10. STATE-OF-THE-ART FOR SOCIO-ECONOMIC MODELLING

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10.1 Definition of socio-economic domain

The consideration of socio-economic issues in water management planning is one of the most important prerequisites for a sustainable water use. Economic efficiency and social harmony are the key socio-economic targets. In addition, sustainable water management, if it should be implemented in real watersheds, cannot ignore the legal-political conditions at local, national and EU level. The quality of water models is therefore influenced by how far those conditions are considered.

With regard to the economic efficiency criteria, such as the cost-effectiveness and cost-benefit ratio of water-related measures, water management modelling has to focus first of all on reaching a rational water allocation between competing water users (e.g. private households, agriculture and industries) or between different purposes of water use (e.g. drinking water, irrigation and process water and waste water). Furthermore, in terms of water quality, environmental standards should be reached as cost-effectively as possible. In practice, this helps essentially to implement those standards (as the costs become more acceptable). With regard to the criteria of social harmony water management modelling has to consider issues, such as impacts on equity of living conditions (including environmental quality), economic development, employment, and other social welfare effects resulting from water-related measures.

Political instruments to achieve a sustainable water use include legislation (water quality standards, water rights and environmental taxes), voluntary approaches (subsidies and co-operative agreements) and organisational-institutional arrangements (advisory boards, information systems and decision support systems). Therefore, in integrated water management models the legal constraints given in watersheds and the political instruments to achieve a sustainable water use should be considered as well.

10.2 Needs of QA guidelines

The need for a consideration of socio-economic and legal-political issues in QA guidelines follows from the key principles of the EU Water Framework Directive (WFD). The management of water resources within the river basin catchment has to be based on the concept of integration. This includes the integration of a wide range of measures, including and economic (e.g. water pricing) and financial instruments.

The specification of relevant economic elements in water policy has been started in the working group on economics, named WATECO (for WAter an ECONmics), established in December 2000. The members of WATECO are economists and technical experts and stakeholders from European Union Member States and from a limited number of candidate countries to the European Union. The French Government (Ministère de l'Aménagement du Territoire et de l'Environnement) and the European Commission (DG Environment) have the responsibility for the secretariat and animation.
of this working group. The main objective of this group is the development of a non-binding and practical guidance document for the economic elements of the WFD. The papers and reports produced by this working group contain useful advises on how to define the relevant socio-economic and legal-political variables to be incorporated in water management models.

Up to now the socio-economic and political elements in the future EU water policy may be summarised as follows (WATECO, 2002):

- Clarifying the economic impacts of individual water management decisions, in particular the trade-offs at stake in a river basin with different water users and other people concerned.
- Reaching the least-costly way for the economy or for specific economic sectors for achieving environmental objectives for water resources.
- Assessing the (expected) economic impact of a proposed programme of measures aimed at improving water status (i.e. who are the losers, who are the gainers; compensatory measures may be necessary).
- Balancing environmental objectives for water resources with economic and social objectives in a search for overall sustainability in individual regions and with respect to individual water bodies.
- Developing and assessing economic and financial instruments (e.g. water prices, water abstraction charges, waste water charges and other environmental taxes), that may be effective in achieving sustainable water use (such as e.g. improving the quality of water or facilitating efficient inter-sectoral allocation of water). Whereas the economic instruments aim to reach an efficient water use ('economic incentives'), the financial instruments are related to the expenditures of water users (for instance, the instrument becomes financial when the total value of water is not considered and only financial values are considered).

Especially with regard to the criterion of cost-effectiveness it is important that the same costs (i.e. types) are considered in the different countries, river basins and for different measures. The same is true with respect to the methodology of cost calculations. Otherwise a comparison between the different outcomes of the cost-effectiveness analyses will be hardly feasible at EU-level.

A further task of WATECO is to test the economic analysis by means of pilot studies in river basins. The main purpose of these studies is to discuss implementation issues and identify potential obstacles. The watersheds chosen include the Ribble Basin (UK), the Ebro River Basin (Spain), the Rhône-Méditerranée Corse basin and Adour-Garonne basin (France), the Scheldt international river basin (France, Belgium, The Netherlands) and the Middle-Rhine sub-basin (Germany). The practical experiences gained from these pilot studies might help to develop QA guidelines and vice versa. Thus QA guidelines might contribute to a better modelling of integrated water management decisions which focus on the socio-economic issues.

The role of integrated water management models is to facilitate the implementation of the WFD by considering the above-mentioned socio-economic and political elements in the future EU water policy. Consequently, these elements of the future EU water policy are important criteria for the development of QA guidelines. In particular, the application of water management models should help to develop integrated river basin management plans as laid down in the EU WFD (by 2009).

Modelling of water management decisions should be comprehensive as far as possible, integrating all users and sources and considering all relevant domains (including the socio-economic and legal-political issues). Using watersheds or river basins as the regions of modelling makes it possible to account both for all the water
sources (e.g. groundwater, surface water and storage water) and for the way the resources are divided among the different users (Bouhia, 2001). Models may cover several river basins and the submodels may be linked together at the regional, national or international level (as analysed by the HarmonIT project). Simulation and optimisation procedures should consider simultaneously hydrological, ecological, agricultural, industrial, municipal, economic, social, legal and political variables to model the interrelationships among all relevant parameters in a watershed.

For instance, water availability greatly affects agricultural production and consequently the socio-economic situation in this sector. Water abstractions rights and the cost of water for farmers are important decision variables. The same is true with regard to the industrial and municipal water demands. The design of appropriate water allocation can benefit from improved modelling of water allocation at the river basin level. Therefore, QA guidelines have to incorporate socio-economic and legal-political issues as far as possible.

10.3 Discussion in scientific literature

Even though the agricultural water use is emphasised, the report of McKinney et al. (1999) provides a comprehensive overview of integrated hydrologic-economic modelling at the river basin scale. In addition, the report identifies important socio-economic parameters, such as:

- Transaction costs (e.g. information, monitoring, contracting and enforcement).
- Productivity of water and net benefits of different water users (e.g. agricultural, domestic and industrial use).
- Demand for and economic value of water (e.g. production cost and willingness to pay).

For instance, the modelling of the demand for and the economic value of water in the agriculture sector is based on a production function that relates crop production to the use of water and other inputs (e.g. fertilisers). An aggregated crop-water production sub-model should address issues at the basin level. McKinney et al. (1999) elaborate some requirements concerning the flexibility of those sub-models, for instance, it should be easily adjustable to various farming conditions. Furthermore, various methodologies for simulation and optimisation procedures applied in water management models are presented (such as linear, polynomial or multiseasonal user production functions, deterministic or stochastic functions, linear or dynamic programming, partial or general equilibrium models).

For instance, linear programming seems to be best suited for determining reservoir capacity. General equilibrium models are based on entire watersheds whereas partial models address the optimisation at farm level. Modelling of the demand for and the value of water requires a decision rule to determine the farmers' choice of optimal cropping pattern, water use and application of irrigation technologies, conditioned on input costs (e.g. fertilisers, water, labour etc.) and prices of agricultural products.

In optimisation models at the level of watersheds or water catchments the economic value of water may be determined by dynamic adaptation processes resulting in a state of general equilibrium (which is changing over time). Such models have been used to analyse the consequences of, for instance, establishing a market for water and charges for water. The complexity of modelling of those economic interrelationships at water catchment level grows with the number of different types of water demand involved (e.g. domestic, industrial, etc.).
The values of the model parameters at the state of equilibrium can be principally computed, so that the condition of a 'competitive' water market in practice is not necessary in order to reach an optimal water allocation among different water users. For instance, the economic value of water from the viewpoint of different water users may be estimated on the basis of survey questions regarding the amount they are willing to pay to improve water quality from its current state to a specified level ('contingent valuation' technique method). By applying this approach those effects of water use can be considered which are not registered on any market ('external effects'), such as e.g. adverse impacts on the aquatic environment or water scarcity in the long-term perspective. There are further economic evaluation methodologies, such as the 'hedonic price' technique (e.g. price differentials of estates) and the 'property damages avoided' technique (e.g. restoration costs). This indicates the importance of a clear definition of the term economic value in modelling integrated water management decisions.

The economic net benefit of water management decisions leading, for instance, to increments in water supply, may be estimated by means of computable general equilibrium (CGE) models at the level of river basins. On the other hand, sub-models covering only single water domains, such as flood risk reduction or water use in agriculture, can be suitable as well to estimate economic costs and benefits of water management decisions. Such sub-models with different domains may be linked together in order to create an integrated water management model at river basin level (see the above-mentioned HarmonIT project).

However, water management models integrating natural and social sciences based on an interdisciplinary approach are presently rare. This is notable as combined economic and hydrological models at the river basin level are best equipped to assess water management and policy issues (McKinney et al. 1999, Young 1995). However, in water-related social studies the economic components dominate, such as cost-benefit analysis for irrigation, industrial, and domestic water use, or economic input/output analyses exist with insufficient hydrological modelling. This reflects actually a lack of interdisciplinary research on water issues. A number of barriers must be overcome to achieve the goal of integration (McKinney et al. 1999):

- Economic models prefer optimisation procedures whereas hydrological models often use simulation techniques.
- The boundaries considered in the economic system - political and administrative - might not be the same as those of the hydrological system.
- There are frequently different spatial development scales, and different time intervals and time horizons (economic models are usually more aggregated and use generally larger time intervals, such as e.g. seasonal or annual, and longer time horizons).

As McKinney et al. (1999) conclude, the state-of-the-art in river basin modelling has advanced dramatically over the past several years with the rapid improvement in computer hardware and software. However, to be useful in applied empirical policy analysis, river basin models should be designed to provide answers to water policy questions, including socio-economic issues. A prototype of an integrated hydrologic-agronomic-economic-institutional model has been developed by a joint research group from the International Food Policy Research Institute (IFPRI), the Center for Research in Water Resources (CRWR) at the University of Texas at Austin, and the International Water Management Institute (IWMI) in Colombo, Sri Lanka. (Cai et al. 2001). In the analytic framework the interactions between water allocation, farmer input choice, agricultural productivity, non-agricultural water demand, and resources degradation are formally modelled to estimate the social and economic gains from improvement in the allocation and efficiency of water use. The model provides the description of the underlying physical processes,
provides the description of the institutions and rules that govern the flows of water, salts, and other pollutants through the river basin,

- depicts the demand sites along the river basin, including consumptive use locations for agricultural, municipal, industrial, and in-stream water uses (incorporating also reservoirs and aquifers) and

- evaluates economic benefits to water use by applying production and benefit functions with respect to water for the agricultural, environment, urban, and industrial sectors.

The above-mentioned river basin model represents a user-friendly DSS integrating the advantages of GIS techniques, describing the water resources in the real world (including economic and policy issues) and aims to optimise the allocation of the water resources at regional level. Thus, the modelling framework serves both as a research tool for policy analysis and as a support system for water authorities. To explore the relationships between physical and economic efficiency, the river basin model was applied to the Maipo River basin in Chile, which faces growing water shortages and increasing competition for scarce water resources and where the water use for irrigation is the major problem. Policy implications are derived from the discussion from a series of modelling scenarios. One of the most important insights gained from the model is that it is not sufficient to follow the criterion of physical efficiency in terms of technical measures, including the improvement of the water distribution system (water loss) and water use. An overall efficiency can only be achieved as long as marginal benefits are larger than the marginal costs of the improvement. As costs of technical improvements can be very large, the focus needs to shift towards increased non-structural measures that enhance both economic and physical water use efficiencies. Both physical improvements and managerial or institutional changes (by applying economic and policy instruments, such as e.g. water pricing and assigning water abstraction rights) can lead to high efficiency in water use. Of special significance is the water demand management obtained by using economic instruments and mandatory rules (e.g. environmental standards).

In the recent literature, further integrated modelling approaches can be found, such as e.g. the economic-engineering analysis of California water management (Lund, et al., 2001). In Germany where physical water management models are practised, further research activities are needed to achieve an interdisciplinary approach in water management modelling by considering socio-economic issues (Horsch, et al., 1999).

10.4 Existing guidelines

As far as the present analysis of literature shows there exist no generic QA guidelines which focus on socio-economic or legal-political issues. The main reason for that may be the extreme complexity of the interrelationships between these domains and the hydrological processes in water catchments. Whereas in many cases hydrological processes can be represented fairly by models, the modelling of economic, social and political processes is usually difficult due to their large uncertainty and complexity. Wherever, for instance, decision rules of actors (e.g. farmers, industrial or domestic water users) are supposed, they are mostly extensive simplifications of the real world. On the other hand, such models might help to make at least rough approximations possible.

However, in the Dutch 'Good Modelling Practice Handbook' economic models are briefly mentioned (STOWA/RIZA, 1999). As the authors emphasise, some hydrological-economic models exist and only a few of them are practised in the water policy (e.g. in the Netherlands). Most of the models focus on special domains and are
based on different use functions (such as e.g. for recreation, inland navigation, potable water and agriculture). Although economic aspects are extremely important in water management, presently the application of such models and model programmes is very limited. Similarly, McKinney et al. (1999) wrote in their overview of existing water management models: "Despite the critical importance of economic variables in water resources allocation and management, water resources studies have generally been dominated by hydrological studies for flood control management and water resources planning from an engineering point of view. At the same time, economic or policy analysis studies have usually focused solely on profit maximisation of water uses for irrigation, industrial and domestic purposes, conditioned on the amount of water supplied at the off-take or delivery point.". QA guidelines have to take this situation into consideration by a specification of socio-economic variables to be incorporated in the water management models. In the Dutch 'Good Modelling Practice Handbook' some crucial issues to be considered for the modelling have been elaborated, such as:

- Interest and inflation aspects.
- Temporal and spatial scales (e.g. unlike variances of water-relevant processes).
- Scope of analysis (local, regional or macroeconomic level).
- Participation of the corporate sector (e.g. the branches in question) and specialised agencies in collecting data and calibrating and validating the model.
- Uncertainty of data inputs and use functions influencing the model outcomes (e.g. only possible to give a development bandwidth).

Certainly these points must be completed and be specified in relation to the various purposes of water management models. With regard especially to the scope of analysis the modelling approach adapted must be sufficiently detailed to permit the development of basin-specific solutions requiring on-site empirical modelling. As McKinney et al. (1999) emphasise, water management and policy solutions must be tailored to countries, regions and river basins, because of the great differences in the hydrological, socio-economic and institutional conditions. Modelling of river basins must treat water resources allocation in an integrated fashion in order to reflect the interrelationships from the local water management perspective. It is at the basin level that various domains can be integrated into a comprehensive modelling framework.

On the other hand, the river basin modelling should be capable of providing a comparative perspective to develop generalizable 'best practices' for water management under alternative conditions. The modelling framework to be developed should be sufficiently flexible and thus generalizable to other river basins. These requirements are to be taken into consideration in incorporating socio-economic and legal-political issues in QA guidelines.

Following McKinney et al. (1999) the characteristics of an integrated hydrological-socio-economic-political model at the basin scale may be summarised as follows:

- Integration of hydrological, agronomic, industrial, domestic, and socio-economic and policy relationships in an endogenous system that will adapt to environmental, ecological, socio-economic, and legal-political statuses related to the river basin domain.
- Specification of an integrated river basin network, on which mathematical models are built (including e.g. water supply system, delivery system, water users system, waste water disposal and treatment system, and the connections between these subsystems).
- Representation of the spatial and temporal distribution of water flow and pollutant transport through the river basins, and of water demands from all water-using sectors for analysis of inter-sectoral water allocation policies.
• Evaluation of the economic net-benefits from each of these demands incorporating water application and quality (including water use production functions, in e.g. agriculture and industry). Ecological values are to be incorporated.

• Incorporation of policy instruments (including mandatory rules, economic incentives and voluntary arrangements for e.g. pollution control, water conservation and ecosystem protection).

The purpose of such an integrative modelling framework is to examine the outcomes of alternative water uses in terms of economic efficiency, social equity, and environmental impact. Moreover, subjects of the analysis are the (expected) effects of various policy instruments taking into account the development of the hydrological and socio-economic variables of the model. Guidelines for modelling should provide advice on how to specify, select and combine the relevant variables of the mathematical models.

As Packman (2002) emphasises, the socio-economic analysis involves an additional level of information and may require specific QA procedures. Especially in UK, several official planning documents exist which contain guidelines for integrated water management decisions. Such documents include the Catchment Abstraction Management Strategies (CAMS), Catchment Flood Management Plans (CFMPs) and River Basin Management Plans (RBMPs). Various manuals are produced by UK Government Departments and Agencies to provide guidance on socio-economic appraisals (Packman, 2002). They contain descriptions of methods how to proceed in considering socio-economic impacts of water management decisions. This reflects the increasing significance of such appraisals in the UK water policy.

Important areas of application include the CFMPs and the RBMPs. Socio-economic elements, such as e.g. cost-benefit analysis and stakeholder consultation, are incorporated in these plans. For instance, a range of flood management strategies can be thus relatively compared on cost-benefit grounds and subsequently taken to consultation with stakeholders. It is to emphasise that the proposed procedures include numerous links and feedbacks required as well as inputs from consultation and modelling tools at different points. They provide comprehensive guidance on methods for integrating the many important considerations needed to determine efficient water management decisions, and an annex of data sources, decision frameworks, stakeholder involvement, scientific and economic analysis methods (Packman 2002).

But also in other Member States similar guidance documents can be found. They might help in developing QA guidelines considering socio-economic issues, as they indicate the requirements in integrated water management from the viewpoint of governmental and other agencies.

10.5 Conclusions and recommendations with respect to the further HarmoniQuA work

First of all, a determination of the relevant socio-economic and legal-political variables is necessary (see the previous chapters). Then a standardisation of those variables must be achieved in order to reach harmonised QA guidelines. In addition to the economic parameters (such as e.g. water value, net benefit of water management decisions) social, legal, institutional and political parameters are to be incorporated. It appears to be helpful to use the findings of the EU WATECO working group in developing a standardised system of such model parameters.
A particular challenge results from the need to evaluate important (including ecological) variables in economic terms. Such an evaluation is necessary for an assessment of the different effects of water management decisions by using a common unit (by making these effects comparable).

A special task is the estimation of the economic value of water (shadow price) or the net benefit of water management decisions at the state of an efficient or optimal water allocation on the basis of partial or general equilibrium models. The purpose of those models is the optimisation of an objective function subject to several constraints on water and other resources. The subject of the modelling is to compute the changes of the value of the object function resulting from a variation of the constraints (model decision variables). For instance, the change of net benefits for different water users in a river basin caused by an alternative water allocation (e.g. water abstraction rights) among them may be estimated by means of such models.

The procedures should be identified by which typically socio-economic variables have been combined with hydrological parameters in recent water management models. In general, a loose connection between the different socio-economic and hydrological components might be found, i.e. only output data are usually transferred between the components (as analysed in the HarmonIT project). The main difficulty of this approach is the transformation of information between these different, often very complex, components. In contrast, in the more holistic approach both components are connected to a consistent model and an integrated analytical framework is provided. However, the hydrological component is often considerably simplified due to model-solving complexities. Information transfer is conducted endogenously. The first approach is likely to be more realistic for application, but further research is needed into the development of more dynamic connections, through which the socio-economic and hydrological components can be solved in an interactive way (McKinney et al. 1999).

QA guidelines should be analysed how far socio-economic and legal-political parameters can be incorporated. The requirements on integrated modelling procedures considering such parameters should be identified. The classifications of model parameters provided by the WATECO working group should be taken into account as they reflect the goals of the EU Water Framework Directive. However, the requirements on modelling will be dependent on the different purposes of water management modelling (such as e.g. simulation, optimisation or prognosis, including different spacial scales and time horizons) and on the domains covered by the models. These differences must be identified before extending hydrological QA guidelines by socio-economic and legal-political components.

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10.7 References


