Interdisciplinary co-operation: the key to river basin management?

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1 Introduction

River basins fulfil a variety of functions such as: agriculture, living, recreation, nature, industry and many more. These functions interact with each other; sometimes stimulating each other while in other cases these functions counteract. Managing a river basin requires insight in the interaction between these functions in the river basin. However, the scientific basis for each of these disciplines such as sociology, economy, ecology or fluid dynamics, describing these functions, differs widely. This affects the scientific expectations such as predictability and reliability for each of these disciplines. In managing a river basin this conflict of expectations makes that scientific co-operation which is essential for developing a policy in river basin management, and which is sometimes is not working as efficient as it should be. In this paper we will present lessons on interdisciplinary scientific co-operation from previous projects on water management we have been involved in. The two main themes in this paper are "what are causes of the problems in interdisciplinary research (par. 3 and 4)" and "how can these problems be overcome? (par. 5)." For details on the projects in this paper we refer to de Kok et al. (1998) and Wind et al. (1996, 1997, 1998).

2 What is river basin management?

River basin management is the process by which policies related to the river basin are brought to a successful conclusion. It has three aspects (after Turner 1993 pp 14 en 15):

The objectives:	scope, organisation, quality, costs and time (and risk),
Management processes:	plan, organise, implement, control,
Levels:	integrative, strategic and tactical, operational.

A river basin policy will be defined as the actions aimed at achieving specified objectives with well-specified measures and within a fixed time frame. The term "objective" is often interchanged with the words goal and target. However, properly speaking, a goal is more broadly stated, less likely to be quantitative, and usually unspecified in time; a target, on the other hand, is concrete, quantitative, specified as to time, and operational. An objective lies somewhere between. Managers would like to be able, for the sake of analysis, to measure the degree to which an objective will be attained by the measures considered. For this reason, if the original objective cannot satisfactorily be quantified, one must often define a proxi objective: a substitute that points in the same direction of the original objective but which can be measured (Miser and Quade 1985, pp. 129). A measure is a feasible technical or non-technical action. This thinking in terms of measures-objectives or means-end or cause-effect relations is the basis for rational management. Obviously, also non-rational aspects play a role in river basin management but in this paper the focus will be on the rational aspects.

3 A system diagram: measures and objectives related

A system model can be used to describe the relationship between measures and objectives. A simple representation of the system, in which the whole system is aggregated in one system S is shown in Fig. 1. The system S relates the measures M to the objectives O. The system description itself consists of system variables, system parameters and it system relations. Such a descriptive system is a representation of the natural system and is a model of the natural system. This does not mean that the system variables or the system relations are equally known for all disciplines. This point will be discussed in paragraph 5.

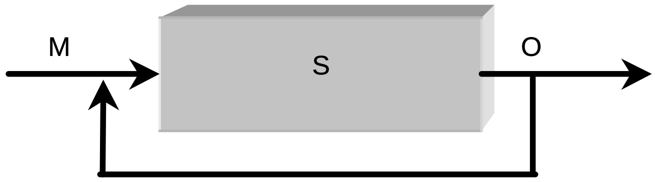

Fig. 1. The system S relates the measures M to the objectives O

In Fig. 2 the system is represented at a lower level of aggregation. The measures and output variables (objectives) are related to specific processes in the system diagram. The system diagram consists of boxes connected to each other by means of arrows. Each box represents a process or set of processes which transfer input into an output. By reducing the aggregation level in Fig. 2B and 2C, more and more processes arise.

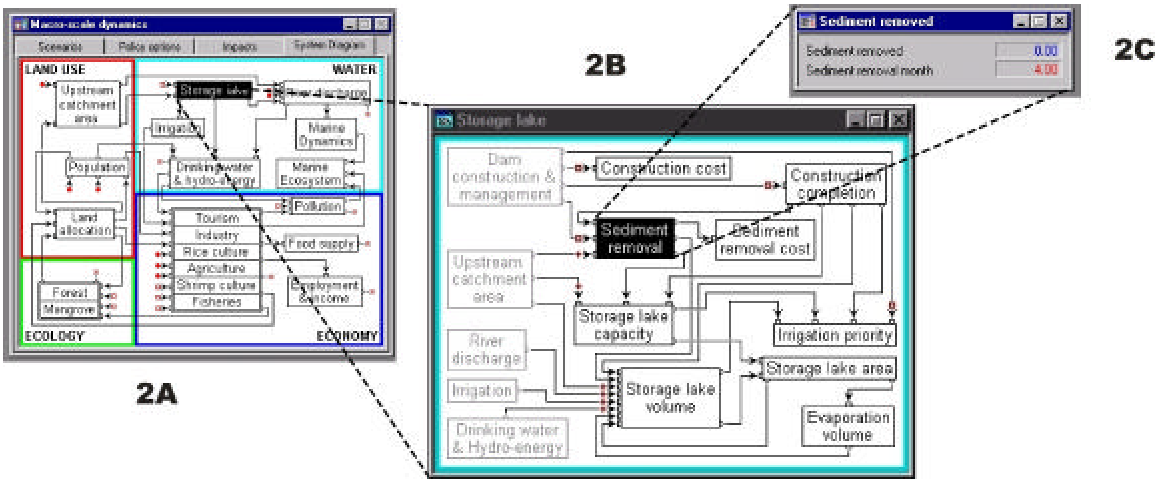

Fig. 2. System diagram from (Wind et al, 1997)

At the top of Fig. 2 the words scenarios, policy options, impacts and system design are shown. Policy options refer to measures. Impacts contain among others also the effects of the measures on the objectives. Scenarios are internal and external developments which affect the system but are beyond the control of the system, such as a change in interest rate, population growth etc. Impacts, policy options and scenarios are dealt with in separate screens in Wind et al. (1997) and are not discussed in this paper.

The system diagram in Fig. 2 is subdivided into four separate disciplinary areas: water, economy, ecology and land use. During the development of the project it turned out that the disciplinary contribution of each of these disciplines differed to the extent to which the process variables were known as well as the process relations. This will be illustrated in the next paragraph.

4 Knowledge of process variables and process relations in the contributing disciplines

4.1 Water

The relationships describing the motion of fluids are based on the continuity equation and the momentum equation. From this fundamental approach a wide variety of approximations have been derived. In all these sub-theories the expression for the process variables such as convection, diffusion and pressure gradient are known. The parameters related to the process variables are derived from data and contain also some of the effects of the approximations. The relations combining the process variables and -parameters are known.

4.2 Economy

Economy does not have a unifying theory as is available for the motion of fluids. In economy a wide range of theories exists describing economic phenomena, for instance the relation between economic input and output; economies on various spatial scales (micro, meso and macro) as well as theories used for describing economic decisions such as cost-benefit. Within each of these theories the type of process variables is defined but the specification of the process variables for a given case requires sometimes further research. This is also the case for the relations combining the process variables. The assumptions on which the economic theories are based, such as the cost benefit analysis, are subject of continuos debate leading to different schools. The phenomenon of different schools is not known in water sciences.

4.3 Ecology

In ecology, fundamental schools exist together with empirical schools. In the fundamental schools research in fisheries sciences is focused for instance on equations for the bio-mass, representing the life cycle of the species. The process variables as well as the relations combining the process variables are known in this case but the specification of the process variables is the weak link. The empirical approach is focused on obtaining the relevant process variables and also on finding a relation which mimics the observed ecological phenomenon. Not all process variables and process relations are known a priori. A number of different schools exist.

4.4 Land-use cover changes

Land-use cover changes is a field with many approximations. In the RAMCO model (White and Engelen 1994 and Wind and Kok 1997), the macro model yields a demand for spatial change for each function in the river basin. On the micro level this demand is spatially differentiated based on:

- suitability of each cell,
- potential of each cell for transition to a new land-use type,
- interaction of the cells with the surrounding cells.

The interaction with the surrounding cells is based on the degree by which functions push or pull each other and the distance this effect takes place. Hence it is assumed that the important process variables are known. There is no relation combining the process variables but some information is known about the way the process variables interact.

4.5 Anthropology

Table 1. Differences in knowledge about process variables and process relations between the contributing disciplines

	Process variables	Process parameters	Process equations	Predictability relative to water
Water	Known	Derived from empirical data	Known	
Economy	Known within a theoretical concept	Derived from empirical data	Known within a theoretical concept	++++
Ecology	Partially known	Within wide ranges	Empirical	+++
Land use change	Partially known	Push and pull	Unknown	++
Anthropology	To many known	Unknown	Unknown	+

In the contribution of the anthropology it was made clear that determining the relevant process variables is part of the research. Furthermore, the effect of some of the process variables was clear but not for all variables. A relation combining the process variables representing the observed anthropological phenomenon was expected to be out of the question.

Summarising, we found that the degree to which the process variables and the process relations are known differs between the participating disciplines. This is shown in Tab. 1.

5 Interdisciplinary co-operation guided by consistency and accuracy

The differences in knowledge of process variables and process relations between the disciplines may explain the differences in accuracy by which the disciplinary results can be reproduced as well as the possibility of predicting developments in future. In interdisciplinary studies it is claimed that the mutual interaction between the phenomenon described by the disciplines is essential for the analysis of impacts of measures. In the past the recognition of the differences in accuracy and predictability led to disciplinary approaches, neglecting the interdisciplinary effects.

In order to develop an interdisciplinary approach, information must flow between the disciplines as shown in Fig. 2A where water effects economy etc. etc. However, this requires that the inputs and outputs are coherent and consistent. Consistency implies that the output of the one system is significant on the time and space scale for the input of the other system. Obviously the disciplinary process itself may be represented on a lower level of aggregation but at the end the results must be aggregated to the level of the receiving input. In case a system has more than one input, the inputs should be of the same order of magnitude. If one of the inputs is an order of magnitude smaller than the remaining inputs, then the smaller one could be considered to be left out. This will simplify the system. Finally the output of one discipline should be the input for the other discipline.

In addition to consistency, accuracy is also an important concept for an interdisciplinary system. In each disciplinary process the input is transferred into an output and at the same time the output will be less certain than the input. The increase in uncertainty in a disciplinary contribution depends on the spatial and temporal distribution as well as the state of the science in that discipline. Hence the designers of the integrated system have to determine for each of the processes (disciplines) which accuracy is required and hence which spatial and temporal disciplinary representation is required. A first clue can be obtained from the theory of error propagation in (linear) systems.

It will be clear that designing a system based on concepts such as consistency and accuracy should be a first step in making system modelling more a science than an art, as it is now.

6 Discussion

The present paper is based upon a limited number of interdisciplinary projects in water management. It is expected that some of the conclusions presented in this paper will be recognised by other researchers in the field. However, the number of projects at present is too small to draw general conclusions.

In this paper the contribution of a number of disciplines to an integrated approach of river basin management has been analysed. It was found that the knowledge about process variables and process relations changed when going from fluid dynamics via economy and ecology towards the social sciences. This difference between disciplines may also explain the differences outlined in Tab. 2.

This analysis learns that integration of disciplines from different disciplinary sciences leads to differences in expectations, scientific tradition, and predictive capability.

In the design of an integrated system, consistency and accuracy can be used as guidelines. However, only simple methods are available which can be used in the design process. This makes the design of an integrated system a process of a team of scientists, each contributing a number of options by means of which a discipline can be represented. Expert opinions on accuracy and consistency should lead to an initial design which then can be used for a formal approach based on sensitivity analysis and accuracy analyses.

Tab. 2. Differences in scientific traditions between the contributing disciplines

	Predictability	Number of scientific schools	Process versus data	Lab versus field
Fluid dynamics	Predictive	Limited number of schools	Process oriented	Laboratory oriented
Economy	↕	↕	↕	↕
Ecology				
Social sciences	Descriptive	Many schools	Data oriented	Field oriented

Although the call for an integrated approach of river basin management is strong there are some important drawbacks for an interdisciplinary approach as shown in Tab. 3.

Tab. 3. Advantages and disadvantages of disciplinary and interdisciplinary research

	Disciplinary research	Interdisciplinary research.
Scientific principles	Known	Unknown
Publication	Easy	Difficult
Scientific esteem	High	Low
Type of work	Individual	Team
Funds	Simple	Difficult

The drawbacks in Table 3 make clear that interdisciplinary research will not flourish by itself.

This study has also shown some of the challenges of an interdisciplinary approach: it is scientifically innovative; it opens new perspectives and is essential for a sustainable development of river basin management. However the key towards such an integrated approach, in terms of a scientific methodology, is still lacking.

Literature

Hoogerwerf, A. (1989) Overheidsbeleid (in Dutch). Alphen aan den Rijn: Samsom HD Tjeenk Willink

Kok, J.L. de, Wind, H.G., Titu, M. (1998) Applicability of fuzzy logic to incorporate social science concepts in a decision support system for coastal zone management. Proceedings of the Third International Conference on Hydroinformatics, 387-393

Miser, H.J., Quade, E.S. (1985) Handbook of system analysis. New York: John Wiley

Turner, J.R. (1993). The handbook of project-based management: improving the processes for achieving strategic objectives. London: McGraw-Hill

White, R., Engelen, G. (1994) Cellular Dynamics and GIS: Modelling spatial Complexity. Geographical Systems 1, 237-253

Wind, H.G., de Blois, C.J. (1996) Assessment of flood damages and benefits of remedial actions: "What are the weak links?", with application to the Loire. Physics and Chemistry of the Earth. XXI General Assembly of the European Geophysical Society, 6-10 May, Ref.no.: S0079-1946(96)00011-0 Den Haag. 20 (5-6), 491-495

Wind, H.G., Kok, J.L. de (1997) Rapid assessment mode for coastal-zone management. Bordomer '97. Amenagement et protection de l'environnement littoral. Tome 2. Actes du colloque. IFREMER (28-29 Octobre) Bordeaux, France

Wind, H.G., Verbeek, M., Nieuwkamer, R.L.J., de Blois, C.J., Kok, J.L. de (1998) An approach to consistent and efficient system building for decision support in water management. Proceedings 3rd International Conference on Hydroscience and Engineering. 31 aug. – 3 sept. 1998. Cottbus/Berlijn. (pp 15)

Wind, H.G., Reijngoud, T.T., Engelen, G., Keizers, N. (1999) Decision support systems for river management, based on experience with WadBOS. International BMBF/UFZ Confernce "River Basin Management". 8-9 June 1999, Magdeburg, Germany