BBN models as trade-off tools for ecosystem services

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Introduction
Introduction

- Ecosystem services – benefits humans obtain from ecosystem
  - Supporting services (nutrient recycling, soil formation)
  - Provisioning services (food, raw materials, energy)
  - Regulating services (pollination, pest and disease control)
  - Cultural services (ecotourism, therapeutic)
Introduction

- Application of ecosystem services in water management

Problem:
- exploitation of one ecosystem service may lead to the deterioration of another
Objectives

- To identify the link between water management options and ecosystem services
- Determine how the ecosystem services change when certain management actions are applied
- To develop a trade-off tool using Bayesian belief network
Materials and methods

- Study area
Study area
Estimating ecosystem services through modeling

- Bayesian belief networks (BBNs)
  - Probabilistic graphical model
  - Presented as directed acyclic graph
  - Nodes represent discrete(ized) variables
  - Arrows indicate causal relations
  - Conditional probability table displays conditional probabilities of a single variable \( wrt \) others

Nodes

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>state0</td>
<td>100</td>
<td>state0</td>
<td>100</td>
</tr>
</tbody>
</table>

Conditional probability tables for variables A, B, and C.
BBNs in estimating ecosystem services (ESS)

- **Advantages**
  - Easy interpretation, visualization
  - Flexible with available data
  - Can be applied as a trade-off tool

- **Disadvantages**
  - Feedback loop not allowed
  - Discretization needed
  - Incorporation of detailed processes
Modelling

- General layout of BBN for ESS

Landuyt et. al, 2013
Modelling ESS

Defining variables
- Altitude
- Precipitation
- Soil texture
- Landuse
- Flow velocity

Management variables
- Fertilizer
- Pesticide

Biophysical structure

Functions
- Provisioning functions
- Regulating functions
- Cultural functions

Services
- Food production
- Fresh water
- Ecotourism/Recreation

Benefits
- Food
- Water provision
- Enjoyment
## Input data

<table>
<thead>
<tr>
<th>Nodes</th>
<th>Input</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altitude</td>
<td>Data (shape files)</td>
</tr>
<tr>
<td>Precipitation</td>
<td>Data (shape files)</td>
</tr>
<tr>
<td>Soil texture</td>
<td>Data (shape files)</td>
</tr>
<tr>
<td>Land use</td>
<td>Data (shape files)</td>
</tr>
<tr>
<td>Flow velocity</td>
<td>Data (field work)</td>
</tr>
<tr>
<td>Fertilizer</td>
<td>Data &amp; expert knowledge</td>
</tr>
<tr>
<td>Pesticide</td>
<td>Data &amp; expert knowledge</td>
</tr>
<tr>
<td>Crop</td>
<td>Literature</td>
</tr>
<tr>
<td>Chemical water quality</td>
<td>Data (measured pesticide residue &amp; chemical attributes of water)</td>
</tr>
<tr>
<td>Biological water quality</td>
<td>Data (field work)</td>
</tr>
<tr>
<td>Food production</td>
<td>Literature &amp; expert knowledge</td>
</tr>
<tr>
<td>Water provision</td>
<td>Expert knowledge (rule-based)</td>
</tr>
<tr>
<td>Ecotourism/recreation</td>
<td>Expert knowledge (rule-based)</td>
</tr>
</tbody>
</table>
Data collection

- Physical-chemical variables (e.g. velocity, pesticide)
- Biological data (macroinvertebrates)
- Shape files (ministry)
- Other information (documents)
- Literature
Model development
Sensitivity analysis

- Water provision

![Bar chart showing water provision categories and their respective percentage contributions. The categories include Fertilizer, Food production, Pesticides, Ecotourism, Biological water quality, Landuse, and Chemical water quality. Chemical water quality has the highest percentage, followed by Landuse.]
Sensitivity analysis

- Food production

[Bar chart showing sensitivity analysis for various factors affecting food production, with 'Crop type' having the highest impact.]
Sensitivity analysis

- Ecotourism/recreation

![Bar chart showing the percentage of different factors in sensitivity analysis]

- Food production
- Fertilizer
- Pesticides
- Landuse
- Flow velocity
- Water provision
- Chemical water quality
- Biological water quality

Percentage (%)
Management options

Altitude
- Coast: 81.8
- Lowland: 15.0
- Highland: 3.19

Precipitation
- Low (<1000 mm/y): 5.86
- Medium (1000-2000 mm/y): 30.5
- High (>2000 mm/y): 63.5

Soil texture
- Loam: 19.8
- Clay loam: 27.3
- Sandy loam: 11.3
- Other: 41.5

Landuse
- Nature: 12.6
- Urban: 0.88
- Agriculture: 86.5

Flow velocity
- Low: 51.2
- Medium: 39.2
- High: 9.64

Crop type
- Rice: 95.9
- Cacao: 0
- Corn: 4.08

Fertilizer
- Intensive: 65.8
- Non-intensive: 34.2

Pesticides
- Intensive: 54.6
- Non-intensive: 45.4

Chemical water quality
- Bad: 59.7
- Moderate: 25.8
- Good: 14.6

Water provision
- Cooking: 11.9
- Hygienic: 12.8
- Irrigation: 21.6
- Not usable: 53.7

Biological water quality
- Very bad: 23.8
- Bad: 17.6
- Poor: 20.6
- Moderate: 17.5
- Good: 14.3

Ecotourism
- High: 42.2
- Low: 57.8

Food production USD/ha
- < 200: 0
- 200 - 400: 0
- 400 - 600: 0
- 600 - 800: 0
- > 800: 100
Management options

[Diagram of various factors related to agriculture, such as altitude, precipitation, soil texture, land use, flow velocity, crop type, fertilizer, pesticides, chemical water quality, biological water quality, food production, water provision, and ecotourism/recreational use.]
Conclusions

- A trade-off tool was developed using BBN.
- The developed model was able to identify the link between water management options and ecosystem services.
- The model facilitate the determination of changes of ecosystem services when certain management actions are applied.
Further studies

- Incorporation of other crops (e.g. Banana and palm)
- Addition of other ecosystem service (e.g. energy production, wood production)
- Model validation
- Incorporation of other defining variables for pesticide and fertilizer (farm size, farming type)
Thank you for your attention

Questions?