A decision support system (DSS) for river-basin management in the Elbe catchment

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Summary

Water resources management on the river-basin scale as the EC Water Framework Directive demands, flood control, and also the maintenance of rivers as navigable waterways constitute together a highly complex task. The understanding of the consequences of anthropogenic interventions in river ecosystems presupposes knowledge of the impacts that have to be expected. Only then decisions can be taken that ensure adequate consideration of the interests of river-landscape protection as well as the social use interests. For this reason the German Federal Institute of Hydrology (BfG) initiated the development of a Decision Support System (DSS) with the example of the River Elbe in the process of pooling the results achieved within the BMBF Research Association "Elbe Ecology". The DSS pilot version has the purpose to make knowledge on the interactions of natural and anthropogenic factors available for administrative tasks and policy decision making in a userfriendly and practice-oriented way. Further a DSS is also a tool for communication and discussions between scientists and decision-makers. Now, this approach has to stand the practical test to identify options for further developments. In the present version, the functionalities are organised in form of examples covering the topics water quality/reducing pollutant loads, flood control/flooding risks, ecological state of floodplains, navigability, as well as external scenarios such as climate change, agricultural policy, and demographic developments.

Introduction

River basin management means controlling a complex system in which natural and anthropogenic factors are closely interwoven, while the demands of society regarding the uses and the protection of landscapes and waters have been growing. Accordingly, multidisciplinary knowledge needs to be combined in order to meet legal requirements like the EC Water Framework Directive (WFD), (EUROPEAN UNION 2000), the Flora-Fauna-Habitat Directive (FFH), (EC 1992), but also to be able to respond adequately to sudden events like the flood in the River Elbe in the year 2002. For these reasons, the German Federal Institute of Hydrology (*BfG*) initiated the development of a decision support system (DSS) using the River Elbe as example. A DSS makes interdisciplinary knowledge available for administrative purposes and for policy decision-making processes. The DSS pilot version has the main aim to provide exemplary functionalities for federal institutions and those of the federal states. The groundwork for the pilot-DSS was laid in the interdisciplinary research of the association "Elbe Ecology" (GRUBER et al. 2001), of the *BMBF-GLOWA-Elbe* project (http://elise.bafg.de/?2692), and other projects, e.g. WIND et al. (1999), ENGELEN et al. 2000, and MATTHIES et al. (1999). Poject partners are listed in the Project Description.

Methodology: Objectives and underlying idea of the Elbe-DSS

Supporting decision-making

Following SIMONOVIC's (1996) definition, the Elbe-DSS is understood as a computer-based information system that structures complex problems. Sectoral knowledge and available models are summarized in a basic framework and supplemented by a user interface, a database, and a tool kit with software instruments for effective work with the underlying models and data. A knowledge base that is kept at several locations is virtually combined and broadens the basis for decision making.

Instrument for policy decisions

A DSS has the purpose to enable the assessment of the impacts of different options. It should highlight cause-effect relations and the sensitivity of different actions. In the foreground of the considerations are more scenarios than "concrete" construction projects. Policy questions such as "Which action among several options is the better one?" can be analyzed; whereas the question "How much better is this option against the other?" can be answered only with some reservations.

Harnessing available models

Generally, available sectoral (research) models should be employed. By applying a customized user interface they are made applicable in the management context. The DSS approach itself, as it is presented here, is not a model.

Communication

The application and the development of a DSS serve also the communication between scientists, stakeholders, and decision-makers.

Transparency and acceptance

The structure of the user interface is oriented at customer requirements. It is developed in a participative process, thus ensuring transparency in the system. By means of a library function, all incorporated data and models are registered regarding their sources, and the limits of the accuracy of the system are indicated. In order to enhance the acceptance of the DSS in practice, the pilot-DSS can run on any PC without any ancillary programs, its operation does not require any additional licences or specific software knowledge (e.g. GIS).

Updating and transferability

The technical implementation is designed so that single components, whether data or models, may be replaced at any time without distorting the whole system or re-building it anew. The DSS approach itself is transferable, of course, provided validated data and models are available for the new river basin. The adaptation of the functionalities depends on the user requirements and on the management-issues to be treated.

Results: Development of a DSS using the Elbe river basin as example

Participative approach

In order to ensure the practical relevance and to identify user interests, the DSS was developed in a cooperative effort with potential users, including e.g. competent authorities of the federal government and the federal states (*Länder*), the Elbe river-basin association, representatives of municipalities, and environmental associations. This group also selected the currently relevant development objectives. Moreover, meetings were held with potential users of the system on selected topics (flood defence, river training, water quality, mass transport, etc.). These meetings defined priorities in the work process, the form of presentation of indicators (maps, graphics, etc.), finalized the formulations in the dialog boxes, and tested the ergonomics and user-friendliness of the system interface critically.

Which functionalities does the DSS offer to its user?

A modular, scale-related system diagram was drawn up that at present includes the modules "river basin" (Elbe basin - German part), "drainage network", "main river" (river plus floodplain), and "river reach" (at Havelberg [Elbe river-km 411 - 422] including the floodplain) (Table 1). These modules work in different spatial and temporal resolutions. Figure 2 outlines all elements of the system diagram. The activities, external scenarios, and development objectives shown there illustrate the possibilities the user has to intervene into the system or where to address his/her questions to.

Usually, the parties involved in river-basin management, "the participants", have diverging development objectives and ideas about the actions to be taken. The users of such a system may select in the DSS and enter the planned "activities" by which they want to achieve their "development objectives". The previously defined "indicators" are state parameters that describe the degree of attainment of a development objective. With the indicators presented in the DSS, the user can have the consequences of his/her activity policy displayed and assessed (balanced). An

evaluation is not given in the present version. Additionally, the user may select previously computed "external" scenarios, such as climate-change scenarios or land-use scenarios.
The external scenarios and the activities are interrelated. They are implemented in the system kernel according to the parameters in the models that are affected. The ranges within which the user may vary these parameters are defined on a case-by-case basis in order to avoid meaningless or contradictory settings.

Tab. 1: Implemented functionalities, scales, spatial-temporal resolutions in the modules of the pilot-DDS

Module **Catchment**	**Module** **River network**
⇒ scale	
ca. 100.000 km^2, german part ofthe catchment	river network, 3rd level
⇒ time scale / temporal resolution	
months up to years	months up to years
⇒ spacial scale	
low, sub-catchments, 100 - 1000 km^2	ca. 40.000 river stretches of 1-2 km
⇒ management objectives / indicators	
• protection of the north sea / reduction of pollutant loads (referring to pathways, diffuse and point sources, mean annual loads N, P and other pollutants)	• amelioration of the ecologic and chemical state of the of the river network (concentrations N, P and other pollutants)
⇒ measures / management options	
• landuse changes • agricultural practices • communal waste water treatment • reduction of surface sealing	• Change in drainage systems (soil delivery ratio) • upstream/downstream migration/passage passability (parameters of weirs and dams)
⇒ external scenarios	
• climate change, agro-policy, demography	
Module **Main Channel**	**Module** **River Section**
⇒ scale	
main part of the Elbe River, ca. 500 km	Elbe-km 400 - 425, section at Havelberg / Sandau
⇒ time scale / temporal resolution	
discharge statistics, partly single events	process oriented, hours up to years
⇒ spacial scale	
100 m - 10 km, 1D-Model approaches	10 m - 50 m
⇒ management objectives / indicators	
• flood protection / estimation of flood risks (damage potentials, return periods of flooding) • amelioration of the ecological status of the floodplain (vegetation / biotope-distribution) • navigability (average days/year)	• flood protection / estimation of flood risks (damage potentials, return periods of flooding) • amelioration of the ecological status of the floodplain (habitat conditions for species (river, riparian and floodplain area)
⇒ measures / management options	
• dyke maintenance / creation of retention areas / polders • river engineering measures • land use changes	• dyke shifting scenarios / variants • river engineering measures • landuse changes (e.g. afforestation in the floodplain)
⇒ external scenarios	
• assumption of certain statistical derived flood events (selected return periods)	• season (→Makrozoobenthos) • dyke break scenarios

It is intended to use the DDS approach presented here in the decision-making by different participants for suggesting activities or preparing decisions. Moreover, certain functionalities of the DDS shall be used for public information purposes in plan-approval procedures.

Technical aspects and user interface

The rough structure of the Elbe DDS consists of four functional basic components: User interface, tool-kit, simulation kernel and models, GIS/database. The individual components communicate via standardized software interfaces that are defined in the GEONAMICA® application architecture. GEONAMICA® was developed as program-development environment by the project partner RIKS. It supports the development of spatial DSSs on the basis of complex integrated models. The basic components "simulation kernel" and "models" make up the actual core of the DSS. The simulation kernel processes commands from the level of the user interface and controls the simulation operation. The simulation kernel knows the structure of the integrated model and controls its individual model components via a standardized software interface, thus facilitating the relatively easy replacement of single model components. Some of the DSS functionalities are implemented in external programs that are activated by the DSS (e.g. GREAT-ER). An important aim of the Elbe-DSS development was to create an "open system" that can be updated and further developed in the future. A precondition for this are documented and vendor-independent data formats that are accessible with public-domain software.

The appearance of the Elbe-DSS is that of a Windows program with interactive user interface (Figure 1). Specific elements are an interactive system diagram and auxiliary tools like a layer viewer to display grids and vector maps and dialog boxes, which enable the user to set various actions (like taking a measure or choosing a climate scenario). At the highest level of abstraction, the interactive system diagram is an illustration of the Elbe-DSS model structure and the information fluxes between the individual thematic fields and models. Simultaneously, the interactive system diagram opens the different functional areas of Elbe-DSS (“system”, "external scenario", "measures" and "management objectives") with the associated diagram sheets that are accessible via "index-tabs"/markers.

The context-sensitive library function is generated by means of an on-line help format (WinHelp, HTMLHelp). It is structured through hypertext and internet links and allows rapid access to the desired information.

The Elbe-DSS is a PC application for Windows NT, 2000, XP. Under Windows NT at least 256, better 512 MB, are recommendable; under Windows XP at least 512, better 1 GB.

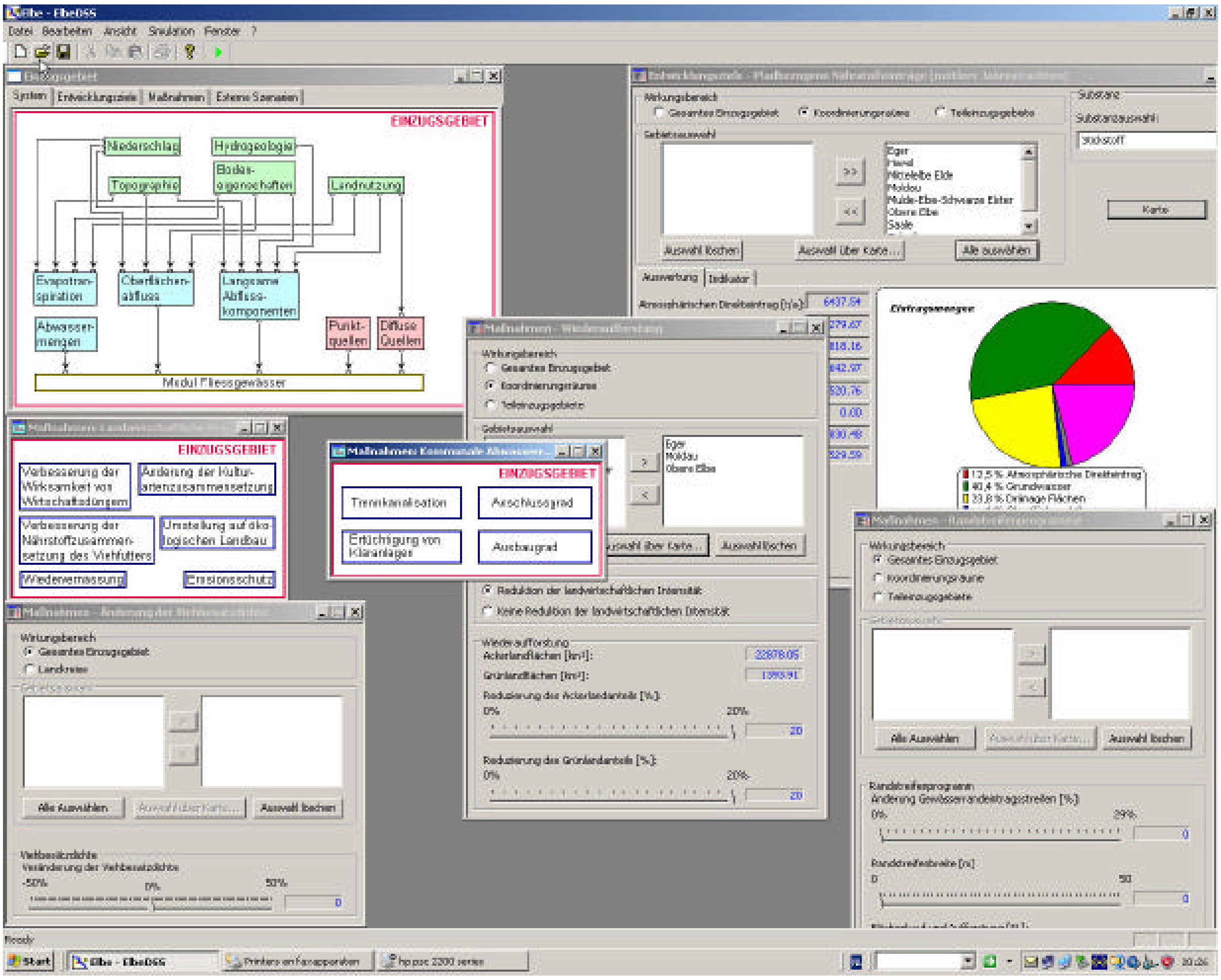

Fig. 1: Example: User interface of the (pilot)-DSS on the Elbe river basin

Discussion and outlook

In its basic functions, the pilot-DSS Elbe is a working system. The user of such a system should be able to see - irrespective of the context of the River Elbe - which potentials it offers to the institution concerned and the tasks to be fulfilled. However, the possibilities offered by the pilot-DSS are still limited. For instance, complex, highly resolving models, that allow to simulate the components of the ecosystem in a floodplain, are - for the time being - applied only along a limited river reach (Elbe river-km 412-422). The available resources for the pilot-DSS allow to use only the offered range of existing models or models that were adapted to the River Elbe in the context of Elbe-research activities (e.g. ELBA or HEC-6 from the perspective of hydrology/hydraulics). In order to achieve full flexibility regarding user requirements, i.e. the integration of complete model systems instead of pre-calculated scenarios, in the future modules will have to be modified according to user requirements, and up-to date data must be integrated, what will be technically feasible without major problems. At present, the efforts for integration of economic target values and indicators into the DSS are continuing. The results obtained in the research association "Elbe Ecology" (*inter alia* DEHNNARDT UND MEYERHOFF 2002) provide a broad foundation for such developments. Moreover, the extension of the study area over the southern part of the Elbe catchment in cooperation with Czech partners is desirable.

The pilot-DSS is the first step towards an Elbe-DSS, which will then offer a system interface that is designed for the concrete user requirements and will work with up-to-date data that the users provide. Only in this stage of development will it then be appropriate to speak of a fully-fledged DSS for decision-making.

The intention is that a DSS as described here will be used in decision-making by the different participants in river-basin management to propose options for action or to take decisions. Moreover, there is a possibility that a DSS will be used in participative decision-making processes as provided for in the WFD. One can imagine a combined procedure with multi-criteria decision optimization, as proposed by e.g. HOSTMANN et al. (2003). Furthermore, the use of certain DSS functionalities for public information campaigns in the context of plan approval is envisaged, what is practicable for instance by means of the GIS functionalities that can be handled even by a layman/laywomen.

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Project description

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Figure 2 System diagram of the pilot-DSS Elbe