ANALYSIS OF THE UNCERTAINTY IN THE MONETARY VALUATION OF ECOSYSTEM SERVICES - A CASE STUDY AT THE RIVER BASIN SCALE

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the lack of monetary valuations has been identified as one of the underlying causes for the observed degradation of ecosystems and the loss of biodiversity (TEEB 2010)

small differences in the value of quantified benefits might influence CBA decision on whether or not to perform a conservation management action (Ben Dor et al. 2011)
## Sources of uncertainty in ecosystem services valuation

<table>
<thead>
<tr>
<th>Ecosystem Service</th>
<th>Change in Constituent</th>
<th>Endpoint</th>
<th>Change in Valued Attribute</th>
<th>Beneficiaries</th>
<th>Valuation Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lake recreation</td>
<td>P and/or N</td>
<td>Lakes</td>
<td>Water clarity</td>
<td>Lake recreationists, Lakeshore property owners</td>
<td>Recreational demand model: Willingness to pay for recreation. Hedonic pricing</td>
</tr>
<tr>
<td>Clean drinking water</td>
<td>N</td>
<td>Sourcewater treatment facilities</td>
<td>[Nitrates] above 10ppm</td>
<td>Treatment facility &amp; taxpayers</td>
<td>Avoided treatment costs for nitrate</td>
</tr>
<tr>
<td>Clean drinking water</td>
<td>N</td>
<td>Groundwater</td>
<td>[Nitrates] above 10ppm</td>
<td>Well owners</td>
<td>Avoidance costs (bottled water); Remediation costs (treatment); Replacement costs (new well)</td>
</tr>
<tr>
<td>Clean drinking water</td>
<td>N</td>
<td>Drinking water (surface or groundwater)</td>
<td>[Nitrates]</td>
<td>Consumers, particularly at-risk subpopulations</td>
<td>Increased risk of disease * value of statistical life/health; Avoidance costs</td>
</tr>
<tr>
<td>Commercial fisheries</td>
<td>N</td>
<td>Bays, estuaries, coasts</td>
<td>Fish and shellfish productivity</td>
<td>Fish and shellfish industry and consumers</td>
<td>Fishery rents; Value per unit fish/shellfish</td>
</tr>
</tbody>
</table>

### 4. Parametric uncertainty

Linking water quality and well-being for improved assessment and valuation of ecosystem services
Keller B. et al. PNAS 2012, 109, p:18619–18624
Llobregat basin: 4950 km$^2$
Barcelona: 3 million people
Annual rainfall: from >1000mm in mountains to <600mm near coast.
3 Reservoirs, 1 Drinking WTP
Impact of climate extremes on hydrological ecosystem services in a heavily humanized Mediterranean basin
Ecosystem services – Biophysical Modelling

Impact of climate extremes on hydrological ecosystem services in a heavily humanized Mediterranean basin

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Observed</th>
<th>Predicted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water supply ((\times 10^6 \text{ m}^3 \text{ y}^{-1}))</td>
<td>606</td>
<td>606</td>
</tr>
<tr>
<td>TN export ((\text{Mg y}^{-1}))</td>
<td>6000(^a)</td>
<td>5998</td>
</tr>
<tr>
<td>TP export ((\text{Mg y}^{-1}))</td>
<td>420</td>
<td>422</td>
</tr>
<tr>
<td>Sediment export – 1 ((\text{Gg y}^{-1}))</td>
<td>200(^b)</td>
<td>150</td>
</tr>
<tr>
<td>Sediment export – 2 ((\text{Gg y}^{-1}))</td>
<td>602–1418(^c)</td>
<td>1535</td>
</tr>
</tbody>
</table>

\(^a\) Based on literature
\(^b\) Zero discharge
\(^c\) Includes boundary inputs

Model calibration: La Baells reservoir
Model validation: outlet

(a) Land use
- Dams
- Drinking WTP
- Urban
- Non-irrig. agr.
- Irrig. agr.
- Grass & shrubs
- Forest
- Stream

Impact of climate extremes on hydrological ecosystem services in a heavily humanized Mediterranean basin
Threats included (a) urbanization; (b) agriculture; (c) roads; (d) mines

vascular plant richness from orthophotos and field work 1996–2006

Model development for the assessment of terrestrial and aquatic habitat quality in conservation planning
Terrado M. et al. Science of the Total Environment, 2015, in press (available online)
### Valuation Framework

#### Ecosystem and Biodiversity
- **1. Biophysical structure and process**
  - Rainfall-vegetation interaction
  - Biotic and abiotic processes
- **2. Functions**
  - Water balance
  - Removal or breakdown of OM, xenic nutrients and compounds
- **3. Services**
  - Water provisioning
  - Waste treatment

#### Human Wellbeing
- **4. Benefits**
  - **WP1** Water for drinking purpose
  - **WP2** Water for irrigation purpose
  - **WP3** Hydropower production
  - **WT1** Higher surface water and groundwater quality
  - **WT2** Enjoyment of recreational areas
- **5. Valuation metric**
  - **WP1.1** Market price: value of water for drinking purpose
  - **WP2.1** Production based approach: value of water for irrigation purpose
  - **WP2.2** Market price: value of water for irrigation purpose
  - **WP3.1** Market price: value of water for hydropower production
  - **WT1.1** Avoided cost: cost of water treatment for drinking purpose (contaminant removal)
  - **WT1.2** Avoided cost: cost of water treatment for drinking purpose (contaminant removal)
  - **WT1.3** Avoided cost: cost of health care linked to poor water quality
  - **WT1.4** Avoided cost: cost of ecosystem damages
  - **WT2.1** Contingent valuation: willingness to pay for clean water bathing areas
Valuation Framework

Vegetation and geomorphology → Sediment retention → Erosion protection → Habitat for species

Habitat availability

Refugium for species and maintenance of genetic diversity

EP2 Avoided soil losses
EP3 Extension of water management infrastructures lifetime
EP4 Soil carbon storage
EP5 Enjoyment of recreational areas

HS1 Existence / conservation of genetic and species diversity

EP2.1 Cost of soil restoration
EP2.2 Market price: loss of income from productivity loss
EP3.1 Avoided cost: cost of dredging dam reservoirs
EP3.2 Avoided cost: cost of dredging dam reservoirs
EP4.1 Market price: value of soil carbon storage
EP5.1 Contingent valuation: willingness to pay for clear water bathing areas
HS1.1 Contingent valuation: willingness to pay for species conservation
HS1.2 Public investments: investments in biodiversity conservation
HS1.3 Market price: sale of fishing licences
HS1.4 Market price: sale of hunting licences
## Valuation Results

### Water Provisioning

<table>
<thead>
<tr>
<th>Benefits</th>
<th>Valuation metrics</th>
<th>Value (M€ yr(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>WP1.1 Water for drinking purpose</td>
<td>Market price</td>
<td>279</td>
</tr>
<tr>
<td>WP2.1 Water for irrigation purpose</td>
<td>Production based approach</td>
<td>87</td>
</tr>
<tr>
<td>WP2.2</td>
<td>Market price</td>
<td>0.63</td>
</tr>
<tr>
<td>WP3.1 Hydropower production</td>
<td>Market price</td>
<td>1.83</td>
</tr>
</tbody>
</table>

### Waste Treatment

<table>
<thead>
<tr>
<th>Benefits</th>
<th>Valuation metrics</th>
<th>Value (M€ yr(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>WT1.1 Higher surface water and groundwater quality</td>
<td>Avoided cost</td>
<td>68</td>
</tr>
<tr>
<td>WT1.2</td>
<td>Avoided cost</td>
<td>4.1</td>
</tr>
<tr>
<td>WT1.3</td>
<td>Avoided cost</td>
<td>3.2</td>
</tr>
<tr>
<td>WT1.4</td>
<td>Avoided cost</td>
<td>24.5</td>
</tr>
<tr>
<td>WT2.1 Enjoyment of recreational areas</td>
<td>Contingent valuation</td>
<td>182</td>
</tr>
</tbody>
</table>

### Erosion Protection

<table>
<thead>
<tr>
<th>Benefits</th>
<th>Valuation metrics</th>
<th>Value (M€ yr(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>EP1.1 Higher surface water quality</td>
<td>Avoided cost</td>
<td>49.5</td>
</tr>
<tr>
<td>EP2.1 Avoided soil losses</td>
<td>Replacement cost</td>
<td>0.84</td>
</tr>
<tr>
<td>EP2.2</td>
<td>Market price</td>
<td>0.79</td>
</tr>
<tr>
<td>EP3.1 Extension of water management infrastructures lifetime</td>
<td>Avoided cost</td>
<td>8.4</td>
</tr>
<tr>
<td>EP3.2</td>
<td>Avoided cost</td>
<td>7.9</td>
</tr>
<tr>
<td>EP4.1 Soil carbon storage</td>
<td>Market price</td>
<td>5.2</td>
</tr>
<tr>
<td>EP5.1 Enjoyment of recreational areas</td>
<td>Contingent valuation</td>
<td>0</td>
</tr>
</tbody>
</table>

### Habitat for Species

<table>
<thead>
<tr>
<th>Benefits</th>
<th>Valuation metrics</th>
<th>Value (M€ yr(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>HS1.1 Existence/conservation of genetic and species diversity</td>
<td>Contingent valuation</td>
<td>350.7</td>
</tr>
<tr>
<td>HS1.2</td>
<td>Public investments</td>
<td>14.9</td>
</tr>
<tr>
<td>HS1.3</td>
<td>Market price</td>
<td>0.001</td>
</tr>
<tr>
<td>HS1.4</td>
<td>Market price</td>
<td>0.082</td>
</tr>
</tbody>
</table>
Including more than one service reduces significantly the uncertainty (C.V. drops 50% from 1 to 2 services)
Including more than one beneficiary/benefit also reduces significantly the uncertainty (C.V. drops 50% from 1 to 2 benefits)

Only erosion control has >3 benefits
Using 128 combinations of valuation metrics, that uncertainty is 3\textsuperscript{rd} in rank compared to single service (C.V. = 0.57) and single benefit (C.V. = 0.47) …

Monetary Value (M\texteuro\text{yr}^{-1})
... and in par with the uncertainty arising from valuation metric parameters (assuming uniform pdf within reasonable range).
Conclusions

Quantifying the uncertainty in monetary valuation step of ecosystem services assessment is important.

**Structural uncertainty was more significant than parametric uncertainty** in this case study.

We recommend including at least two ecosystem services and two benefits/beneficiaries (taking care to avoid double counting) per service.

- Most available models (e.g. InVEST) do not meet this requirement.