The value of Earth Observation for marine water quality management

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Introduction

- Tool: Expert elicitation approach (questionnaire) to assess the contribution of EO to decision-making

1. Additional information from Earth Observation
2. More effective decision-making
3. Welfare impact of more effective decision-making
4. Incremental cost of Earth Observation
5. Is benefit>>cost? Fritz et al. (2008)

- Two case studies: North Sea and Great Barrier Reef

- North Sea: focus on the prediction of potentially harmful algal blooms.

- Great Barrier Reef: focus on increased spatial and temporal insight in chlorophyll-a and sediment flows
The value of information is determined by its impact on the expected utility of decision making (Hirshleifer and Riley 1979)

<table>
<thead>
<tr>
<th>Acts</th>
<th>s=1</th>
<th>s=2</th>
<th>Utility of the acts</th>
</tr>
</thead>
<tbody>
<tr>
<td>a=1</td>
<td>c_{11}</td>
<td>c_{12}</td>
<td>u_1</td>
</tr>
<tr>
<td>a=2</td>
<td>c_{21}</td>
<td>c_{22}</td>
<td>u_2</td>
</tr>
<tr>
<td>Beliefs as to the state</td>
<td>(\pi_1)</td>
<td>(\pi_2)</td>
<td></td>
</tr>
</tbody>
</table>

\[
 u(a) \equiv \pi_1 v(c_{a1}) + \ldots + \pi_{aS} (c_{aS}) \equiv \sum_{s=1}^{S} \pi_s v(c_{aS})
\]
The value of information is determined by whether the decision-maker updates his beliefs. Bayes’ rule:

\[
\pi_{s,m} = \Pr(s | m) = \frac{\Pr(m | s) \Pr(s)}{\Pr(m)} = \frac{q_{m,s} \pi_s}{q_m}
\]

\[
q_m = \sum_{s=1}^{S} q_{m,s} \pi_s
\]

We require information about \( \Pr(m | s) \) or the likelihood of the message given state 1 or 2.

Basically, this is similar to saying we need information about the type 1 and type 2 error of EO information.
**Questionnaire**

- **Respondents:** policy makers, water managers, researchers

- **Qualitative and quantitative results:** open questions and probabilities

- Development algal bloom 2003
  - In the Voor delta

- Spatial coverage (high spatial resolution to monitor large areas)
- Temporal coverage (time resolution to allow looking at long-term trends)
- Cost-effectiveness (large area at low costs)
- Visual evidence (confidence in monitoring programs)
- Integrating tool for ecosystem approach
- Rapid assessment/real-time information
**North Sea**

- **Welfare impact alternative actions:** Move fishing nets (cost: 2 million euro) to avoid economic damages (cost: 20 million euro)

<table>
<thead>
<tr>
<th>States (s)</th>
<th>Actions (x) (million euro/week)</th>
<th>Likelihoods (q_{m,s})</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>x1: Move nets</td>
<td>x2: No move</td>
</tr>
<tr>
<td>S1: Bloom</td>
<td>-2</td>
<td>-20</td>
</tr>
<tr>
<td>S2: No bloom</td>
<td>-2</td>
<td>0</td>
</tr>
</tbody>
</table>
• Cost of EO information
  – Approx. annual cost of EO information for Dutch marine water quality management (2.5 million euro)
  – Approx. reduction in monitoring costs Dutch marine water quality management (2 million euro)

• Hence .. predicting HAB should generate benefit of at least 500,000 euro/year

• Comparison costs and benefits:
  – 95% confidence interval of benefits ranges from 340,000 to 1,030,000 euro/year
  – 75% probability that investment in early warning is welfare enhancing
### Great Barrier Reef

<table>
<thead>
<tr>
<th>States (s)</th>
<th>Actions (x)</th>
<th>Priors</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>s₁:</strong> No spatial variability in effectiveness of emission reduction</td>
<td>$x_1$: Reduce N and sediment in entire catchment</td>
<td>$\pi_s$</td>
</tr>
<tr>
<td></td>
<td>-1.1 billion USD</td>
<td></td>
</tr>
<tr>
<td><strong>s₂:</strong> Spatial variability in effectiveness of emission reduction</td>
<td>$x_2$: Reduce N and sediment in selected catchments</td>
<td>$\pi_1$</td>
</tr>
<tr>
<td></td>
<td>-1.3 billion USD</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-1.1 billion USD</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-0.6 billion USD</td>
<td>$\pi_2$</td>
</tr>
</tbody>
</table>

1.1 billion USD

$\pi_1$

$\pi_2$
Great Barrier Reef

The value of EO information (million USD/year)

<table>
<thead>
<tr>
<th>$\Pi_1$</th>
<th>Current value</th>
<th>Sensitivity range</th>
<th>Potential value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.8</td>
<td>21.2</td>
<td>4.6- 36.2</td>
<td>48</td>
</tr>
<tr>
<td>0.7</td>
<td>49.8</td>
<td>30.9- 67.3</td>
<td>82</td>
</tr>
</tbody>
</table>

- Prior beliefs derived from actual decision-making
- Current accuracy estimates on average 66%. Future expected accuracy around 80%
- Cost information not available: but benefit range gives indication of when EO investment is welfare enhancing
Conclusions

- Use of expert elicitation approach generates valuable insights regarding the perceived value of EO
- Disregarding the (perceived) accuracy of information results in overestimation of benefits..
- ... and paying attention to the accuracy of information also helps EO technology developers to do their job
- Assessment of economic benefits depends on a) prior beliefs and b) alternative actions and welfare impacts
- Applications confined to marine water quality, but can be applied to other core areas of EO
- Further research required to fine-tune methodology and pay attention to risk-aversion of decision-makers too
Thank you!

For further reading please see the conference proceedings and


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