

An ecosystem service approach to support integrated pond management: An application of Bayesian belief networks

Dries Landuyt, Pieter Lemmens, Rob D'hondt, Steven Broekx, Inge Liekens, Tom de Bie, Steven Declerck, Luc De Meester, Peter Goethals

dries.landuyt@vito.be

Introduction

Freshwater ponds are multi-functional ecosystems that provide a broad range of social, ecological and economic benefits for human well-being. Examples of such benefits, collectively referred to as ecosystem services, typically delivered by pond systems, include nutrient retention, fish production, water retention, water supply and recreation. To attain cost-effective delivery of these services, decision support tools are needed to guide pond management. Although several tools have been developed in the past, they generally focus only on one or a very limited number of objectives and do not account for uncertainties and risks, associated to management outcomes. To be able to account for the delivery of multiple services and uncertainties, we developed a decision support tool based on Bayesian belief networks. We applied the tool to evaluate three alternative pond management practices in the pond complex 'Midden-Limburg': intensive fish farming, extensive fish farming and nature conservation management.

Methods

Three ecosystem services were selected to be included into the analysis: nitrogen retention, fish production and cultural services, including both recreation and non-use values. This selection of services was based on socio-economic relevance, data availability and whether or not their delivery is affected by pond management. The delivery processes of the selected services were modelled with a Bayesian belief network model, a graphical probabilistic model that models a system based on the causal relations that exist among the system's variables. Major advantages of this modelling technique are the ability to account for uncertainties and the ability to integrate multiple data types. In this study, we made use of local knowledge (management costs), survey data (cultural value), expert knowledge (bio-physical pond processes) and literature data (nitrogen retention) to develop the model. The model was used to evaluate three pond management practices: intensive fish farming, extensive fish farming and nature conservation management. These practices were evaluated based on net benefit, modelled as the monetary value of ecosystem service delivery minus the management costs. Also the uncertainties associated to this predicted net benefit were compared across management practices.

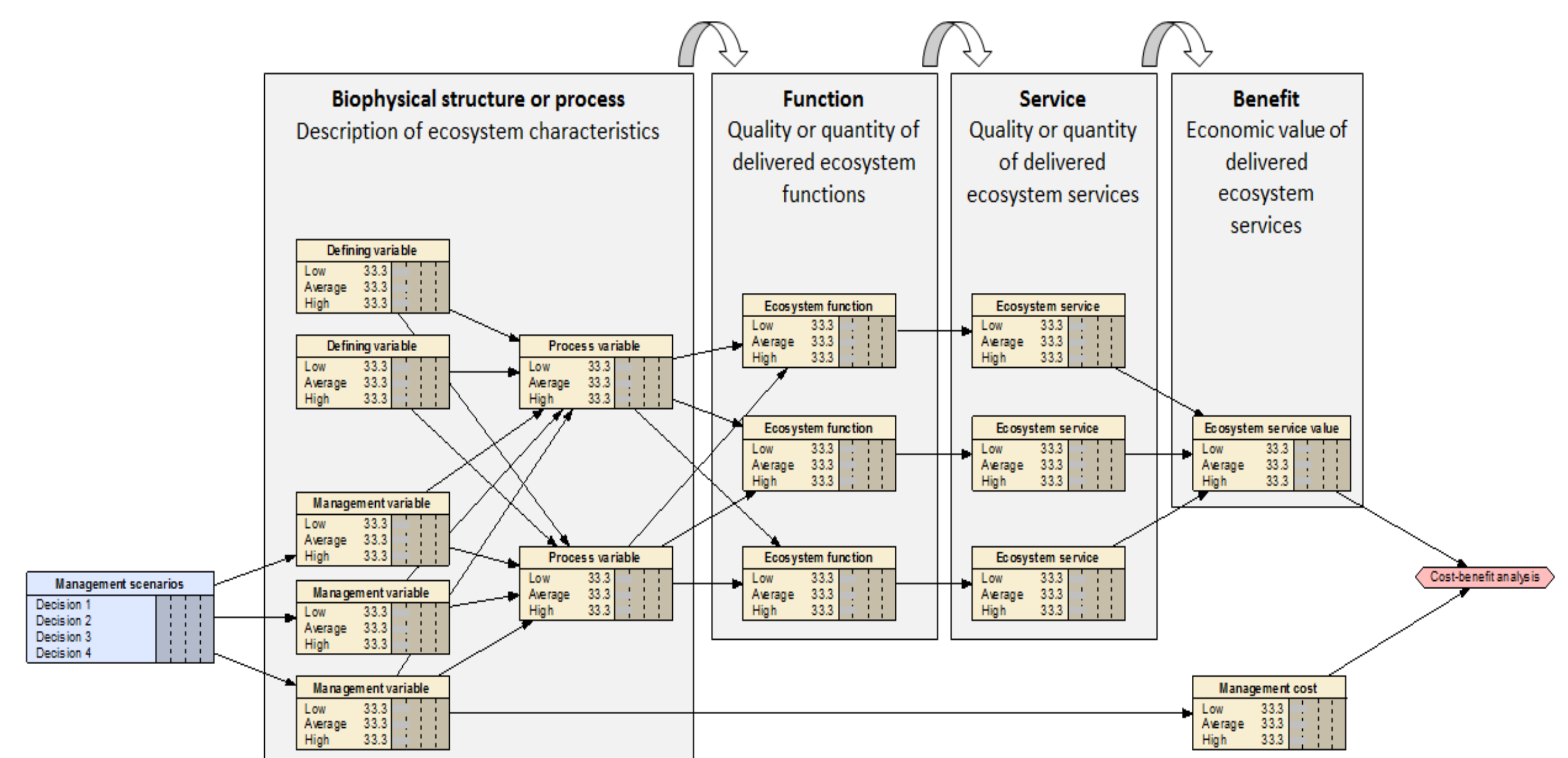


Figure 1. Bayesian belief network model to assess cost-effectiveness of management practices, accounting for both management costs and benefits associated to ecosystem service delivery

Results

Ecosystem service delivery is positive under all management scenarios, with only nitrogen retention being slightly negative under intensive fish farming management. Nature conservation and extensive fish farming management seem to be associated with a more balanced ecosystem service delivery (Figure 2). A more in depth analysis of the probabilistic model predictions suggests that nature conservation management is the most profitable management practice (Figure 3a). Figure 3b and 3c illustrate the effect of taking into account fewer services. In case only fish production is considered as a relevant service, the intensive fish farming scenario stochastically dominates all other scenarios and, thus, would be considered the most profitable (Figure 3c). Both the probability of achieving a positive net outcome (intersection of the curve with the vertical line) as the probability of achieving high benefits is higher compared to the other management types. When the other services are additionally taken into account, the curves converge, resulting in more comparable expected net benefits (Figure 3b and 3c).

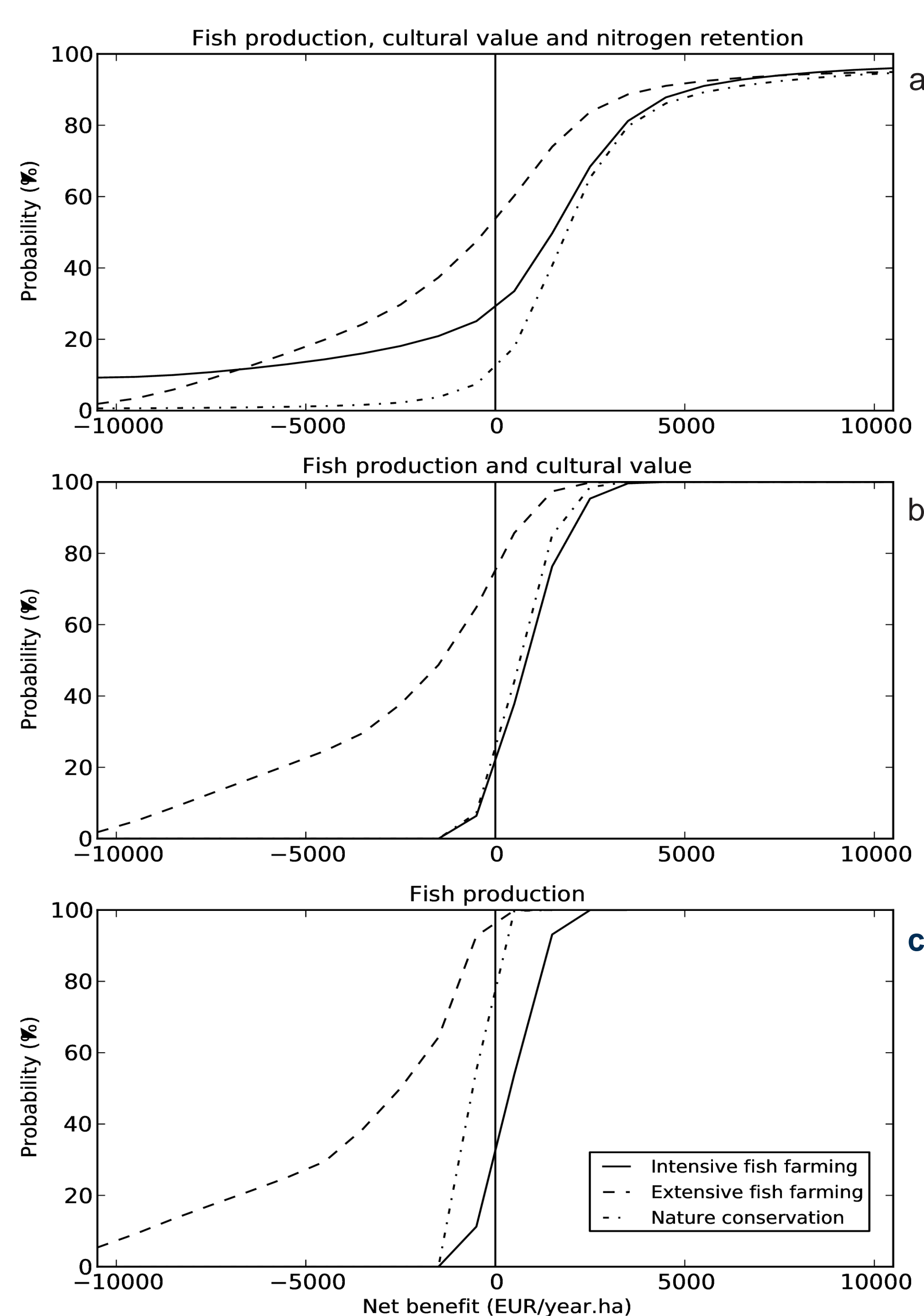


Figure 3. Cumulative probability curves of the predicted net benefit associated to three alternative pond management practices, taking into account three different sets of ecosystem services (a, b and c). The more right the curve, the more profitable the scenario, the steeper the curve, the more certain the expected net outcome of the management practice.

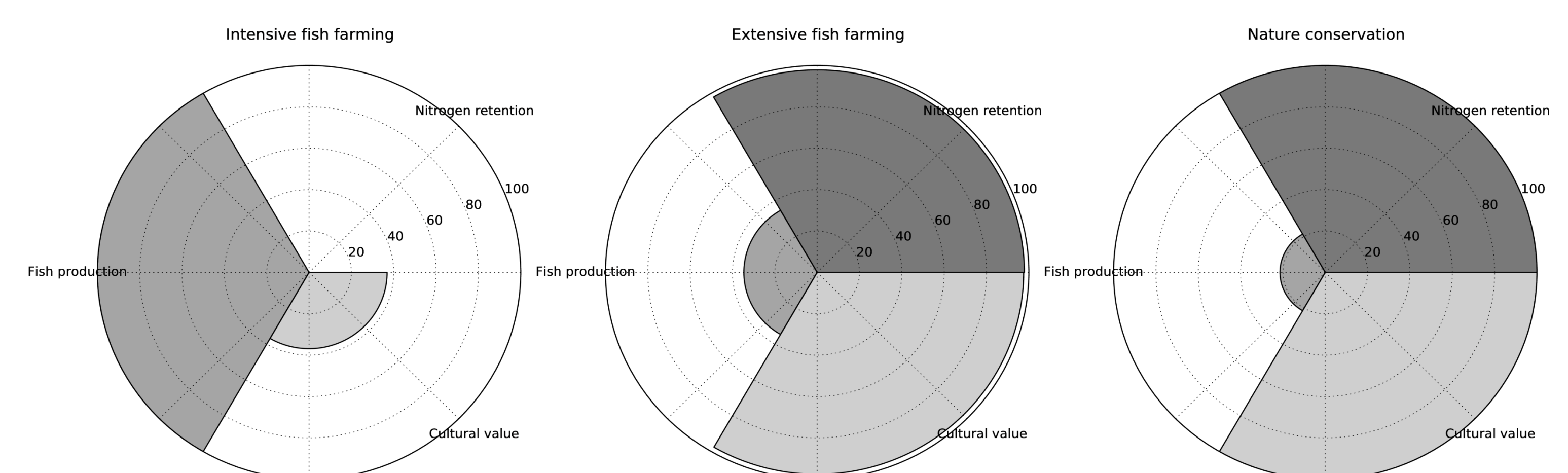


Figure 2. Relative delivery of ecosystem services for three alternative pond management practices.

Conclusions

This study clearly illustrates the potential of Bayesian belief networks to integrate and structure knowledge from diverse scientific domains ranging from ecology to economy. Meanwhile, this study stresses a general weakness of ecosystem service assessments, being that whether or not a particular ecosystem service is included in the analysis seriously affects the results and, in this case, the suggested optimal management practice.

Reference

Landuyt, D., Lemmens, P., D'hondt, R., Broekx, S., Liekens, I., De Bie, T., Declerck, S. A. J., De Meester, L., & Goethals, P. L. M. (2014). An ecosystem service approach to support integrated pond management: A case study using Bayesian belief networks - Highlighting opportunities and risks. *Journal of environmental management*, 145, 79-87.