Involving stakeholders in transboundary water resource management: The Mesta/Nestos 'HELP' basin[#]

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Abstract

Alternative options for new private and public investment projects in the transboundary Mesta/Nestos River catchment between Bulgaria and Greece involve new dams and water storage reservoirs, agricultural irrigation systems, new tourist resorts and various water-related facilities for urban and industrial water supply. These developments are designed to be implemented in both parts of the basin (in Greece and Bulgaria), where different socio-economic conditions prevail, resulting in each country having different preferences and objectives. Alternative options should consider environmental consequences, to the impact on ecosystems and human health, and also financial and social risks. Any negative impacts on the environment, and whether these negative impacts can be prevented, should be weighted against the economic and social benefits foreseen.

Sustainable implementation of private or public utility projects cannot be achieved without public participation and a clear consensus between stakeholders. The UNESCO HELP (Hydrology for the Environment, Life and Policy) initiative provides a rationale for breaking the 'paradigm lock' existing between the most recent scientific findings on the one side and the public, stakeholders and decision makers on the other. In this paper stakeholder involvement in the decision making process is promoted firstly by communicating the results of integrated modelling of water resource management at the basin scale, and secondly by suggesting alternative models and software in order to facilitate negotiations and final decision making processes in transboundary water resource management These models help to rank alternative projects according to the attributes of stakeholders in each country; the aggregated attributes of the stakeholders in both countries; and the aggregated goals of each country.

Keywords: integrated water management, modelling, public participation, decision support, conflict resolution

Introduction

The Mesta/Nestos transboundary river basin between Bulgaria and Greece is a HELP (Hydrology for the Environment, Life and Policy) demonstration basin. Integrated water management in the basin involves different issues relevant to national authorities of each country, such as monitoring, planning, coordination of different uses, institutional and legal aspects and financing of water related projects. However, the key element for effective water resource management is cooperation between the two riparian countries at different levels, i.e. local, regional and national. Political willingness for cooperation is very important and institutions and stakeholders on both sides of the border should exchange data and information and develop common plans for water resource management. Lack of cooperation may lead to conflicts and disputes that may aggravate the problems and delay sustainable socio-economic development in the region.

As a member of the UNESCO-HELP network, the UNESCO Chair and Network INWEB (International Network of Water-Environment Centres in the Balkans) represents different organisations and stakeholders in Greece and Bulgaria responsible for water resource management in the Mesta/Nestos River basin. The main objective of the UNESCO HELP initiative is to provide a rationale for breaking the 'paradigm lock' existing between scientists on the one hand and the public, stakeholders and decision makers on the other.

In this paper the progress made towards achieving this objective is reported. Firstly, an integrated modelling approach was developed covering main areas like hydrology, hydropower, agricultural economics and climate change scenarios. Secondly, the results of integrated modelling of water resource management were communicated to stakeholders at the basin-scale level to promote their involvement in the decision making process, and alternative models and software were developed in order to facilitate negotiations and final decisions in transboundary water resource management. These models help to rank alternative projects according to the attributes of stakeholders in each country; the aggregated attributes of the stakeholders in both countries; and the aggregated goals of each country.

Main characteristics of the Mesta/Nestos basin

The Mesta/Nestos River basin is a transboundary river basin shared by Bulgaria and Greece in South-Eastern Europe (SEE) (Fig. 1). Prior to 1992 there were only six international river basins in the SEE region, whereas after the collapse of the Yugoslav Federation, the number of internationally shared river basins in the area more than doubled. Nowadays there are 14 internationally shared river basins as well as 4 transboundary lake basins (Ganoulis et al., 2004).

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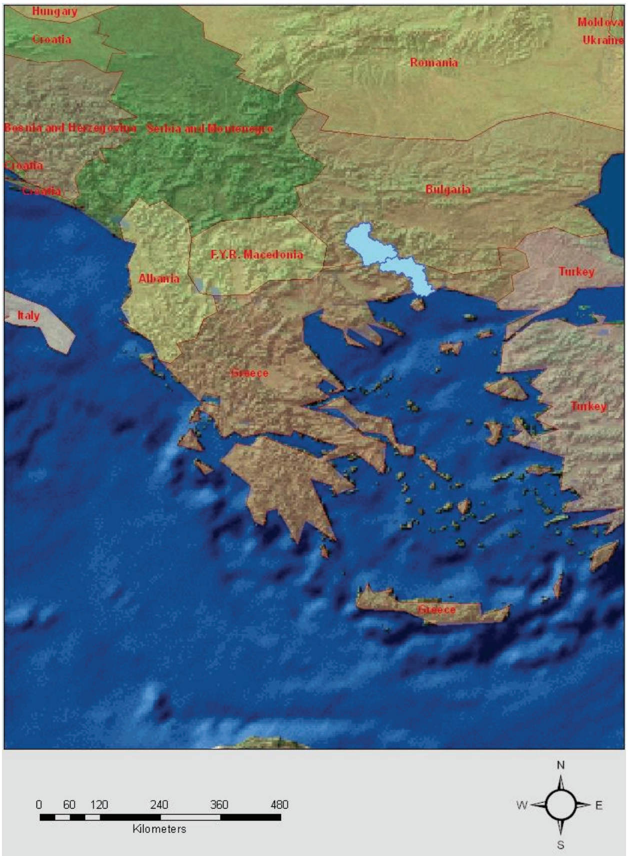

Figure 1
Geographical location of the Mesta/Nestos River catchment

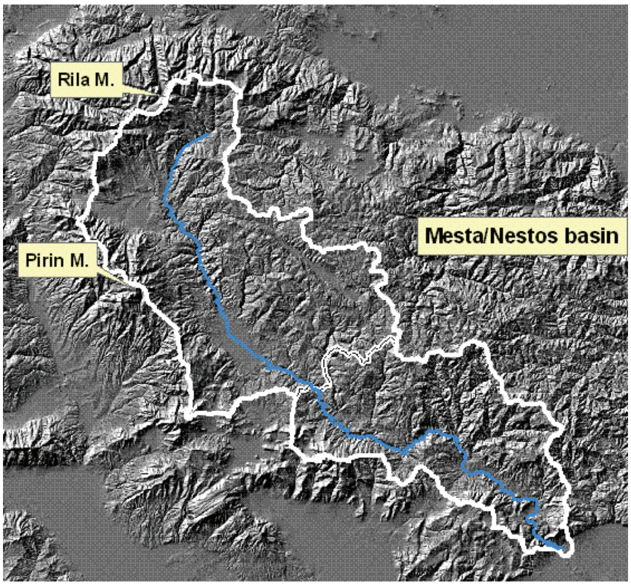

Figure 2
Watershed of Mesta/Nestos over SRTM map at 100 m resolution

The Mesta/Nestos River rises in the Rila and Pirin Mountains in southern Bulgaria at an altitude of 2 925 m (Fig.2). In Bulgaria the river flows through a valley of granite geology until it reaches the Rhodopi mountain chain, where it crosses the border between Bulgaria and Greece. Then the river follows a south-easterly direction and crosses a particularly beautiful region of marble formations known as the 'Nestos Gorges'. The river flows some 230 km through Bulgarian and Greek territory before emptying into the North Aegean Sea. The river flows for about 126 km through Bulgaria (2 770 km² catchment) and for about 130 km through Greece (2 843 km² catchment) thus the total catchment area of the river is 5 613 km². The Mesta/Nestos River water is used by both countries for municipal water supply, irrigation and hydroelectric power production. The past estimated mean runoff of the Mesta/Nestos River is 20 to 30 m³/s and the annual discharge 1 120 Mm³. The Mesta/Nestos River is the most important water resource in its region and has been the subject of bilateral negotiations for many years.

The morphology of the catchment is mountainous with the exception of the delta region. The climate is Mediterranean and becomes transitional Mediterranean further north. According to recorded mean monthly flows (1965-1990), the maximum discharge has rarely been above 150 m³/s, while the minimum has often been less than 10 m³/s. During recent years 2 dams have been constructed on the Greek side of the river (Thissavros, Platanovryssi) for hydropower generation and irrigation. The Greek part of the Mesta/Nestos River basin belongs to three prefectures (Drama, Xanthi and Kavala), comprising 82 communities with a total of about 35 000 inhabitants. Only the largest town of Chrisoupoli (7 100 inhabitants) has a central sewerage system and treatment plant. The famous delta (440 km²) is protected as a RAMSAR site but is in danger due to pollution caused by various human activities and to large-scale hydraulic works (dams) constructed along the river.

Integrated modelling at the basin scale

Hydrological modelling aims to simulate the surface and groundwater flows in the basin. Hydrogeological models are used together with agronomic models, and various sources of geographic information gathered in the past. The integrated modelling of the basin also takes into account the operation of the dams in the Greek section.

Hydrology

For the temporal evolution of the water tables and river flows in the Mesta/Nestos Riverbasin, two spatially distributed hydrologic models were used: the MODCOU simulation model, 'modélisation couplée des transferts de surface et des transferts souterrains' (Ledoux et al., 1989; Ledoux et al., 2002), and the HEC-HMS model, Hydrologic Engineering Center - Hydrologic Modeling System (USACE, 2006).

The MODCOU is a coupled physical model which simulates both surface and subsurface flows. It also allows these two types of flows to be modelled separately, while always taking into consideration the interactions between the two domains. The principal characteristic of the MODCOU model is the separation of the hydrologic cycle into independent processes. This decomposition helps each stage of the hydrologic cycle to be better manipulated. This model is based on a dense spatial grid made of variably sized square cells (Fig. 3). The characteristics of the surface domain such as runoff directions, altitude, soil and land-use (Fig. 4) are attached to each cell. The water budget is computed in each grid box using the so-called 'production functions', which are a system made of four reservoirs, including seven parameters which must be calibrated. The production functions are used to compute the actual evaporation, infiltration and runoff, with a time step of one day.

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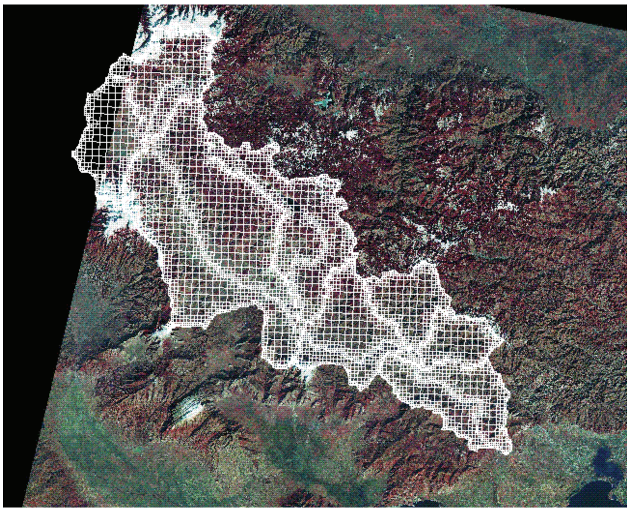


Figure 3
Multiscale grid of the MODCOU spatially distributed flow model applied in the Mesta/Nestos River catchment

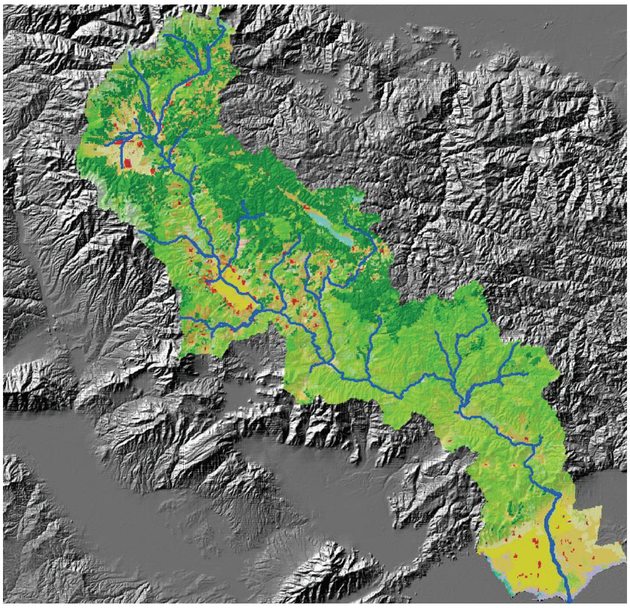


Figure 4
Corine land cover classification showing the Mesta/Nestos basin land use

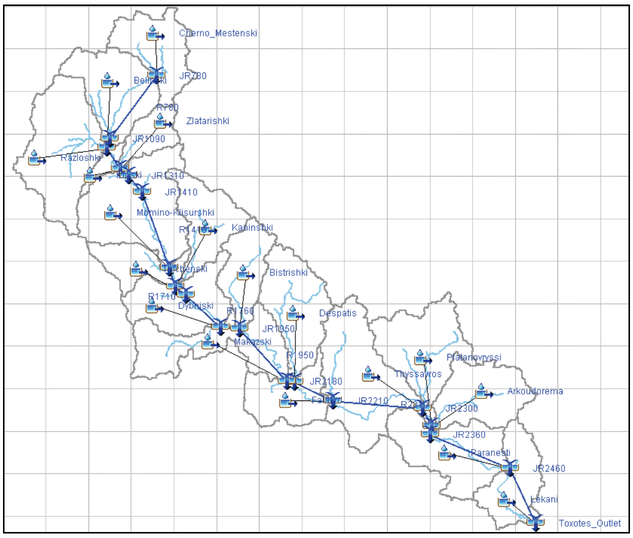
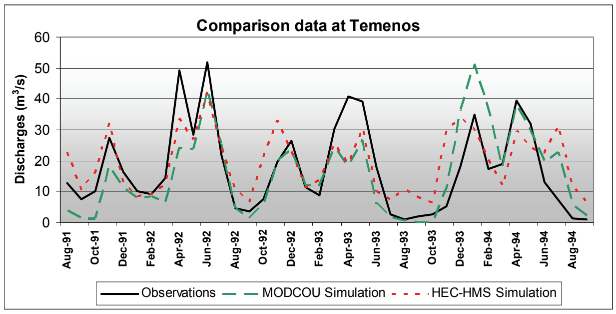
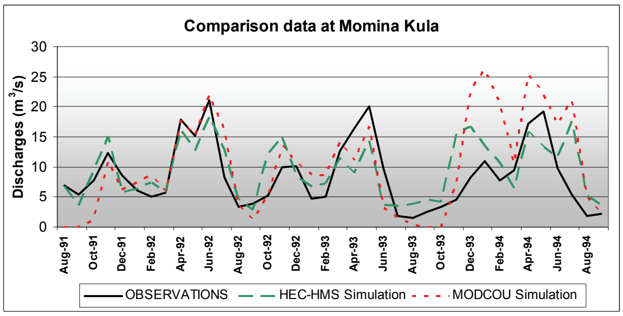


Figure 5
Representation of the Mesta/Nestos catchment and sub-catchments under the HEC-HMS model



(a)



(b)

Figure 6
Comparison between flow rate simulation and data (a) at Temenos, (b) at Momina Kula

The Hydrologic Modelling System (HEC-HMS) from the Hydrologic Engineering Center (HEC) of the US Army Corps of Engineers is designed to simulate the precipitation-runoff processes of dendritic watershed systems (Fig. 5). It has a wide range of applications including large river basin water supply and flood hydrology, and small urban or natural watershed runoff. One of the applications of the programme relates to flow modelling in watersheds. It is a spatially lumped model, which separates the hydrologic cycle of specified sub-watersheds into different but interconnected pieces. HEC-HMS uses separate modules in order to represent the river network, including:

- Water loss in order to estimate the volume of runoff, given the precipitation and properties of the watershed (runoff-volume models)
- Direct-runoff model that can account for overland flow, storage and energy losses as water runs off a watershed and into the stream channels
- Baseflow specification
- Hydrologic routing that accounts for storage and energy flux as water moves through stream channels
- Representation of naturally occurring confluences and bifurcations
- Modelling of water-control measures, including diversions and storage facilities.

The hydrological models have been calibrated using monthly river flow measurements from the Momina Kula (Bulgaria) and Temenos (Greece) stations with monthly and daily precipitation records where available. Figures 6a and b demonstrate the simulation results at the Greek and Bulgarian gauging stations respectively.

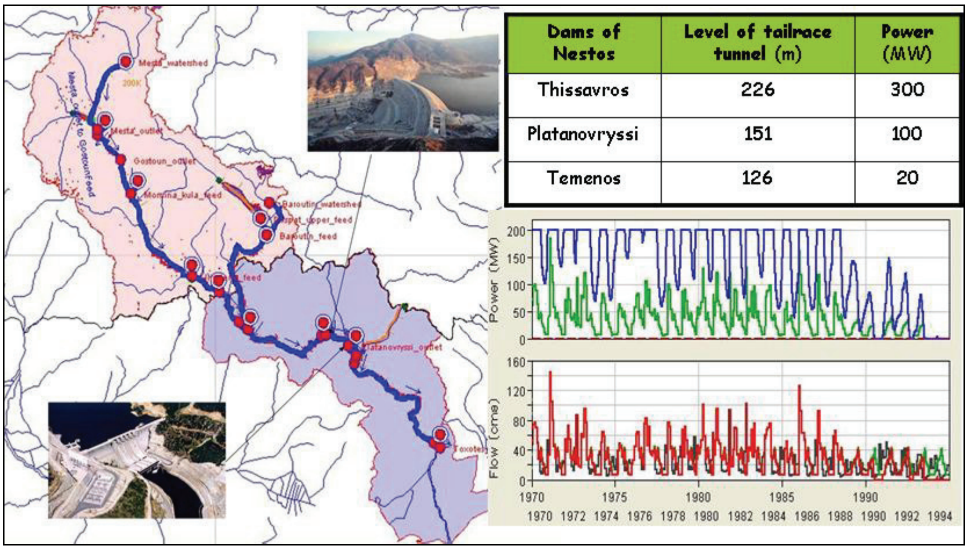


Figure 7
Representation of the Mesta/Nestos River with HEC-ResSim and simulation of the operation of Thyssavros Dam from 1970-1994

Hydropower and irrigation

The results from the hydrologic simulation were used as input to the Reservoir System Simulation (HEC-ResSim) from the Hydrologic Engineering Center (HEC) of the U.S. Army Corps of Engineers in order to simulate the recently constructed dams' complex on the Nestos River, as shown in Fig. 7 (USACE, 2003). HEC-ResSim was implemented to simulate the dams' operational and economic feasibility and the amount of water discharged from the dams, in order to cover the minimum ecological discharge of 6 m^3/s as well as the agricultural demands for water. Future scenarios have been developed not only for the construction of future projects, such as the construction of the Temenos Dam, diversion tunnels for the irrigation of Drama's and Xanthi's plains, but also for climate changes.

Agricultural economics

In the delta part of the Mesta-Nestos basin, which is a large irrigated agriculture region of great importance to the local and regional economy, it is crucial to couple climate change models with other already implemented models. The effect of climate change on river basin management is complex and needs a comprehensive model covering all areas related to water usage. More specifically, models of crops and farming economy need to be developed and integrated with the already implemented basin flow and hydropower operation models.

The model of crops and farming economy will be based on the coupling of the STICS agronomic crop model and the AROPAj micro-economic farming model, both developed by INRA (Jayet et al., 2005). Their coupling allows the modelling of a wide range of alternative economic policy scenarios combined with various management and agro-environmental conditions.

The economic model AROPAj determines, for every exploitation, which combination and which level of livestock and agriculture production make it possible to reach the optimum. Model STICS is a tool for harvest simulation in real conditions. Its principal goal is to simulate the effect of the climate, ground management and farming techniques on production (quantity and quality) and the environment. The 'coupling' of the two models allows the search for the economic optimum amount of fertiliser needed (here nitrogen), under variable conditions, also taking into account the available amount of water for irrigation purposes.

Climate change scenarios

Any sustainable integrated project of a river basin management should take climate change into account. . Therefore, the results from climate change models should be coupled with other modelling techniques for river basin management. It is particularly important to study the irrigated agriculture regions of a basin in the light of climate change in order to achieve an economic and environmental balance for the sustainable development of the basin.

Using the results of the Hamburg World Data Center for Climate (CERA), the climate change scenario A2, represents the worst case of the climate evolution range. The results are given in the form of average precipitations on 200 km² grid cells. The 'downscaling' of the data and their adaptation to the Mesta/Nestos basin was a real challenge. The implementation of the A2 scenario proved that the dual purpose (hydropower and irrigation) of the Thissavros and Platanovryssi Dams, as well as any other investments related to the Mesta/Nestos River, will not be economically feasible. The administrative authorities of the dams should give priority to either power generation or to irrigation; the current coupled operation will not be feasible. The impacts of this scenario on agriculture are under further investigation.

Figure 8 shows the simulated streamflow for the years 2016 to 2065 at the Bulgarian-Greek border, when using the precipitation data obtained from the A2 scenario as input to the MODCOU hydrologic model. The trend line shows the decrement of streamflow as a consequence of the decrement of precipitation.

Resolving potential conflicts

Despite earlier agreements, Bulgaria has in the past withheld water for increased agricultural and industrial needs. Since 1975 the Mesta/Nestos yearly flow has declined from 1 500 million m^3 to 600 million m^3 resulting in repeated Greek protests. Despite a series of negotiations no new, satisfactory agreement has been reached, and failure to resolve the situation has resulted in conflicts between the two countries. In 1995 an agreement was reached concerning the sharing of water quantity between

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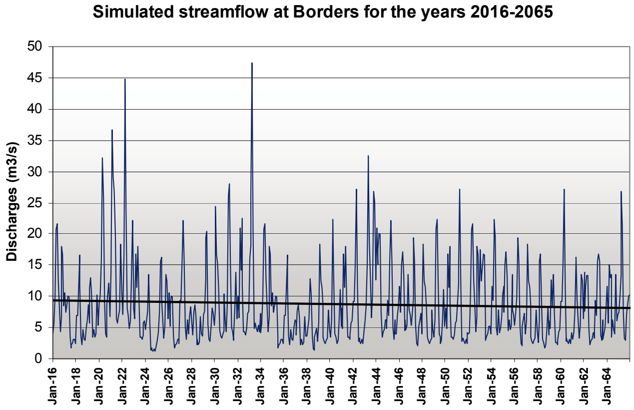

Figure 8
Decrement of simulated runoff based on precipitation data of A2 climate change scenario for the years 2016-2065

the two countries. According to this agreement, Bulgaria should leave Greece 29% of the total flow generated in Bulgaria for the 35 years following the agreement. Nowadays noticeable pollution from the Bulgarian part, especially after heavy rainfall, has raised the level of tension in a region of Greece highly dependent on irrigated agriculture and hydropower. Since the beginning of 2007 Bulgaria has been a full member of the EU. There is an urgent need for cooperation and application of European Union (EU) guidelines for integrated water resource management (IWRM) in the Mesta/Nestos transboundary river basin.

Conflict situations in transboundary water resource management occur on at least two levels:

- Conflicts between stakeholders over objectives and attributes
- Conflicts between countries over different goals.

MCDA (multi-criterion decision analysis) techniques help to consider different alternative projects, the best of which may then be analysed in depth before being finally implemented.

Multicriterion Decision Analysis (MCDA) was adapted as a decision support methodology for managing potential conflicts in transboundary areas related to different attributes and goals set by different countries. For this purpose, alternative methods are suggested in order to facilitate negotiations and reach final decisions. All are based on the combined use of integrated modelling, experts' opinions and a decision support methodology called Composite Programming (CP). This is a distance-based technique, which defines the 'best' solution as the one, of the set of feasible solutions, located at the least distance from the ideal solution (Ganoulis, 2003). The aim is to obtain a solution that is as 'close' as possible to some ideal. The distance measure used in CP is the family of L_p-metrics given as:

$$L_p(a) = \left[\sum_{j=1}^{J} w_j \left|\frac{f_j^* - f_j(a)}{M_j - m_j}\right|^p\right]^{\frac{1}{p}} \qquad (1)$$

where:

L_p (a)	=	L_p-metric or composite index for alternative a
f_j (a)	=	Value of attribute j for alternative a
Mj	=	Maximum value of attribute j
m_j	=	Minimum value of attribute j
f_j^*	=	Ideal value of attribute j
w_j	=	Weight of the attribute j
p	=	Parameter reflecting the attitude of the decision maker with respect to compensation between deviations

As shown in Fig. 9, starting from a list of attributes as basic indicators, the three pillars of sustainability, i.e. the economic, social and environmental objectives are defined hierarchically, which are then aggregated into third level socio-economic and social indicators.

Goals

Broadly speaking, every state has social, economic and political goals linked to water resource development, conservation, and control and protection of the river basin. Economic goals may be to obtain new water resources in order to increase food production, conservation goals may be to control water pollution, and control and protection goals may concern defence from floods or drought control. These goals may be achievable by jointly building water reservoirs. This would entail the states involved cooperating together and solving possible areas of conflict.

Purposes in accomplishing goals

Goals are accomplished by various water resource developments, transfers of water from adjacent river basins with surpluses, water conservation, control and protection. Each particular goal means satisfying some particular purpose, which may have to do with irrigation, drainage, hydropower production, navigation, water supply, water pollution control, flood defence, drought control, or other.

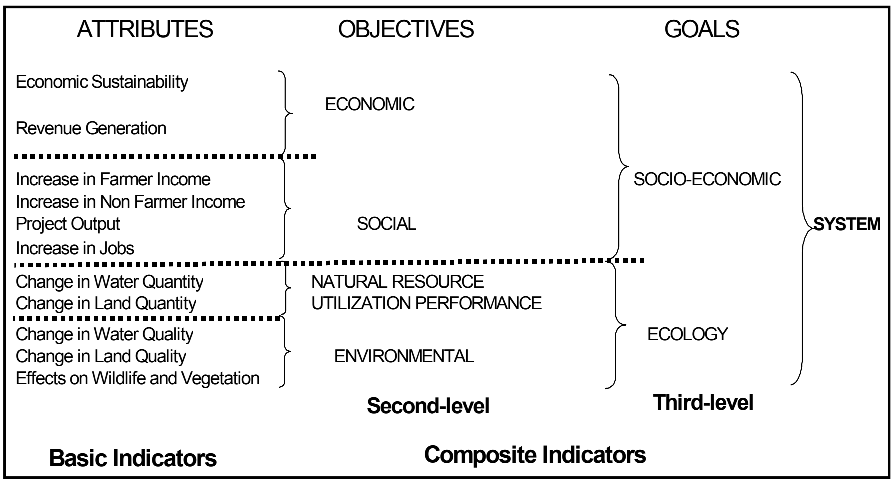

Figure 9
Social, economic and environmental attributes, objectives and goals

Objectives and attributes in accomplishing purposes and goals: Finally, to satisfy the purposes of state goals in water resource development one must define and then maximise or minimise the economic, social, monetary and political objectives. The particular goals, purposes, objectives and interests in water resource development of the river basin should be carefully taken into consideration in any cooperation on conflict resolution between the states.

Involving stakeholders

Different degrees of socio-economic development on each side of the border resulted in different problems and issues related to water related projects. In the Greek part the river flow is controlled by 3 major dams for energy production. Downstream of the dams there is significant agricultural activity and the river's delta is protected by the RAMSAR treaty. Intensive use of fertilisers, overexploitation of groundwater and the intensive use of drills have created water quantity and quality problems. As irrigated agriculture is the main area of development in the region, it is important to maintain a level of involvement through a long-term programme and a level of interference. The water from the river also covers urban needs and provides the opportunity for recreational activities. In the Bulgarian part the lack of wastewater treatment plants (WWTP) and significant shortcomings in infrastructure have created unfavourable conditions for water use. Tourism is negatively affected by the underdeveloped road infrastructure, and agriculture by the limited availability of land for the development of intensive farming.

Options for water management

In a framework of virtual negotiations different projects or options are supposedly suggested by the two countries. Options 1 to 4 are for Greece (GR) and options 5 to 8 are for Bulgaria (BUL):

- Option 1 (GR): Strengthening Agricultural Practices and Crop Redistribution
- Option 2 (GR): Review and Reappraisal of Irrigation Development Projects
- Option 3 (GR): International Wildlife Tourism Development
- Option 4 (GR): Inland Fisheries Resource Development Project
- Option 5 (BUL): Water Supply Distribution Project
- Option 6 (BUL): Construction of New Reservoirs for Multiple Water Uses
- Option 7 (BUL): Construction of WWTP
- Option 8 (BUL): Development of Local Tourism and Related Activities

Ranking by using each country's attributes

To help stakeholders in evaluating different options, integrated modelling may be used as a tool. Because of different preferences in attributes used by the two countries, ranking of alternatives options differ, each country giving priority to its own suggestions. When options are to be implemented in the entire river basin area, this may result in a conflicting situation.

Ranking by aggregating stakeholders attributes and countries' goals

Using Eq. (1), the stakeholders' attributes are aggregated in two composite indices: a socio-economic one, which integrates all social and economic attributes (Fig. 9) and an ecological one, which integrates environmental, water and land quality and also biological attributes (Fig. 9). In the case of countries' goals, each option may be defined by two indices, one for each country, resulting in the integration of the different attributes up to the third level as shown in Fig. 9. Composite indices and countries' goals range from 0 (worst case) to 1 (ideal case). In a two-dimensional representation the better options are those located nearest to the ideal point. Options 3 and 6 are preferable in both cases, as they are closest to the ideal case (Fig. 10 a; b) and could be suggested as a compromise solution during negotiations. Special software under development may assist calculations and the drawing up of figures such as Fig. 10.

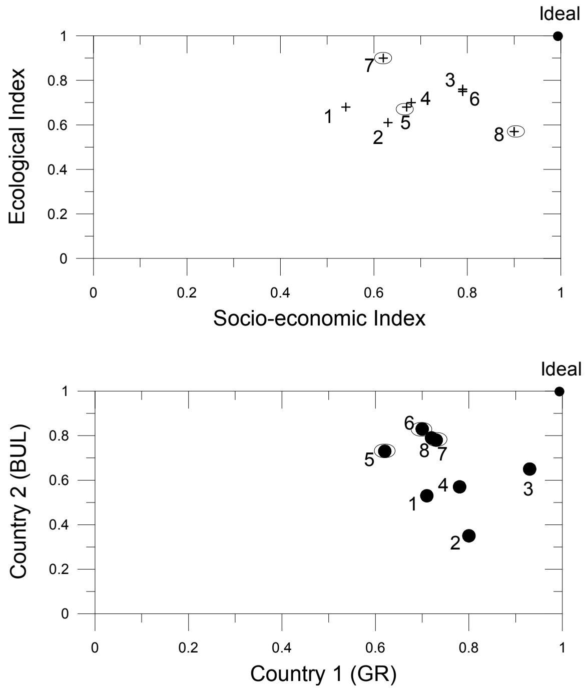

Figure 10
Ranking Options 1 to 8 by aggregating stakeholders' attributes (a) and countries' goals (b).

Conclusions

A methodology is suggested based on MCDA techniques in order to facilitate stakeholder involvement in conflict resolution in transboundary water management problems. Integrated modelling at the basin scale are used as tools to help stakeholders in order to evaluate every alternative option of water management. In order to compromise different countries preferences, trade-offs are made either at the level of stakeholder attributes, or at the level of countries' different goals. The methodology for ranking different options is easy to use and the results obtained are fair, transparent and simple to communicate to decision makers.

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