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WATER RESOURCES MANAGEMENT AND ENVIRONMENTAL SECURITY IN MEDITERRANEAN TRANSBOUNDARY RIVER BASIN

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Abstract

Water has been recognized as a key natural resource for environmental security, socio-economic development and human well-being. In the Mediterranean area, sustainable water resources management is a major issue, given the semi-arid climate, the variability of hydrological characteristics and the fragile socio-economic conditions. The majority of the population around the Mediterranean lives in transboundary river basins. Sharing water and securing social and political stability in these regions present several technical and cooperative challenges.

In this paper, Multi-Criteria Decision Analysis (MCDA), based on integrated risk assessment, is proposed as a tool for conflict resolution in internationally shared water resources management. The case of the Mesta/Nestos River in South Eastern Europe (SEE) illustrates the methodology.

1. Introduction

Nowadays the concept of human security on a global scale may be extended from its traditional meaning of worldwide political and military security to also embrace the idea that every citizen should be able to benefit from sustainable socio-economic development From amongst different natural resources, water has been recognized as the key environmental resource for social security, economic growth and prosperity. Human security can therefore be seen to be related to environmental preservation (water, ecosystems and biodiversity) and to socio-economic stability and sustainable development. The concept of sustainable management of water resources was first mentioned in Stockholm in 1972, during the United Nations World Conference, and then at the Rio summit in 1992 with Agenda 21.

Historically speaking internationally shared water resources in transboundary river catchments have always been of importance. Rivers and lakes have often been used to determine frontiers between countries (e.g. the Rhine between France and Germany, the Rio Grande between the USA and Mexico and the Evros/Meric between Greece and Turkey). There have been numerous conflicts but also cases of cooperation over transboundary water resources. In many cases, one or several countries may occupy parts of the upstream or downstream area of the river catchment. This makes the issue of water sharing even more complicated (e.g. the Nile between Egypt and the Sudan, the Middle East conflict over the Jordan River and the Danube between many European countries).

On a global scale, the importance of transboundary water resources is far from negligible: according to reports submitted to the UN, about 50% of the world's landmass (excluding Antarctica) is located in internationally shared water catchments. About 40% of the world's population lives in internationally shared water catchments, extending over more than 200 international river basins.

In the Mediterranean, transboundary water resources are extremely important. In SEE, 90% of the area lies in international basins. The Nile basin is shared by 10 countries from deepest Africa to Egypt. In North Africa and in the Middle East, transboundary aquifers are very important.

The aim of this paper is to show how traditional engineering planning and design methods for reducing risks in water supply and management can be extended to consider environmental and social risks. Furthermore, a multi-objective decision-making methodology is suggested, in order to help resolve water related conflicts.

2. Main Issues in Transboundary Water Resources Management (TWRM)

TWRM involves addressing not only physical and technical issues but should also take into consideration social actors, institutions and administrative procedures. According to LeMarquant [1], five foreign-policy factors influence international water situations:

1) international posture of each country,
2) international law,
3) linkage between water and other issues,
4) mutual commitment (reciprocity), and
5) national sovereignty.

The main objective of effective TWRM is to satisfy the demands of all riparian countries, given the possibilities and limitations of water supply. This balance between supply and demand should take into consideration both water quantity and quality aspects and the protection of the environment. Water quantity and quality problems are very much inter-related and should be studied in an integrated framework. According to Frey [2], in order to understand the origin of serious conflicts over international water systems, three main factors should be considered:

1) the importance of water (both in quantity and quality),
2) the relative power of the actors, and
3) the respective riparian position of the countries.

2.1 THE ENGINEERING APPROACH

This approach has been developed mainly by engineers and management experts. Depending on the number of objectives and decision-makers and their combination, models may be formulated as *optimisation, multi-objective trade-off* computerized

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codes or on the basis of the *team and game theories*. Most of these models are based on the fundamental notion of Pareto optimality and are predictive in the sense that they suggest a quantitative "optimal" situation, which should be to terminate a conflict by finding an equitable resolution between the countries involved.

Recent advances and related theoretical developments in this area can be found in the literature, including the application of the fuzzy set theory. However, the success in practice of this kind of *engineering* or *rational modelling* is mainly dependent on the interested actors' and countries' acceptance of the model assumptions, which rely on a set of prescribed objectives, and the relative weights or preferences between conflicting goals. In the real world this is not usually the case, and therefore, there is a need to develop better, easier-to-use, interactive and reliable predictive models for TWRM.

2.2 THE INSTITUTIONAL APPROACH

This approach is used mainly by law experts and political analysts, who focus on describing the anatomy of a given situation of conflict or cooperation. They determine the function of different parameters and factors influencing the behaviour of each country, such as the political perception of the importance of water, the international image and status of the country and also social and institutional issues. Such models, including the behaviour of institutional structures, international negotiation strategies, alternative dispute resolutions and political models are very useful. They are mainly prescriptive and not predictive. They do not necessarily give a quantitative output (such as costs and benefits), but are extremely important for understanding the processes and analysing the origin and evolution of conflicts or cooperation.

Many alternative negotiation strategies are available to modify a complex framework of TWRM issues. Decision makers and those who may negotiate on their behalf have a choice of six universal negotiation strategies:

1) "Win-Win" solutions or Positive sum benefits
2) "Lose-Lose" solutions or Negative sum benefits
3) "Win-Lose" negotiations or Zero-sum benefits
4) Unilateral creation of new facts
5) Conflict and threats of violence
6) No action, causing opportunity costs from neglect and/or delayed decisions.

The choice of a particular negotiation technique is always subject to political considerations and controversy. Preferences depend on the balance of power among transboundary stakeholders and the cost of concessions. The more powerful and wealthy stakeholders can resort to the creation of facts with minimal risk of counteraction by weaker and impoverished neighbours. They also can afford to make gestures of friendship through "Win-Lose" agreements in the interest of enhancing regional stability [3].

It may be mathematically proven that “Win-Win” agreements result in positive benefits for both parties and consist of the best trade-off between alternative solutions. The so-called "Prisoner’s Dilemma", well known in the literature, gives insight to the fact that failure to reach an agreement between interested parties may increase benefits to each individual party but will decrease the total benefits. This is because when each party acts independently it will tend to over-use the resource. Cooperation schemes may provide better net benefits to both parties.

However, "Win-Win" solutions may not always be sufficient when considering cases where natural water resources are limited. In these cases regional networks of water stakeholders can play a very important role.

By combining the expertise and state-of-the-art knowledge of different scientific communities and disciplines, such as engineering, economics and environmental and social sciences, regional partnerships may contribute to the development of new methods and models in order to more efficiently resolve conflicts and controversial issues in TWRM.

3. Environmental Risk Assessment and Management

In a typical problem of technical failure under conditions of uncertainty, there are three main questions, which may be addressed in three successive steps.

1. When should the system fail?
2. How often is failure expected?
3. What are the likely consequences?

The first two steps are part of the uncertainty analysis of the system. The answer to question 1 is given by the formulation of a critical condition, producing the failure of the system. To find an adequate answer to question 2 it is necessary to consider the frequency or the likelihood of failure. This can be done by use of the probability calculus. Consequences of failure (question 3) may be calculated in terms of economic losses or profits.

It has been largely accepted that the ***probability of failure*** may be considered as one simple definition of the engineering risk. As explained in [4] we should define as *load* ℓ a variable reflecting the behaviour of the system under certain external conditions of stress or loading. There is a characteristic variable describing the capacity of the system to overcome this external load. We should call this system variable *resistance* r. A *failure* or an *incident* occurs when the load exceeds this resistance, i.e.

FAILURE or INCIDENT : $\ell > r$

SAFETY or RELIABILITY : $\ell \leq r$

In a probabilistic framework, ℓ and r are taken as random or stochastic variables. In probabilistic terms, the chance of failure occurring is generally defined as risk. In this case we have

$$\text{RISK= probability of failure= P}(\ell > r)$$

Uncertainties and risks may be quantified by using probabilities or fuzzy sets, and can be used as a tool for helping decision-making processes [4], [5]. The Integrated-Risk Analysis-Method [5] is one MCDA technique that can be used in TWRM for managing different conflicts. The steps to be undertaken for applying this methodology are the following [4]:

1. Define a set of ***alternative actions*** or ***strategies***, which includes structural and non-structural alternative options.

2. Evaluate the outcome risks or ***risk matrix,*** which estimate the risks corresponding to each particular objective (technical, environmental, economic and social)
3. Find by use of an averaging algorithm the ***composite risk index*** for technical and ecological risks (eco-technical composite risk index) and social and economic risks (socio-economic composite risk index).
4. ***Rank the alternative actions***, using as a criterion the distance of any option from the ideal point (zero risks).

4. Application of MCDA techniques in TWRM

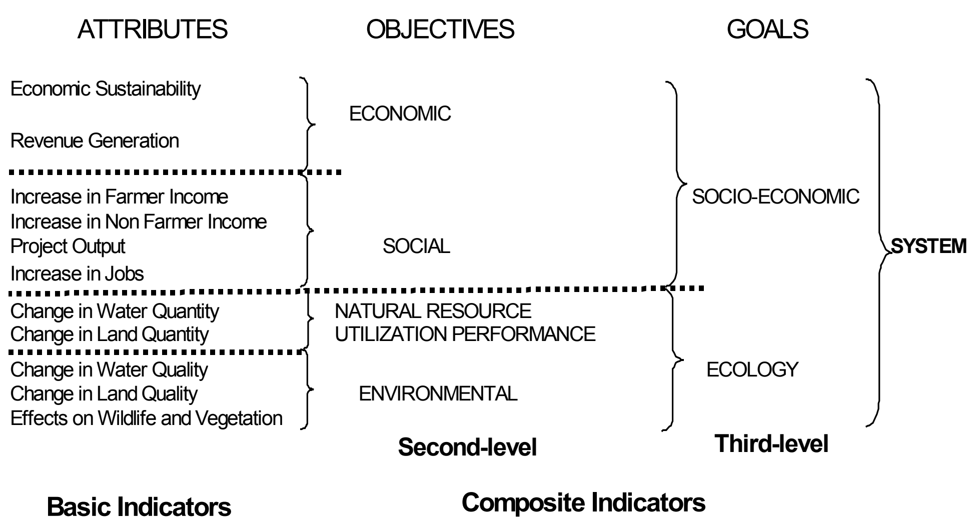
MCDA techniques are gaining importance as potential tools for solving complex real world problems, because of their inherent ability to consider different alternative scenarios, the best of which may then be analysed in depth before being finally implemented. [6], [7], [8], [9], [10], [11].

In order to apply MCDA techniques, it is important to specify the following:

- **The objectives**, which indicate the directions of state change of the system under examination and which need to be maximized, minimized or maintained in the same position.
- **The attributes**, which refer to the characteristics, factors and indices of the alternative management scenarios. An attribute should provide the means for evaluating the attainment level of an objective.
- **The constraints,** which are restrictions on attributes and decision variables that can or cannot be expressed mathematically.
- **The criteria,** which can be expressed either as attributes or objectives.

As shown in Figure 1, the three pillars of sustainability, i.e. the economic, social and environmental criteria, can be defined hierarchically, starting from some basic indicators, which are then aggregated into second and three level indicators.

Figure 1: Social, economic and environmental attributes, objectives and goals.



The methodology we propose addresses two fundamental issues in TWRM, which are conflict situations at two levels [12]:

(a) conflicts among attributes, in particular, economic, technical, environmental and social first-level indicators
(b) conflicts among different countries' strategic goals

This MCDA approach may be applied in three steps:

(1) in the *first step,* each country proceeds separately and evaluates alternatives according to its own attributes, objectives and goals (Figure 2).
(2) in the *second step,* the different attributes used by the different countries are first traded-off and then alternatives are ranked according to the composite goals (Figure 3)
(3) the *third step* is based on the aggregation of the countries' different goals in order to obtain a consensus between them (Figure 4).

Figure 2: Ranking alternative options by each country separately.

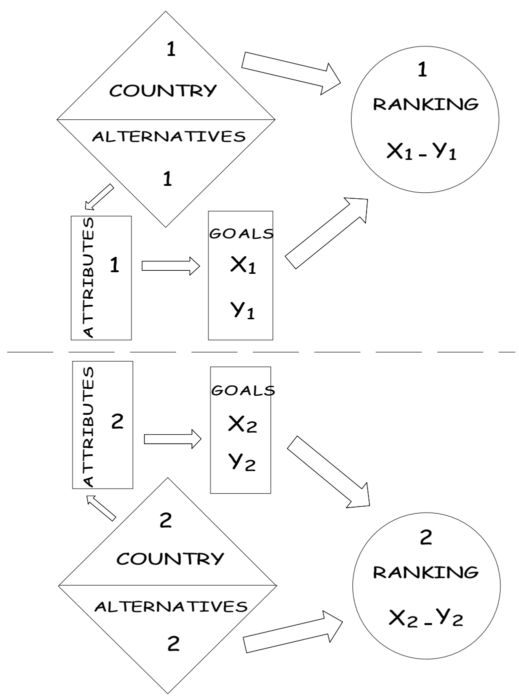


Figure 3: Compromising countries' attributes for conflict resolution.

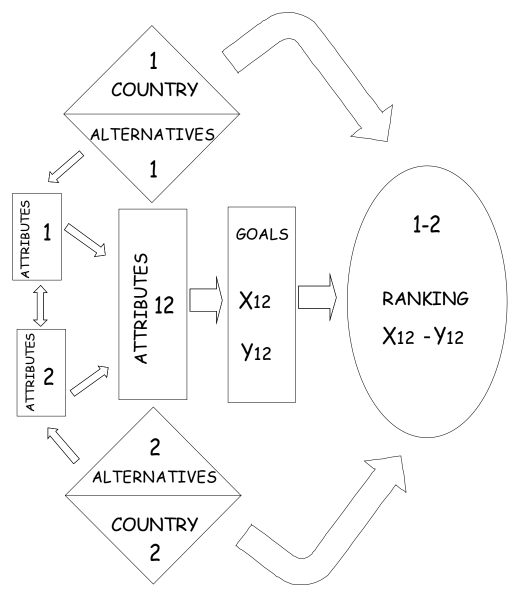
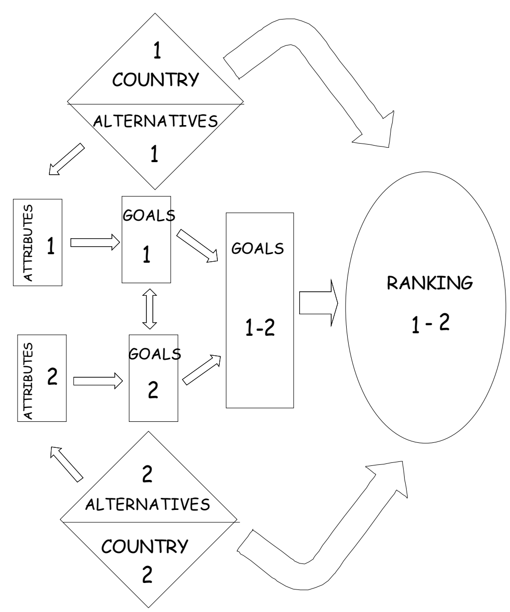


Figure 4: Compromising countries' goals for conflict resolution.



It may be expected that steps 2 and 3 will produce similar results, but these will be different to the rankings produced by each country separately in step 1.

To illustrate the methodology in practice, results from the case of the international Nestos / Mesta River, which flows between Greece and Bulgaria, are briefly presented below. In Figs. 5 and 6, points 1, 2, 3 and 4 represent alternative projects proposed by one country and 5, 6, 7 and 8 those proposed by the other. For both approaches, i.e. trading-off countries' attributes (Fig. 5) or countries' goals (Fig.) the same alternatives 3, 6, 7, 8 are located close to the ideal solution (maximum reliability), with ranking order 36-8-7.

As an extension of the present methodology, two different types of uncertainties may be taken into consideration:

(a) uncertainties in attribute and goal indicator values
(b) uncertainties due to different preference functions (weights) of the decision makers or interest groups.

Figure 5: Conflict resolution by trading off countries' assessment of attributes.

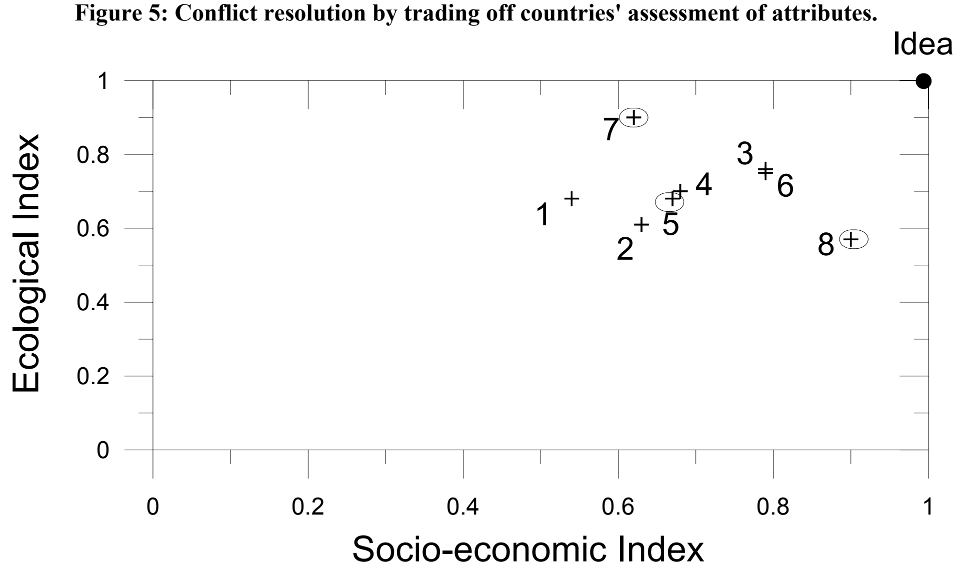
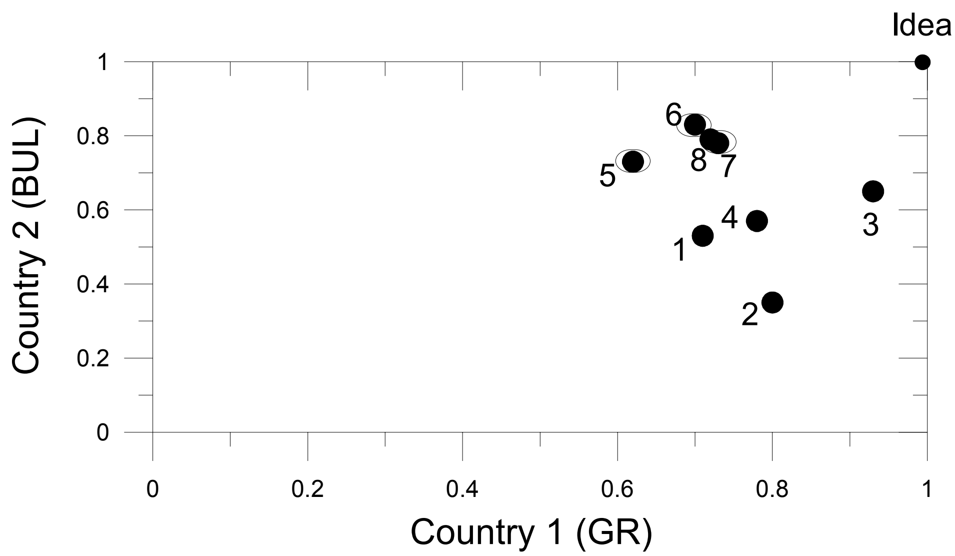


Figure 6: Conflict resolution by trading off different assessment of countries' goals.



4. Conclusions

Conflicts in sharing transboundary water resources are usually due to the fact that countries use either different attributes or different goals to evaluate impacts from alternative strategies

The methodology we propose is based on a combination of Integrated Risk Analysis and MCDA techniques adapted to conflict resolution. Trade-offs are made either at the level of countries' different appreciation of individual attributes, or at the level of countries' different goals.

The methodology is easy to use and the results obtained are fair, transparent and simple to communicate to decision makers.

5. References

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