MODELKEY DSS as supporting tool for River Basin Management Plan definition: results from application to Elbe and Danube

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1 Introduction

The European Water Framework Directive (WFD) 2000/60/CE (EC, 2000) prescribes a series of tasks for properly assessing and managing river basins with the ultimate aim of achieving a good ecological and chemical status of surface waters by the end of 2015. The Ecological Status (ES) of each water body has to be evaluated and classified by using biological Quality Elements (QE) as key parameters and physico-chemical, chemical as well as hydromorphological QE as supportive parameters. Moreover, the Chemical Status (CS) has to be evaluated by comparison of measured concentrations of priority substances in water, sediment and biota compartments with Environmental Quality Standards (EQS) set at EU-wide level.

In this context, one of the main objectives of the MODELKEY project was the development of a risk-based Decision Support System (DSS) guiding decision makers in assessing and managing river basins according to the WFD requirements (i.e. MODELKEY DSS). In particular, Integrated Risk Indices (IRI) based on a Weight of Evidence approach (WoE; Burton et al., 2002) was developed in order to evaluate and classify the ES and CS at site-specific scale (i.e. sampling stations). Moreover, to prioritize hot spots at basin scale (by integrating both environmental and socio-economic information) a mathematical procedure based on Multi Criteria Decision Analysis (MCDA; Kiker et al., 2005) methods was developed.

The MODELKEY DSS was applied to both Elbe and Danube River Basins.

In this paper, main results obtained by DSS application to Elbe are presented and discussed (the results obtained for the Danube River will be given in the oral presentation). A set of biological, chemical, physico-chemical, and hydromorphological indicators have been evaluated in relation to available reference sites and then integrated according to a set of fuzzy rules implemented in the software system. Results at basin and site-specific scales for both river basins were visualized on GIS maps through the DSS's output visualization interface.

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2 The MODELKEY DSS

The MODELKEY DSS is an innovative software system that combines several risk-based assessment tools supporting the river basin management. It allows classifying the ecological and chemical status of individual water bodies or (monitoring) locations and it prioritizes hot spots by integrating environmental and socio-economic information. All these features are available in a simple-to-use, geographically resolved, GIS-based software system structured in three modules: environmental, socio-economic and prioritization. It offers adaptability to various rivers and local conditions, perfect coherence with the language and the reporting requirements of the WFD, technical simplicity and preferential flexibility, transparency and traceability of results, enhanced by strong graphical interface visualization.

The MODELKEY DSS is user friendly and freely downloadable from the MODELKEY project website (www.modelkey.org) after registration.

2.1 Environmental module

The environmental module of the MODELKEY DSS carries out an integrated risk assessment on the basin of concern. It aims at evaluating the overall status of fluvial ecosystems and provides decision makers with useful information for WFD-compliant management purposes: i.e. both ES and CS of rivers, the biological communities at risk (i.e. key ecological endpoints) and the most responsible causes of impairment (i.e. key stressors and key toxicants). This information turns out to be very useful to direct investigative monitoring activities and to target consecutive interventions.

The module uses environmental indicators as input. Environmental indicators are organised into a hierarchy and aggregated according to dedicated fuzzy inference rules. The output is provided through specific visualisation tools.

2.2 Hot spot prioritization module

The hot spots prioritization module is aimed to support water managers in targeting their economic efforts to those sites along river basins that strongly need management interventions. To this end it takes into account both environmental (i.e. risk assessment) and socio-economic (e.g. water uses valuation) perspectives. Specifically, a set of socio-economic indicators distributed across different economic agents (i.e. consumers and firms) and water uses (i.e. agricultural, industrial, energy production, residential and recreational) are proposed and calculated. By integrating socio-economic and environmental information, sampling sites as well as water bodies are ranked and hot spots are visualized and selected by means of GIS tools.

3 Application to Elbe River Basin

3.1 Used dataset and indicators

Information on habitat typologies and related reference sites were provided by the German Federal Institute of Hydrology (BfG) as confidential information.

Based on data availability in the BASIN DB (official database of the MODELKEY project), the Integrated Risk Assessment (IRA) methodology was applied to assess the environmental quality of Elbe in 2006. Raw data were available to calculate the following indicators in the majority of sampling sites:

- Biological indicators: Evenness (Pielou, 1969), Margalef (Margalef, 1984), Shannon (Shannon & Weaver, 1949) and Simpson (Simpson, 1949) for invertebrate fauna and phytobenthos (general degradation); NBI-N (Nutrient Biotic Index-Nitrogen), NBI-P (Nutrient Biotic Index-Phosphorus) (Smith et al., 2007), BBI (Belgian Biotic Index), BMWP (Biological Monitoring Working Party), SPEAR (Species At Risk) (Liess & von der Ohe, 2005, Von de Ohe et al., 2007) for invertebrate fauna (eutrophication, general degradation, organic pollution and toxic pressure);

- Chemical indicators: Chemical Status (CS), Toxic Units (TU), Potentially Affected Fractions (PAF; Posthuma et al., 2002), Chemical Comparison With Reference (CCWR);
- Hydromorphological indicators: Simplified AusRivAS (Parson, 2002).

Socio-economic data were available in each region only for 2008. The following indicators were calculated for five water uses, i.e. agricultural, residential, energy production, recreational and industrial:

- Water consumption in cubic meters;
- Market efficiency as GDP per cubic meter;
- Lerner Index (Varian, 2006) as representative of market competition conditions.

3.2 Examples of results at site-specific and basin scales

Figure 1 reports the ES final classification for a group of sampling sites located in the Sachsen region of the Elbe River Basin. Each pie chart shows the sampling point's membership degree to one (100%) or two (complementary percentages) WFD status classes (i.e. high, good, moderate, poor and bad) represented by using WFD standard colours coding: slices are larger or thinner according to the probability of belonging to each status class. The membership degree mainly ranges from poor/moderate to good/high apart from one site characterised by a partial membership degree to bad status.

As an example, the site Schirmbach Mundung is investigated (black arrow in Figure 1). The IRA methodology assigns about 70% membership degree to good status and about 30% to moderate status.

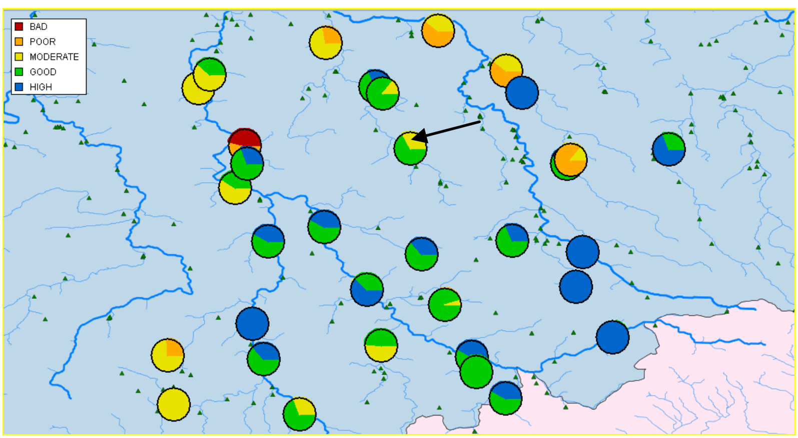

Figure 1. *Pie charts visualising membership degrees to WFD status classes for a group of sampling sites located in the central part of the Elbe River Basin. The black arrow indicates site Schirmbach Mundung.*

The availability of socio-economic information allowed the estimation of the socio-economic importance of various regions. As an example the socio-economic output of a specific administrative region of the Elbe River Basin is visualised (Figure 2). The region under investigation is Berlin that has a membership degree varying from low to medium class. Exploring the intermediate results that give a contribution to the estimation of the socio-economic importance of the region, the overall water usage for industrial and agricultural purposes seem to be the most relevant.

Figure 2. *Pie chart showing the socio-economic importance of Berlin (blue, yellow, red mean high, medium, low socio-economic importance, respectively).*

Finally, Figure 3 reports the site priority distribution over the Sachsen region of the Elbe River Basin (as environmental indicators could not be calculated in other regions).

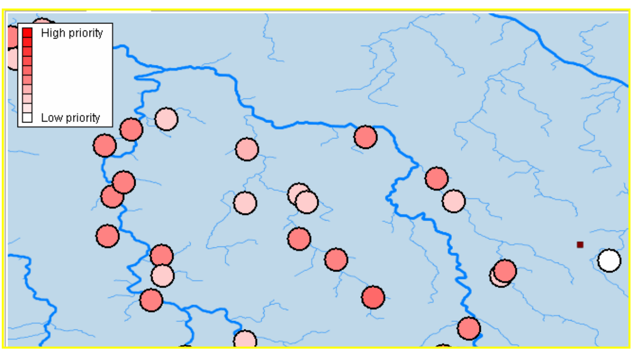

Figure 3. *Site priority distribution over the Sachsen region of the Elbe River Basin. Red, pink and white colours mean high, medium and low priority, respectively.*

4 Conclusions

The experimental application of the IRA methodology turns out to have several advantages. It allows using and aggregating information on different quality elements as recommended by the WFD. It expresses ES classification as membership degree to one or two WFD classes: this provides decision makers with easy-to-understand results including uncertainty estimation. The user can consider any types of data and indicators according to his assessment goals, can adjust membership functions defined for biological indicators based on local responses at reference sites, and can provide his expert judgment to biological indicators' hierarchical aggregation. CS is refined by taking into account other chemical indicators such as TU and PAF that enlarge the spectrum of chemical substances and estimate potential toxicity of mixtures. The IRA methodology is transparent and flexible, and the tiered assessment procedure allows to address new monitoring activities when there is missing information or discordance among indicators and results are highlighted.

In addition, the results of the hot spots prioritization procedure will guide the decision maker to focus further investigations and to target remedial efforts to those sites or water bodies where poor environmental conditions could compromise current or future important socio-economic uses of water resources. This kind of results, visualized by GIS maps, could help the decision maker in discriminating among sites or water bodies characterized by similar water quality but showing a different socio-economic usage of water resources: in this case the procedure assigns higher priority to those regions where water resources are largely and rationally used.

For the abovementioned reasons, the MODELKEY DSS is suggested as the new tool for supporting the future generations of River Basin Management Plans.

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