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Participatory operations model for cost-efficient monitoring and modeling of river basins — A systematic approach

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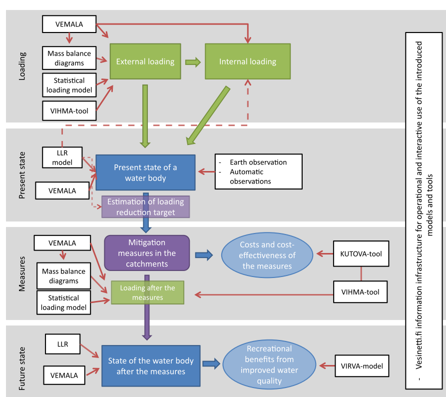
HIGHLIGHTS

- Ecological and economic efficiency of river basin management measures need to be evaluated
- Operational model need to be more effectively automated and integrated
- The web-based map services are useful for the participatory management
- Consultancy services for end users ought to be tailored and provided.
- More emphasis should be placed on the estimation of the economic benefits

GRAPHICAL ABSTRACT



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ABSTRACT

The worldwide economic downturn and the climate change in the beginning of 21st century have stressed the need for cost efficient and systematic operations model for the monitoring and management of surface waters. However, these processes are still all too fragmented and incapable to respond these challenges. For example in Finland, the estimation of the costs and benefits of planned management measures is insufficient. On this account, we present a new operations model to streamline these processes and to ensure the lucid decision making and the coherent implementation which facilitate the participation of public and all the involved stakeholders. The model was demonstrated in the real world management of a lake. The benefits, pitfalls and development needs were identified. After the demonstration, the operations model was put into operation and has been actively used in several other management projects throughout Finland.

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1. Introduction

Despite increasing efforts to reduce nutrient loads from river basins, eutrophication problems and algal blooms have continued. The economic downturn and climate change have exacerbated the problem and increased the need for a cost efficient operations model for the monitoring and modeling of surface water bodies (Hering et al., 2010). Apart from modeling and monitoring with enough frequency and spatial coverage (e.g. Carvalho et al., 2006, 2007; Hering et al., 2010) are costly and time-consuming, there is a pressing need for more efficient operations models and tools (Borowski and Hare, 2007; Malve, 2007; Hering et al., 2010).

For example, results of Water Framework Directive (WFD) monitoring programmes revealed that 66% of 527 assessed lakes had high (H) or good (G) ecological status and that 28% had moderate (M), 6% poor (P) and 1% bad (B) status. Percentage classification of Finnish coastal waters was 15% (H + G), 57% (M), 25% (P) and 3% (B) respectively (Mäenpää and Tolonen, 2011). The milder winters and resulting increase in nutrient load to aquatic systems (Puustinen et al., 2010; Andersen et al., 2006; Ulén and Weyhenmeyer., 2007; Mullana et al., 2012) is worsening algal blooms in Finnish surface waters.

Despite well-structured and costed WFD Programs of Measures (PoMs) in Finland, the status of many water bodies remains unknown due to a lack of chemical and biological data. There are also uncertainties in the analysis of pressures and impacts when evaluating the status of water bodies and planning nutrient loading mitigation measures. The mandatory WFD costs benefits analysis (WATECO, 2003) has not been done systematically due to the lack of efficient operations model.

What is more, the planned management measures cannot be implemented without public and stakeholder involvement and participation. For example management measures in Finland are not binding on stakeholders, many actions are voluntary and public involvement is mandatory (European Commission, 2000, article 14). Thus, all the information and knowledge gained should be disseminated in an accessible and lucid format to ensure public involvement and participation (Borowski and Hare, 2007).

Fortunately, there is a set of integrated decision support systems like AQUATOOL (Andreu et al., 1996) and BASINFORM (Klauer et al., 2012) for the planning and operational management of complex river basins. They comprise the identification of the problems, modeling and evaluation of management measures for the selection of cost-efficient combinations of measures. In addition, Gottardo et al. (2009) introduced a decision support system called MODELKEY for the assessment and evaluation of impacts on aquatic ecosystems and to manage and integrate different types of data, parameters and models. A critical source area framework for the development of supplementary diffuse phosphorus load mitigation measures in Irish catchments was presented by Doody et al. (2012). It integrates a wide range of spatial data, P risk assessment tools, P export models and decision support tools. In the Netherlands, a hydrological water quality model (SWAT) was coupled with an economic optimization model (Environmental Costing Model, ECM) (Cools et al., 2011) and in Denmark Petersen et al. (2009) demonstrated a straightforward and systematic implementation of the WFD in the Odense estuary and its upstream catchment. They presented how reference conditions and an ecological status classification have been conducted with historical data and modeling tools. The pressures and impacts of nitrogen loading in the estuary were modeled, the required load reduction was estimated and an integrated cost-effectiveness analysis was conducted to select the most suitable mitigation measures.

There are pressing and highly relevant questions concerning the use of these tools; how do they cope in a large administrative, geographical context with limited monitoring and modeling resources? How well do they facilitate public participation and can it resolve the mutual misunderstandings of water managers and the research community around the role and importance of model-based tools in implementing water management (Borowski and Hare, 2007)? Therefore it is necessary to (1) improve researchers' understanding of water management processes and the role their tools play within such a process, (2) identify the importance of these tools in social learning-oriented management processes for both communities, (3) improve the role of software consultancies as carriers of research results and (4) consider new methods of model transferability between target basins.

This paper demonstrates a new, cost-efficient and participatory operations model for the monitoring, modeling and management of lakes and river basins in order to commit stakeholders to implementation of PoMs. The criteria for the evaluation were 1) improvement in the understanding of factors affecting the ecological status of waters, 2) easy access to monitoring data and model-based planning and decision-making tools, 3) portability of operations model and related tools for the uniform and transferable assessment of ecological and socio-economic impacts, 4) transparency of uncertainties and risks and 5) activity of stakeholder involvement and participation. As a result, we provide future development needs for the implementation and development.

2. Material and methods

Our operations model and the related tools included the estimation of nutrient loading as well as its ecological impacts and cost-efficiency of management measures (Fig. 1). The monitoring and modeling results were gathered into the www.vesinetti.fi tool, which provides an information infrastructure for the operational and interactive use and exchange of resulting data and models between research community, authorities, stakeholders and public.

Monitoring and modeling results were housed in the www.vesinetti.fi tool, which provides an information infrastructure for operational and interactive use and exchange of data and models between research community, authorities, stakeholders and the public. The www.vesinetti.fi comprises a GIS data base system and model interface; it includes basic information on water bodies (e.g. area and mean depth, satellite images and in situ observations of coastal areas and lakes). Models can be run and files and comments can be uploaded or downloaded in separate dialogue windows for each water body. The system meets INSPIRE standards and is publicly available in Finnish (www.vesinetti.fi).

Another participatory data gathering system Lakewiki (http://www.jarviwiki.fi/wiki/Main_page?setlang=en) is a web service which is built and maintained in cooperation with the authorities and the public. The public can participate in Lakewiki by adding detailed information on their local lake, entering their own observations e.g. on cyanobacteria, ice-out, water temperature, and uploading photos or videos. Lakewiki was created with the aim of sharing information on Finland's lakes, to raise awareness and promote the protection of our waters. The connection to Vesinetti was established to show content such as basic lake information and a comments section within the Vesinetti map service.

2.1. Description of tools

The tested tools included monitoring, modeling and planning methods, which are outlined briefly in the following sections. Each tool is presented in terms of input, output and main usage in Appendix 1. A short description of each tool connected to the operations model (Fig. 1) is given below.

2.1.1. Nutrient loading estimation tools

VEMALA is an operational, national-scale, nutrient (phosphorus and nitrogen) loading model for Finnish watersheds. It simulates runoff processes, nutrient processes, leaching and transport on land, in rivers and in lakes (Huttunen et al., accepted for publication). The model provides an estimate of the external loading, outflow loading, retention and concentration of nutrients and chlorophyll a in all Finnish lakes (of which there are about 58,000), as well as nutrient loading source