant ecosystem services?

- Classification of ecosystem services
- Final and/or intermediary services, actual or potential ecosystem services
- Role of biodiversity
- Stocks or flows

↓

<u>Choice level 3</u>: what are the relevant valuation principles?

- Monetary or nonmonetary quantification of ecosystem services
- Definition of economic value
- Marginal or total values
- Spatial and temporal scales

↓

<u>Choice level 4</u>: what are the appropriate valuation methods?

- Market valuation
- Non-market valuation
- Value transfer

TEEB in Europe Synthesis

- Key to the successful integration of ecosystem services in existing, modified or new accounting or reporting formats is to
  1) establish reliable, scientific links between the biophysical provision of ecosystem services and their economic values, and
  2) take into consideration the existence of extensively tested guidelines for environmental accounting over the past decades by statistical offices in order to create and maintain a consistent and coherent System of National Accounts (SNA).

Brouwer, R., Brander, L., Kuik, O., Papyrakis, E. and Bateman, I. (2013). A synthesis of approaches to assess and value ecosystem services in the EU in the context of TEEB. Report written for DG Environment, European Commission, Brussels.

Consistency with the System of National Accounts: strengths and weaknesses

Strengths	Weaknesses
Consistent and coherent international accounting framework, which allows for international comparison between EU Member States	Restrictive in terms of the ecosystem services that can be included in the system, i.e. only those for which market prices are available. This clearly omits many of the most economically important (in terms of contribution to human welfare) ecosystem services
Flexible framework in that it allows EU Member States to decide which type of natural resources and ecosystem services they want to include based on national data, information needs and data availability	Establishing an integrated environmental-economic account is time consuming and requires an institutional (statistical) infrastructure (Statistical Office) with a mandate to collect, compile and publish the accounts on an annual or bi-annual basis
	High recurring maintenance costs: initial investment costs may be substantial and afterwards the information system has to be regularly updated and maintained in order to remain relevant and useful for actual policy and decision-making, hence requiring a constant flow of funding

Example 1: IEEA

- **Two main approaches:**
- *Satellite accounts around core SNA*
  - Often biophysical flows linked to monetary flows in core SNA
  - In some cases also monetary valuation of these biophysical flows, but outside the core SNA
- *Integration of monetary ES values in core SNA*
  - Adding/subtracting hypothetical economic values from sectors' value added and GDP
  - In some cases making the implicit value of provisioning services like mineral resources more explicit within SNA production boundary
  - Example Index of Sustainable Economic Welfare (ISEW)

Valuation issues in NCA: *Beyond GDP*

- Idea of "*beyond GDP*" goes back to the 1960s
- Correction mechanisms to derive indicator of "*true*" progress
- Criticism basically twofold:
  - Loss of non-priced assets through resource exploitation, pollution, land degradation etc. is not registered in SNA
  - Economic activities aimed at pollution control, environmental protection and restoration registered as gross output, inflating GDP
- Hence, plea for:
  - Registration of value changes of non-produced natural assets (depreciation of natural capital)
  - Identification & reclassification environmental protection and restoration activities in SNA (subtraction of defensive expenditures from GDP)

Ecosystem Services Valuation

The value of the world's ecosystem services and natural capital

Robert Costanza*†, Ralph d'Arge‡, Rudolf de Groot§, Stephen Farber‖, Monica Grasso†, Bruce Hannon¶, Karin Limburg#*, Shahid Naeem, Robert V. O'Neill††, Jose Paruelo‡‡, Robert G. Raskin§§, Paul Sutton‖‖ & Marjan van den Belt¶¶**

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The services of ecological systems and the natural capital stocks that produce them are critical to the functioning of the Earth's life-support system. They contribute to human welfare, both directly and indirectly, and therefore represent part of the total economic value of the planet. We have estimated the current economic value of 17 ecosystem services for 16 biomes, based on published studies and a few original calculations. For the entire biosphere, the value (most of which is outside the market) is estimated to be in the range of US$16–54 trillion ($10^{12}$) per year, with an average of US$33 trillion per year. Because of the nature of the uncertainties, this must be considered a minimum estimate. Global gross national product total is around US$18 trillion per year.

Because ecosystem services are not fully 'captured' in commercial markets or adequately quantified in terms comparable with economic services and manufactured capital, they are often given too little weight in policy decisions. This neglect may ultimately compromise the sustainability of humans in the biosphere. The economies of the Earth would grind to a halt without the services of ecological life-support systems, so in one sense their total value to the economy is infinite. However, it can be instructive to estimate the 'incremental' or 'marginal' value of ecosystem services (the estimated rate of change of value compared with changes in ecosystem services from their current levels). There have been many studies in the past few decades aimed at estimating the value of a wide variety of ecosystem services. We have gathered together this large (but scattered) amount of information and present it here in a form useful for ecologists, economists, policy makers and the general public. From this synthesis, we have estimated values for ecosystem services per unit area by biome, and then multiplied by the total area of each biome and summed over all services and biomes.

Although we acknowledge that there are many conceptual and empirical problems inherent in producing such an estimate, we think this exercise is essential in order to: (1) make the range of potential values of the services of ecosystems more apparent; (2) establish at least a first approximation of the relative magnitude of global ecosystem services; (3) set up a framework for their further analysis; (4) point out those areas most in need of additional research; and (5) stimulate additional research and debate. Most of the problems and uncertainties we encountered indicate that our estimate represents a minimum value, which would probably increase: (1) with additional effort in studying and valuing a broader range of ecosystem services; (2) with the incorporation of more realistic representations of ecosystem dynamics and interdependence; and (3) as ecosystem services become more stressed and 'scarce' in the future.

Ecosystem functions and ecosystem services

Ecosystem functions refer variously to the habitat, biological or system properties or processes of ecosystems. Ecosystem goods (such as food) and services (such as waste assimilation) represent the benefits human populations derive, directly or indirectly, from ecosystem functions. For simplicity, we will refer to ecosystem goods and services together as ecosystem services. A large number of functions and services can be identified[1–4]. Reference 5 provides a recent, detailed compendium on describing, measuring and valuing ecosystem services. For the purposes of this analysis we grouped ecosystem services into 17 major categories. These groups are listed in Table 1. We included only renewable ecosystem services, excluding non-renewable fuels and minerals and the atmosphere. Note that ecosystem services and functions do not necessarily show a one-to-one correspondence. In some cases a single ecosystem service is the product of two or more ecosystem functions whereas in other cases a single ecosystem function contributes to two or more ecosystem services. It is also important to emphasize the interdependent nature of many ecosystem functions. For example, some of the net primary production in an ecosystem ends up as food, the consumption of which generates respiratory products necessary for primary production. Even though these functions and services are interdependent, in many cases they can be added because they represent 'joint products' of the ecosystem, which support human

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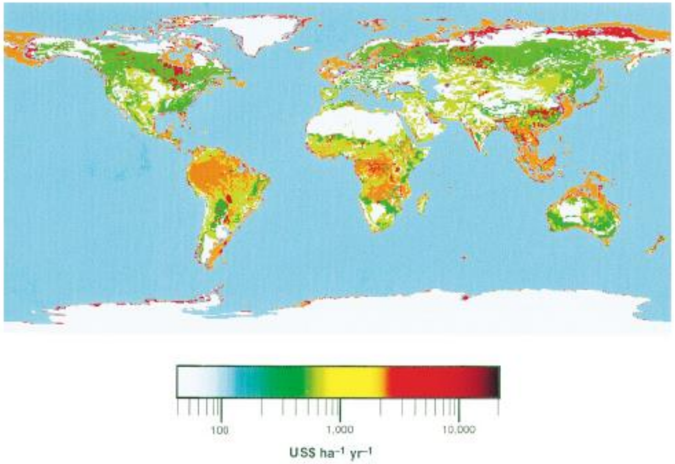


Figure 2 Global map of the value of ecosystem services. See Supplementary Information and Table 2 for details.

Wetlands	$14,785 $ha^{-1}yr^{-1}$	Coral reefs	$ 675
Lakes/rivers	$ 8,498	Open ocean	$ 252
Tropical forests	$ 2,007	Grasslands	$ 232

Key message:

Non-market value ecosystem services 2 x higher than global market based GDP

However, standard deviation so large that adjusted GDP could be 2 x higher or lower

Valuation issues in NCA: *Beyond GDP*

- Part of the ES are already implicitly accounted for in the SNA (e.g. food, timber, land)
- A large share falls outside existing markets >> how to value these?
- **GREENSTAMP**: EC DG XII funded project 'Methodological Problems in the Calculation of Environmentally Adjusted National Income Figures‘ (Contract No. EV5V-CT94-0363):

a) Mismatch statistical realities & theoretical model assumptions
b) Need for scenario development & macro-economic modelling approaches to assess how economies adapt and modify when internalizing non-priced impacts on NC and impact on GDP

Brouwer, R., O'Connor & Radermacher, W. (1999). GREEened National STAtistical and Modelling Procedures: The GREENSTAMP approach to the calculation of environmentally adjusted national income figures. *International Journal of Sustainable Development, 1*(2), 7-31.

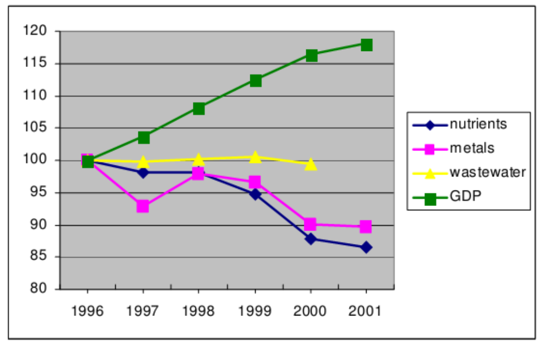
Strengths and weaknesses

	Strengths	Weaknesses
Satellite accounting around core SNA	Provides the necessary and essential biophysical underpinning of the economic values associated with ecosystem services and abiotic resources and allows for the creation of integrated/coupled biophysical and economic growth indicators, allowing policy makers to assess the cost-effectiveness of their policies and the eco-efficiency of economic production and consumption	Requires the biophysical indicators and accounting framework to fit the geographical and temporal scales applied in the SNA, which may be hard given the fact that many ecosystem boundaries do not correspond with the administrative boundaries applied in the SNA (national level, one year) (for instance fitting water in a river basin into the boundaries of a country)
Full integration of ecosystem services in capital accounts in core SNA	Fully integrated inclusion of the economic value of ecosystem services and abiotic resources such as minerals in the SNA, providing a single comprehensive welfare indicator	Difficult given the strict rules and regulations related to National Accounting. There exists a discrepancy between the theoretical economic framework/model used to derive all-inclusive welfare indicators, including sustainable national income, and the practical statistical calculation rules underlying GDP, impairing most probably also the interpretation of GDP as a more comprehensive welfare measure, also after inclusion of ecosystem services capital accounts

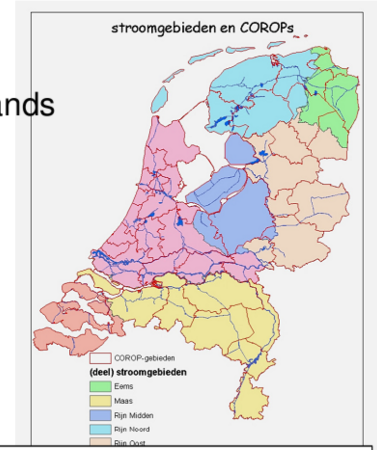
Example satellite accounting framework

Satellite accounts

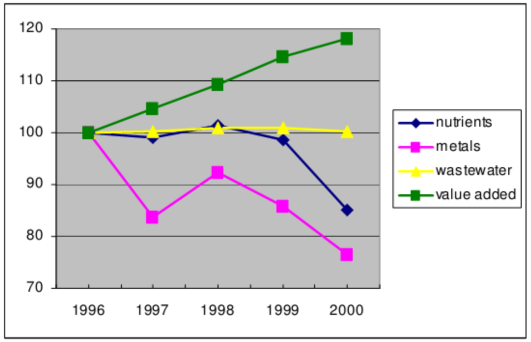
	Agriculture	Industry	Households	*Gross output*	Discharge	Emissions
Agriculture	X1	X2	X3	X1+X2+X3	Y1	Z1
Industry	X4	X5	X6	X4+X5+X6	Y2	Z2
Households					Y3	Z3
Value added	X2+X3-X4	X4+X6-X2		GDP		
Extraction	Y4	Y5	Y6		Balance	
Absorption	Z4	Z5				Deposition



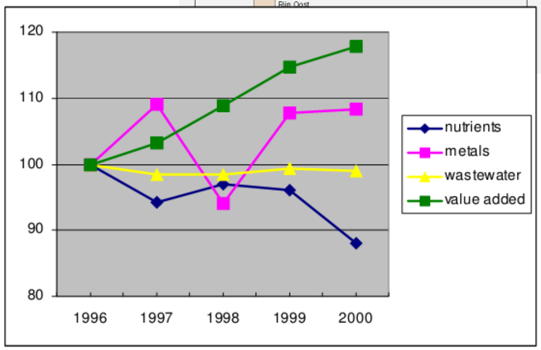
The Netherlands



Rhine



Meuse



Source: Brouwer, Schenau and van der Veeren (2005). Integrated river basin accounting and the European Water Framework Directive. Statistical Journal of the UN, 22(2): 111-131.

Challenges in integrated accounting

- Different statistics from different data sources
- Different classification of sectors
- Different monitoring and management scales
- Different sampling and aggregation procedures
- Confidentiality issues
- Data from observations, calculations and model simulations

Example of different scales

Economic data

- National
- Province (12)
- Corop (40)
- EGS (129)
- Municipalities (>500)
- Postal codes (>5000)

?

Hydrological data

- National
- River basin (4)
- Regional government (8)
- Sub-river basins (17)
- Water boards (56)
- PAWN districts (80)
- Water discharge units (>1000)

Lessons learned

- Time: it took almost 10 years to develop NAMWA
  - 1990 development NAMEA
  - 1996 experimental NAMWA at national level
  - 2001 development of NAMWA at river basin level
  - 2003 update for time period 1997-2001
  - 2004 inclusion of more substances
  - > 2005 regular annual updates
- Need to mature, learn and test

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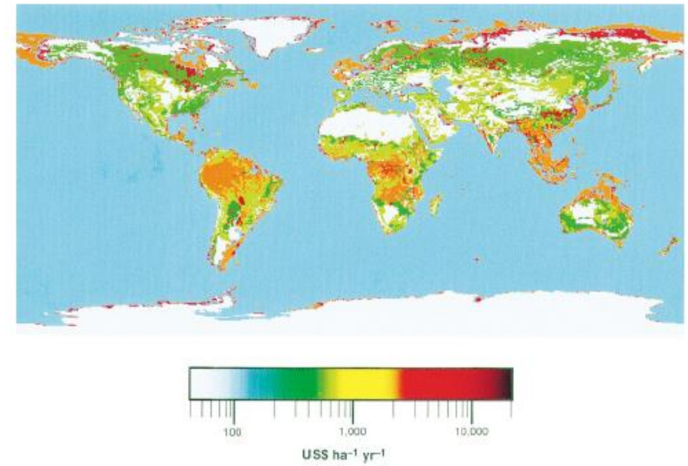

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Key message:

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Data availability challenges

- Very limited amount of data and information available about economic market and non-market values of ES
- Furthermore, available values not standardized, location and problem specific
- Value transfer popular in policy and decision-making because cost-effective approach >> constant value/ha

- State-of-the-art research line: value function approach
- Generates significantly lower transfer errors

Meta-regression model

$$Y_{ij} = \beta_0 + \beta^g X^g + \beta^s X^s + \beta^p X^p + \beta^m X^m + \varepsilon_{ij}$$

Y_{ij} = Ecosystem service value *i* from study *j* (USD/ha/year)

X^g = Good/service characteristics (e.g. type of ecosystem service)

X^s = Site/context characteristics (e.g. relative abundance)

X^p = Population characteristics (e.g. income)

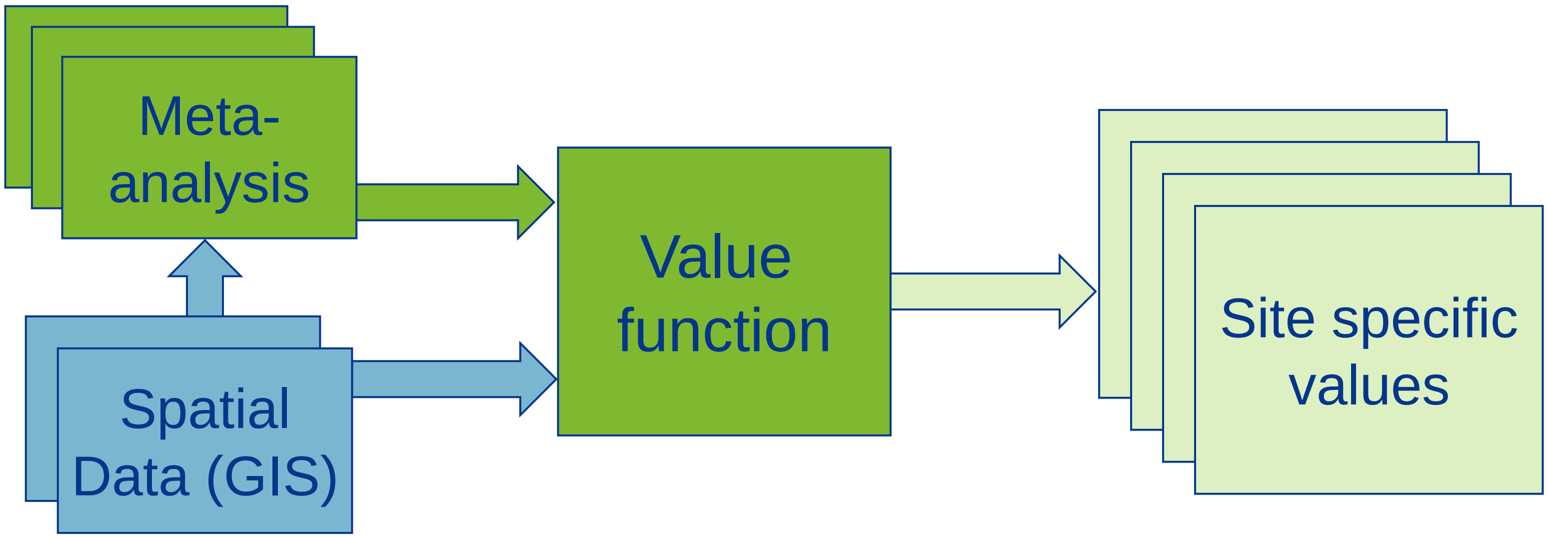
X^m = Methodological characteristics (e.g. valuation method)

β_0 = intercept

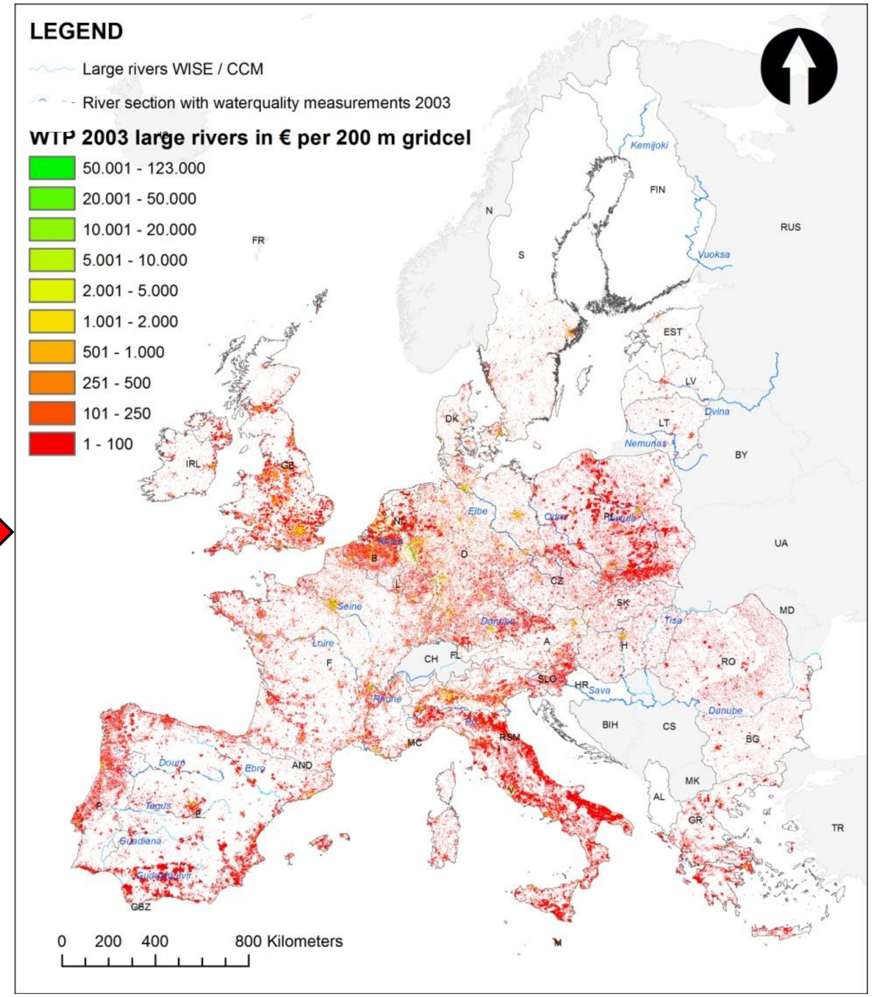
β^g , β^s, β^p, β^m parameters to be estimated

ε_{ij} = error term

Approach


Meta-analysis
Spatial Data (GIS)
Value function
Site specific values

GIS based value mapping (AQUAMONEY)



Source: Brander, Brouwer, Wagentendonk (2010)

Wetlands database

- Brouwer et al. (1999)
- Brander et al. (2006)
- Ghermandi et al. (2010)

400 wetland valuation studies

38 valuing regulating services generating 66 value estimates

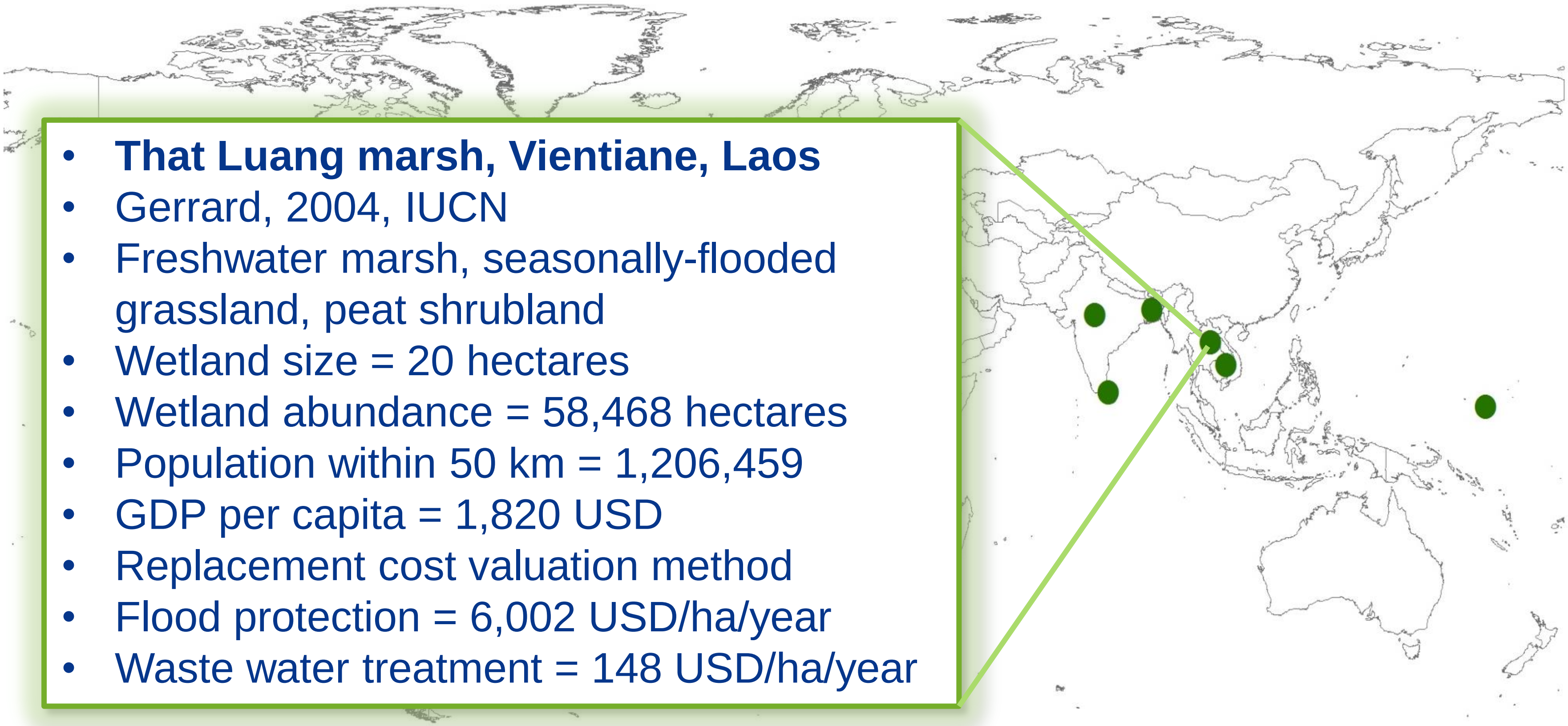
Selection criteria:

- Focus on regulating services (excluding combinations with e.g. recreation)
- Wetland location known and located in agricultural landscape as defined in JRC 2000 Global Land Cover Database
- Values could be standardized in terms of monetary units per area of wetland

Location of wetland valuation studies

- 11 in North America
- 11 in Europe
- 10 in Africa
- 5 in South Asia
- 1 in Micronesia

Location of wetland valuation studies



- **That Luang marsh, Vientiane, Laos**
- Gerrard, 2004, IUCN
- Freshwater marsh, seasonally-flooded grassland, peat shrubland
- Wetland size = 20 hectares
- Wetland abundance = 58,468 hectares
- Population within 50 km = 1,206,459
- GDP per capita = 1,820 USD
- Replacement cost valuation method
- Flood protection = 6,002 USD/ha/year
- Waste water treatment = 148 USD/ha/year

Strong correlation ES and valuation method

- Flood control: n=26
  Replacement costs dams, few cases avoided damage costs
- Water supply: n=26
  Production function approach based on market prices
- Nutrient recycling: n=27
  Costs of equivalent water treatment method

Ecosystem service values

- Values standardised to:
  - USD (PPP adjusted)
  - Hectare
  - Annual
  - 2007 price levels

Regulating service	Mean value (USD/ha/year)	Median value (USD/ha/year)	N
Flood control	6923	427	26
Water supply	3389	57	26
Water quality	5788	243	27

Explanatory variables

- **Service characteristics**
  - Wetland regulating service
- **Site characteristics**
  - Wetland type
  - Size of wetland study site
  - Size of surrounding substitute wetland sites
  - Human appropriation of net primary product
  - Road density
- **Population characteristics**
  - Population density
  - Gross Cell Product

Information sources:

Study report

Own GIS calculations

(radius of 10, 20 and 50 km)

Meta regression model (Ln USD/ha/year)

Variable	Coefficient	Standard error
Constant	3.74*	1.93
Man-made wetland (D)	0.45	0.78
Water supply (D)	-1.30**	0.62
Water quality (D)	-0.80	0.59
Wetland area (Ln)	-0.37***	0.08
Wetland abundance (Ln)	-0.30***	0.08
Population (Ln)	0.45***	0.15
Gross Cell Product per capita (Ln)	0.27**	0.15
N	66	
Adjusted R^2	0.58	

Value transfer

- Promising because allows for (control of) differences in good, site and population characteristics across resources
- Transfer errors due to:
  - Study selection bias (stock of knowledge on ES values is not representative)
  - Measurement error in primary valuation studies
  - Generalization error (values change in time, insufficient control for differences between study and policy site)
- In-sample transfer and estimate absolute % transfer error for each predicted value: (predicted-observed/observed)
- **<u>Transfer error: 92%</u>**

Upscaling

- Identification of wetlands in agricultural landscapes (Global Lakes and Wetlands & Global Land Cover database) >> 36% of all wetlands
- Prediction of economic value for regulating services based on meta-regression model (wetland size, abundance other wetlands, population, gross cell product) >> site specific ecosystem service values in USD/ha/year
- Aggregation across wetland areas per country (next table)

Region	Number of wetland sites	Area (ha; millions)	Mean unit value (USD/ha/yr)	Total value (USD/yr; millions)	Lower 95% CI (USD/yr; millions)	Upper 95% CI (USD/yr; millions)
Canada	3,560	8	223	261	231	375
USA	1,528	59	1,490	1,809	1,334	6,125
Mexico	259	0	2,599	197	156	263
Cent. America & Carib.	463	1	2,505	381	300	486
Brazil	1,402	59	810	1,370	436	6,629
Rest of South America	1,733	20	1,283	1,059	602	2,100
North Africa	1,524	3	1,126	905	806	1,012
West Africa	8,719	32	911	4,533	3,989	5,105
East Africa	2,430	8	983	1,812	1,563	2,063
Southern Africa	1,585	13	1,029	1,512	1,037	2,081
Western Europe	696	2	2,353	661	550	869
Central Europe	40	1	1,743	114	8	477
Turkey	28	0	5,289	105	30	325
Ukraine Region	84	2	2,089	261	61	1,003
STANs	3,292	6	752	789	721	893
Russia & Caucasus	13,197	37	297	1,641	1,426	1,901
Middle East	5,501	8	914	2,001	1,839	2,164
South Asia	1,529	2	5,956	2,252	2,071	2,451
Korea Region	32	0.32	4,205	231	53	822
China Region	2,742	7	1,502	2,061	1,714	2,457
South East Asia	506	8	2,856	1,338	662	2,528
Indonesia	530	17	676	896	388	2,215
Japan	48	0.10	5,817	193	123	284
Oceania	1,124	1	512	134	124	146
Antarctica	42	0.04	24	1	0	1
World	52,594	294	978	26,514	20,223	44,773

Conclusions and recommendations

- Value functions way forward instead of assuming constant economic values per hectare
- Costanza et al. (1997): no correction resulted in a global service value of USD 11,612 ha^{-1} yr^{-1} (2007 prices)
- This study: USD 978 ha^{-1} yr^{-1} (8.4% of Costanza's value)
- Note: wetlands in agricultural landscapes!
- Despite relatively high explanatory power, still considerable transfer error (92%)
- Future work: need to quantify the provision level of regulating services across wetlands, now assumed to be constant

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Thank you for your attention

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