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Participatory Approach in Decision Making Processes for Water Resources Management in the Mediterranean Basin

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This paper deals with the comparative analysis of different policy options for water resources management in three south-eastern Mediterranean countries. The applied methodology follows a participatory approach throughout its implementation and is supported by the use of three different software packages dealing with water allocation budget, water quality simulation, and Multi Criteria Analysis, respectively. The paper briefly describes the general objectives of the SMART project and then presents the three local case studies, the valuation objectives and the applied methodology - developed as a general replicable framework suitable for implementation in other decision-making processes. All the steps needed for a correct implementation are therefore described. Following the conceptualisation of the problem, the choice of the appropriate indicators as well as the calculation of their weighting and value functions are detailed. The paper concludes with the results of the Multi Criteria and the related Sensitivity Analyses performed, showing how the different policy responses under consideration can be assessed and furthermore compared through case studies thanks to their relative performances. The adopted methodology was found to be an effective operational approach for bridging scientific modelling and policy making by integrating the model outputs in a conceptual framework that can be understood and utilised by non experts, thus showing concrete potential for participatory decision making.

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Summary

This paper deals with the comparative analysis of different policy options for water resources management in three south-eastern Mediterranean countries. The applied methodology follows a participatory approach throughout its implementation and is supported by the use of three different software packages dealing with water allocation budget, water quality simulation, and Multi Criteria Analysis, respectively. The paper briefly describes the general objectives of the SMART project and then presents the three local case studies, the valuation objectives and the applied methodology - developed as a general replicable framework suitable for implementation in other decision-making processes. All the steps needed for a correct implementation are therefore described. Following the conceptualisation of the problem, the choice of the appropriate indicators as well as the calculation of their weighting and value functions are detailed. The paper concludes with the results of the Multi Criteria and the related Sensitivity Analyses performed, showing how the different policy responses under consideration can be assessed and furthermore compared through case studies thanks to their relative performances. The adopted methodology was found to be an effective operational approach for bridging scientific modelling and policy making by integrating the model outputs in a conceptual framework that can be understood and utilised by non experts, thus showing concrete potential for participatory decision making.

Keywords: Scientific Advice, Policy-Making, Participatory Modelling, Decision Support

JEL classification Q01, Q25, Q28, Q5

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1. Introduction

1.1 Objectives of the SMART project

This project focused during its three year duration on the comparative assessment of different policy options for water management in five case studies, one for each of the following Mediterranean countries: Egypt, Jordan, Lebanon, Tunisia and Turkey.

The coastal zones of the Mediterranean are undergoing rapid development with growing and conflicting demands on the natural resources, and at the same time they are subject to an often irreversible degradation of these resources. Water resources and the related land use issues are a key element for the sustainable development of coastal regions. They illustrate the dependency of the usually dynamic and fast growing coastal areas on their resource catchment. This project had to explore methods and tools for long-term policy analysis and strategic decision support for integrated coastal development with special emphasis on water resources and land use, and the resource balance between the coastal region and the inland areas.

The approach is based on a multi-sectoral integration of quantitative and qualitative analysis, combining advanced tools of quantitative systems engineering using numerical simulation models, with methods of environmental, socio-economic and policy impact assessment using rule-based expert systems technology and interactive decision support methods. Water resources modelling including both quantitative and qualitative aspects provided the framework for policy scenarios, exploring different development strategies, the consequences and implications of demographic, socio-economic, and technological development, and the interaction of these driving forces towards long-term sustainability of the coastal regions and their hinterland.

A common methodology for policy design, evaluation, and decision making has been developed and tested in a set of parallel case studies, in each of the participating Mediterranean countries. Lessons from the comparative analysis of these case studies will help to ensure a generic and generally applicable methodology, and at the same time help to foster inter-regional contacts and the exchange of experience.

1.2 SMART case studies

As easily understandable from the title, the project concerns particular coastal zones of the eastern Mediterranean area and more particularly 5 Case Studies (CS) in as many Mediterranean countries: Egypt, Jordan, Lebanon, Tunisia and Turkey. Unfortunately, suitable data for a comprehensive Comparative Analysis were finally available in only 3 out of the 5 CS; these coastal areas and their main characteristics are described qualitatively hereafter.

1.2.1 Lebanese Case Study

The Lebanese CS named “Abou Ali river basin” addresses an area stretching along the northern Lebanese coast covering Tripoli City to the north, the second largest in Lebanon, southward to the town of Batroun. The interested coastline length is about

30km while its width varies between 8-12 km inland. The area typifies the Lebanese coast: it consists of a narrow plain followed inland by a series of foothills, plateau, then rising through steep slopes to the coastal mountain chain. It is crossed by a river (Abou Ali) passing through Tripoli and another minor one (like El-Jawz) near Batroun, with intermittent streams, dendrite drainage and dry wadis. The climate is hot sub- humid at the coast becoming milder inland.

1.2.2 Jordan Case Study

The only coastal area in Jordan is the Gulf of Aqba, name of the CS, populated by 150,000 people, where the shoreline amounts to about 45 km. The region is semi-arid to arid and only about 10% of the total area (90,000 km3) receives above 350 mm of rainfall per year. In 2000, the Aqba area was declared a duty free zone in order to attract new investors in trade and industry. This development will increase demand for water for the growing population and future industrial activities. Water supply to the Aqba region is derived from the Red Sea Basin (5.0 MCM groundwater) and the adjacent Dissi aquifer system (20 MCM) plus a great part of treated wastewater.
On the water quality side, seepage from irrigated areas resulting from excess irrigation near the coast of Aqba is already present while the planned industrial activities will soon certainly affect the water discharging in the Gulf of Aqba.
The total area is comparatively small, leading to a high concentration of potentially conflicting economic activities (ie. tourism vs industry) along the coast and thus competition for space in addition to the competition for water.

1.2.3 Turkish Case Study

The Turkish case study focuses on two major and closely related areas in western Anatolia, along the Aegean Sea: the first one is the Gediz River Basin while the second one is the neighbouring city of Izmir. In the basin, water scarcity is a significant problem, evidenced as water shortages due basically to competition for water among various uses. The main use is irrigation with a total command area of 110,000 hectares followed by domestic and fast growing industrial demand in the coastal zone. The second issue investigated is the sustainable management of water resources in the Izmir urban and rural areas where coastal interactions are significant. This problem reflects not only a regional character but also national significance, as Izmir is the third largest city in the country and an important harbour along the Aegean. There are also strong interactions between the basin and the Izmir rural area, as the Izmir metropolitan area consumes a significant portion of the groundwater resources of the Gediz catchment without feeding it back to the basin. There are also two important industrial areas in the zone: the largest is in the Nif Valley immediately east of Izmir in the Kemalpasa municipality while in the western edge of the city of Manisa an important industrial estate is also growing.

Moreover, the seaward fringe of the Gediz Delta is an important nature reserve and has recently been designated as a Ramsar site to protect rare bird species. Originally, the area received excess water from the Gediz River for much of the year, but since the ‘90s droughts, with restrictions on irrigation releases, the reserve suffers from water shortages. This setting, coupled with difficulties to establish an appropriate and well coordinated control over the use of natural resources and pollution, brought in the region environmental degradation, resource depletion and pollution-related damages.

1.3 Local issues

1.3.1 Physical conditions

Even though the case studies analysed have different settings they are all concerned with similar issues. For instance, water scarcity issues are always significant. The Turkish CS reports that this problem became relevant since the recent '90s droughts, mainly because of competition among different users, while the Jordan CS enhances how this is a structural problem due to the particular location of the gulf of Aqba which already relies on water transported from a distance of over 100 km. In the Lebanon CS, although Tripoli appears to be richly endorsed with freshwater availability, mismanagement and bad quality of the surface water leads to relevant problems of water shortages in term of quality. On the contrary, the occurrence of floods appears to be moderately relevant for two of the case studies, Lebanon and Turkey, while Jordan does not give importance to this issue.

The issues related to groundwater quantity and quality are meaningful for all the CS: for instance in Lebanon the non trustable quality of the surface water locally available leads to the widespread use of private wells while all CS globally signal the non sustainable use of the groundwater resources and the lowering of the water tables.

Concerning the coastal interactions, these are always significant: river Abou-Ali in the Lebanese CS seems to bring more and more sediments, solid and liquid pollution in the years, leading to the building of sandy beaches mixed with debris. The Turkish CS addresses only water quality problems for the bay, while the Jordan CS signals how the return flow of irrigation may affect water quality and the incredibly rich and sensitive coral reef present in the Gulf of Aqba.

1.3.2 Water demand

Concerning the water demand, the agricultural sector is by far the major water demander in two of the case studies while in Jordan one the main users is the industrial sector. For the first sector, the Lebanon and Turkey CS signal the same scarce attention paid to the drainage systems and to the quality of the return flows leading to surface water contamination and groundwater salinisation. The tourism sector is reported to be relevant for the gulf of Aqba and partially for North Lebanon (also depending on the political stability of the region). Going more into detail, the domestic sector critically threatens the groundwater principally because of the fast growing population which mainly relies on this resource across all the analysed case studies. In addition, a major problem of non return flow is common to the Turkish and Jordan CS, as water is currently abstracted to be transported to another basin. Only for the Lebanon CS the surface water abstraction for domestic purposes appears problematic because of its already mentioned bad quality. The absence of implemented waste collection is common to Lebanese and Jordan CS areas while only Lebanon reports the absence of diffuse sanitation systems mainly in rural areas. In the Jordan and Turkish CS areas, sanitation instead is not a major problem but other domestic activities contribute to worsening the general situation. Finally, for what concerns the environmental water demand, it is considered particularly important in Turkey and in the Jordan CS areas. The seaward fringe of the Gediz Delta is in fact an important nature reserve and has recently been designated as a Ramsar site to protect rare bird species while the gulf of Aqba is particularly rich in coral reef and needs clean water without sediments.

1.3.3 Water supply

Concerning water supply, the sources are rather different across the case studies. In the Aqba bay all the water is transported from a nearby aquifer; in addition there is also a widespread use of water-saving technologies, with 3,2 MCM of treated wastewater reused annually in the region and an important desalination plant to be built in the near future. In Tripoli's region, the mismanagement of surface water in the area leads to the already mentioned diffusion of private wells affecting the local groundwater reserves and forcing authorities to import the water from other areas, which implies higher costs on the citizen. In the Turkish CS, the source greatly varies according to use: for the domestic and industrial sectors almost all the needs are abstracted from groundwater while the intensive irrigation activities in the basin are mainly supported by three reservoirs and water pumped by cooperatives. Regarding the system chosen to irrigate, most of the farmers from the Turkish CS area prefer flooding methods while irrigation efficiency seems generally to be lacking in all areas, although no major details are provided.

As mentioned earlier, the overall water quality seems to be a concern in both Lebanon and Turkey CS. In the Tripoli area and surroundings water-related diseases recur on an annual basis and almost all water sources (i.e. springs, wells, rivers) are polluted with a high amount of organics, bacteria and other pollutants because of the lack of treatment plants, no control on the flow of pollutants directly into a river or even in wells. In the Turkish case study, it is the unknown ground water quality which appears the major problem as most of the Basin's population relies on it for supply.

Finally, for what concerns the infrastructures, beside the consistent losses due to old networks and bad maintenance noticed in all the CS, all of these areas are concerned with reservoirs and all of them with heavy infrastructures.

1.4 Objectives of the valuation

In all of the case studies analysed, water demand, supply and quality are, as shown, critical issues to which the policy world has to answer with suitable instruments. How can alternative policy responses be considered really effective with respect to one another?

The comparative analysis of the case studies therefore had the following objectives: to identify commonalities and differences and relate them to the specific regional settings; to identify more generally applicable results that are invariant across the case studies; to organise these findings in terms of a comparative policy assessment (existing and desirable, future ones) and best practice examples – contributions to sustainability.

In order to reach these objectives, the following tasks are described in the SMART Description of Work:

- to organise the individual case study results in a common conceptual framework of common indicators of sustainable coastal zone development and resource management;
- to analyse the individual case studies (and their scenarios) within this framework, by means of simulation models;
- to identify and report common trends and best practice examples, through a comparative analysis.

The methodology presented hereafter has tested a participatory approach taking advantage of the quantitative information available thanks to the indicators provided by simulation models and processed within a multi-criteria analysis Decision Support System. The models were subsequently run to simulate alternative scenarios affected by policy responses that may be implemented to remediate or mitigate the critical issues and inserted again as input in the models to evaluate how well these solutions fit the problem, and with respect to one another.

2. Methodology

2.1 The conceptual framework

The DPSIR conceptual framework (extension of the PSR model developed by OECD) proposed by the European Environmental Agency European Commission (EEA, 1999) to aid the understanding of the cause-effect relationships between the different interacting components of social, economic and environmental issues faced in natural resource management, are nowadays a reference in the sector of environmental studies.

The DPSIR consists of nodes representing different elements of the system: the *Driving forces* represent natural and social processes which lead to environmental problems, e.g. energy, agriculture, industry and waste management. The *Pressure* indicators are the outcomes of the driving forces, which influence the current environmental state. A common expression of this is the use of resources: representing an input for a variety of natural processes and leading to the changes of the environmental condition.

The *State* indicators describe physical, chemical or biological phenomena in the given reference area: for instance they may describe the land uses or their current condition (forest health). The *Impact* indicators refer to the consequence of an environment state change. The result of an impact, such as air pollution, is followed by many effects (global warming, loss of biodiversity) at various temporal and spatial scales (extinction of same animal species).

In a generic decisional context, the perception of the existence of relevant *Impacts* (I) in an area induces decision-makers to develop *Responses* (R) which prevent, compensate, or mitigate the negative outcomes of state changes. Responses may be targeted to address the *Driving forces*, the *Pressures* or the *State* itself: either the *Driving forces* may be re-organised (prevention, changing behaviour, etc.), *Pressure* mechanisms may be altered (e.g. the introduction of new production systems), or the *State* of the environment may be restored or adapted to reduce its sensitivity to *Pressures*.

In this framework, the evaluation procedure starts with the collection for each of the case studies of relevant *D and P indicators* (e.g. demographic, climatic) which are processed thanks to the 3 simulation tools to produce on the one hand the estimation of different scenarios under different timelines; on the other hand future *State* of the environment can be assessed and finally be summarised as *Impact* indicators (e.g. water quality, availability, efficiency). The policy *Responses* can finally be considered as driving factors which may or can change *D* and *P* (differently according to the scenarios) as input indicators to the models, thus modifying subsequently S and I indicators.

The different policy performances can then be easily compared by a simple weighted Multi Criteria Analysis on Impact indicators, which has the advantage, among others, to be a procedure easily understandable by non-expert users.

2.2 The elaboration procedure

As previously mentioned, for the elaboration of the trends and quantitative estimations, the SMART project took advantage of three software packages developed or distributed by partners of the project: *LUC*, *WaterWare* and *Telemac*. These tools have been applied jointly in each of the case studies to support the estimation of future scenarios for water availability and quality in the specific local context. Finally, after processing and organising the information collected, the comparative analysis has been supported by another tool: *Mulino-dss*.

LUC[1] - developed by Environmental Systems and Software (ESS), Austria - is a dynamic Land Use Change model based on several components: a set of well-defined land use classes - according to CORINE Land Cover classification (CEC, 1994; Bossard et al, 2000) - and transitional classes for long-term projections; a matrix of a priori transition probabilities; a set of rules, one set for each possible transition, that can modify the a priori probabilities adopting a set of operators that use spatial and temporal aggregate and neighbourhood properties to modify the transition probabilities. LUC calculates dynamic development (annual time step) of land use over decades, and estimates regional water use as a function of land use. This estimate is intended as a rough check on the much more detailed WaterWare water budget, but with a long-term perspective and change over decades.

WaterWare[1], also developed by ESS, is a river basin scale water resources information system and management model, combining several components and functions. First of all, an information system which includes: time series analysis for hydro-meteorological variables which are used in the various simulation models; an embedded GIS with an associated web-based map server; a hierarchical object data base for river basin objects. Moreover, a simulation system includes: a rainfall-runoff model, an irrigation water

[1] http://www.ess.co.at/WATERWARE

demand model, a statistical drought assessment model, a water allocation (demand-supply balance model), and a set of water quality models for surface and groundwater. In addition, the system provides a set of interfaces for external models; in the case of SMART, this provides a link to the TELEMAC coastal water quality model.

TELEMAC[2] is developed by the Laboratoire National d'Hydraulique et Environnement (Electricité De France – Direction des études et recherches) and is distributed by SOGREAH. TELEMAC system is a numerical modelling system designed to study environmental processes in free surface transient flows, applicable to seas and coastal domains, estuaries, rivers and lakes. The TELEMAC numerical modelling system is based on a finite element technique, utilising an unstructured triangular mesh with size to be adjusted to represent in detail any important bathymetry or shoreline features such as channels, tidal flats, etc. This technique also allows to refine the mesh locally and therefore to improve the results given by the model, especially in zones of complex geometry such as channels or in zones of discharge points such as dredging points.

To evaluate the overall performance of the policy scenarios simulated with the cited models, the *MULINO-DSS*[3] (mDSS) tool has been used. mDSS is a computerised decision support system that addresses complex decision problems dealt within water resource management. The system is based on the DPSIR framework, which guides problem structuring and exploration, and contributes to a better understanding of the problem's dynamics. Simulation and modelling outcomes in the form of indicators help to analyse the causes and effects of environmental problems/conflicts and to derive the expected outcomes of the courses of actions proposed, i.e. the responses in terms of alternative policy strategies.

2.3 Comparative Analysis of policy responses

2.3.1 Indicators and conceptual framework

During the SMART project indications for a set of relevant indicators were collected from partners through a guided exercise aimed at analysing the cause-effect relationships that ultimately lead to a certain condition related to the water system, which was perceived to be either acceptable or problematic for each case study. The exercise was also used to provide estimates for the variables that were perceived to be important for characterising the scenarios. The indicators were classified within the DPSIR conceptual framework, following the outline adopted by the EEA Report "Sustainable water use in Europe" (EEA, 2001), where the DPSIR framework constitutes the basis of the analysis of the water resources situation in Europe.

In particular, variables defining scenarios represent both Driving forces (i.e. climatic and population) and Pressures (i.e. water demand and pollution), while sustainability indicators to be used for the comparative analysis are State and Impact indicators. Responses were instead defined on a case-by-case basis, but within common classes:

[2] http://www.telemacsystem.com
[3] http://siti.feem.it/mulino/

water demand management (WDM), water supply management (WSM), water quality management (WQM). Hence, the DPSIR framework allowed to formalise and include all relevant indicators for the SMART project, i.e. variables defining scenarios, inputs and outputs of the models, sustainability indicators, and responses.

The collection of the initial indicators to be used for the Comparative Analysis (CA) has been a long and iterative process; among all the sets of indicators available in International and National databases for characterising sustainable management of water resources, it was necessary to choose the one able to describe crucial Driving Forces and Pressures and which could also represent an input to the two software packages used to assess the quantity and quality of water for each of the case studies.

While indicators representing Driving Forces and Pressures have been transformed into input variables of the models TELEMAC and WaterWare, the model outputs were used to understand the changes in the state of the environment (thus state indicators), especially in terms of water quantity and quality.

Among the whole set of State indicators produced by the two models concerning water availability and quality, summarised performances have to be defined and agreed upon in order to focus the Comparative Analysis on a few indicators which can be calculated in each of the case studies (see Table 1).

These aggregated State indicators are in fact the Impact indicators whose performance value changes each time a different policy Response is set, thus modifying the D and P indicators input to the models.

It is in reaction to the State of the environment assessed here by the software outputs (and thus Impacts) that the policy world may want to develop suitable policy Responses. This can obviously be very different for each of the case studies, and a standardised framework is therefore needed to perform a comparative analysis also across countries.

Table 1: Criteria for the Comparative Analysis: Sustainability Indicators

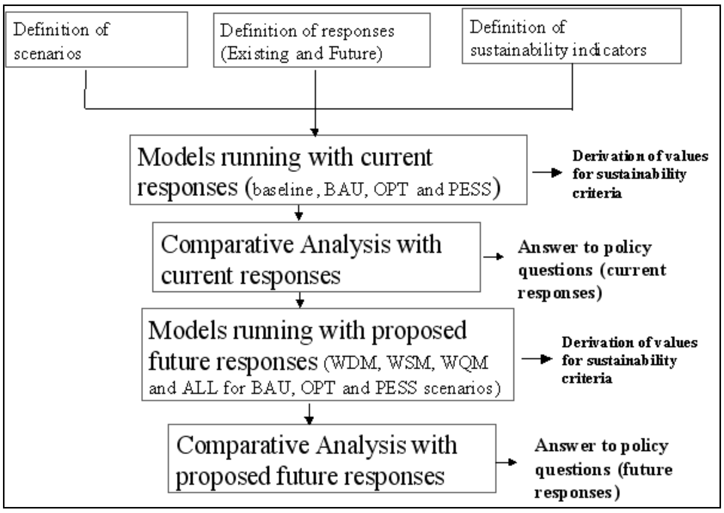
TYPE	INDICATOR	DESCRIPTION	PROPOSED BY:	UNIT	SOURCE
ECONOMIC (Impact)	D/S ratio for agriculture	% of yearly total agricultural demand met by total water supply for the sector	SMART	%	WaterWare
	D/S ratio for industry	% of yearly total industrial demand met by total water supply for the sector	SMART	%	WaterWare
	D/S ratio for tourism	% of yearly total touristic demand met by total water supply for the sector	SMART	%	WaterWare
	Economic efficiency of the system	Value added per unit of water used	SMART	EUR/ m3	WaterWare
SOCIAL (Impact)	D/S ratio for domestic use	Number of days with restricted domestic supply	SMART	days/y ear	WaterWare
ENVIRONMEN TAL	Global quality of coastal waters	Classes of global quality as reported by the Telemac model	UNEP - MAP	class (I-IV)	Telemac

(State/Impact)	D/S ratio for environmental uses	% of yearly total demand for environmental purposes met by total water available	SMART	%	Waterware

2.3.2 Scenario simulation and comparative analysis

In order to perform a meaningful and informative comparative analysis and answer the above questions, case studies will be compared on the basis of the results of models running with comparable assumptions, i.e. the same scenarios (Baseline, BAU, OPTIMISTIC and PESSIMISTIC) and the same type of responses (WDM, WSM and WQM). The main operative steps to perform the comparative analysis are represented in the graph below.

Figure 1: Comparative Analysis procedure



In practice, in each case study the following model runs were performed to derive the values of sustainability indicators:

- 1 run under baseline scenario with current responses
- 3 runs (BAU, OPT and PESS) with current responses and variations depending on the changing forcing variables about climatic and population growth and land use changes (if any)
- 3 runs (BAU, OPT and PESS) with WDM responses
- 3 runs (BAU, OPT and PESS) with WSM responses
- 3 runs (BAU, OPT and PESS) with WQM responses
- 3 runs (BAU, OPT and PESS) with all future possible responses together

According to the above in every case study 16 sets of sustainability indicators' values for each case study were to be analysed in the comparative analysis carried out by means of MULINO-DSS. In practice not all the theoretical combinations were suitable to provide variations in model setting and outputs.

According to the DPSIR framework, SMART scenarios (BAU, optimistic and pessimistic) were defined in terms of D and P indicators. In particular, variables defining scenarios can be classified in four broad categories, i.e. Demography (population growth rate), Climate (precipitation and temperature), Water demand (Urban, Agriculture, Industry, Tourism, Environment) and Water pollution (flow and concentration of pollutants discharged).

Conceptually, scenarios should be distinguished from policy responses. In particular, scenarios include only Driving Forces, i.e. "external" variables - like precipitation patterns, population growth and general economic trends - that are not linked to the implementation of policies explicitly targeting water issues. In the definition of scenarios for SMART, on the other hand, for operational reasons we included some variables – like water demand and pollution – which have a direct link with policy responses. For example, policy responses like the change in cropping patterns, the increase in investments for water conveyance, regulations addressing water pollution problems, etc., can have a direct effect on Pressure indicators such as water demand and pollution.

2.3.3 Participative multi-criteria analysis

The individual performances of the policy options under consideration were aggregated using the multi-criteria approaches (MCA) implemented in mDss: a simple but robust structure, covering a range of decision-makers' attitudes and decision-making styles.

MCA has been conducted in a joint SMART – Nostrum-Dss workshop, in which representatives of partners, of the two projects and of the Nostrum-Dss Steering Committee played the role of experts. In particular they provided a contribution in order to weight the various sustainability indicators identified in order to quantify the evaluation criteria.

In fact, not all the criteria identified (*Impact* indicators) in the case studies carry the same weight. The decision rule applied here was the Simple Additive Weighting, i.e. a weighted additive combination of the values of the indicators, previously standardised by means of value functions.

In order to elicit the weights, various methodologies are available but to raise the acceptability of the proposed solutions, a panel of experts may be involved, as was done in this case. The Simos procedure (Simos, 1990a, 1990b; Figueira et al., 2002) was selected as it provides a simple and effective approach for weight elicitation. It is based on a set of coloured cards, one for criteria, provided to each participant. The participants are asked to rank these cards (or criteria) from the least important to the most important. The rank order of a criterion expresses the importance a single participant wants to ascribe to that criterion: the first criterion in the ranking is the least important and the last criterion in the ranking is the most important. If the two criteria are found to be equally important, these are given the same rank position.

In order to allow participants to express strong preference between criteria, another set of cards (white cards) is introduced. The participants are asked to introduce white cards between two successive coloured cards, while the number of white cards is proportional to the difference between the importance of the considered criteria.

Subsequently, the criteria weights are calculated using the rank positions attributed in the previous step: the rank positions are simply divided by the total sum of the positions of the considered criteria, thus providing a vector of weights to be applied to the evaluation criteria, in the form of real values summing up to 1.

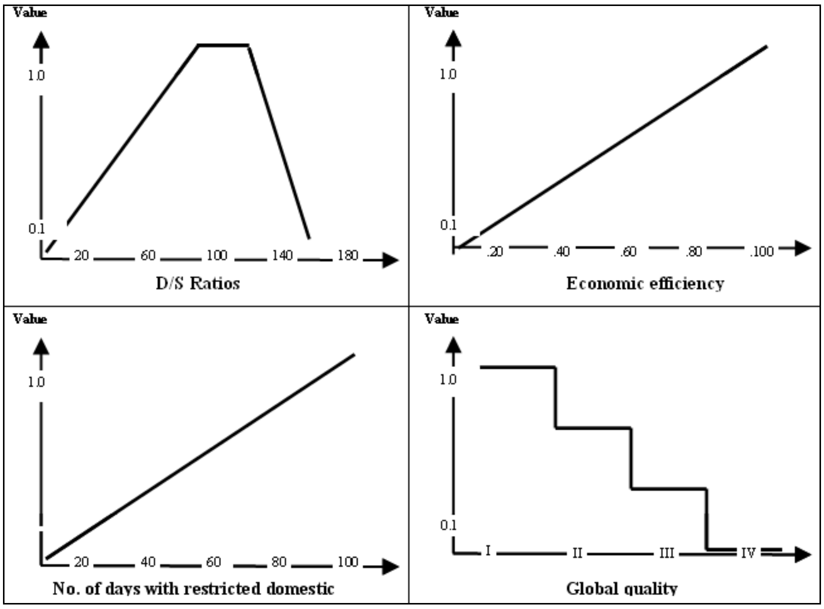
Before performing the MCA with the weighted criteria, it is necessary to attribute them a value function in order to overcome the incoherence related to the unit and magnitude of the criteria. The value function (VF) approach is based on the assumption that the preferential judgements may be substituted by a number of ('value') preserving the preference relations. Value function (VF) translates the performances of the options into value scores, which represent the degree to which a decision objective is matched. In other words, it maps the preference about two options a and b (a is preferred b) in a numerical relation u(a) > u(b).

3. Application of the methodology

3.1 Value functions

In order to perform a weighted comparative analysis as explained in section 2.2 it is necessary to standardise the chosen indicators. The 4 value functions adopted within this analysis are reported in the following figure.

Figure 2: Value functions for the 4 types of criteria



3.2 Simos procedure

The workshop took place in Venice in June 2005 and involved a panel of 14 experts in water resource management mainly coming from the Mediterranean area.

3.2.1 Separate and Collective elicitation

During the workshop, the participants were asked to perform the criteria ranking using the Simos methodology twice: first for the groups of macro-criteria (environmental, economic and social criteria groups) separately, and in succession, for all criteria together. The difference between the weights elicited in such a way would give a clue about a cognitive shortcoming, called splitting bias frequently reported in the literature. The existence of the splitting bias means in our case that different weights can be yielded, depending on the way criteria are organised. As expected, the criteria weights differed considerably. When all criteria were considered together, the weights of the economic criteria were generally overestimated and the weights of environmental and social criteria underestimated (Table 3).

Table 2: Criteria weights elicited by Simos procedure

Macro-criteria	Decision criteria	Weights elicited separately w_s	Weights elicited collectively w_c
Economic	D/S ratio for agriculture	0,1	0.17
	D/S ratio for industry	0,06	0.11
	D/S ratio for tourism	0,06	0.09
	Economic efficiency of the system	0,11	0.17
Social	No. of days with restricted domestic supply	0,33	0.22
Environmental	Global quality of coastal waters	0,14	0.09
	D/S ratio for environmental uses	0,19	0.15

3.2.2 Inconsistencies

As mentioned, a considerable inconsistency was observed between the two exercises of the weight elicitation. The inconsistencies can be generally classified into three classes:

i. strong inconsistency – the preference between two criteria a and b was opposite. For example, while the criterion a was preferred when considering the criteria groups separately; the criterion b was preferred when all the criteria were handled together. There have been two cases (14%) of strong inconsistency.

ii. weak inconsistency – the relation between two criteria changed from indifference (a and b equally important) to a preference relation (a is preferred to /dominated by b).There have been three cases (21%) of a weak inconsistency.

iii. shift in the degree of preference – a relation between two criteria changed from simply preferred to strictly preferred (by inserting one or more white cards between the criteria a and b).

As a result of the above-described inconsistency, the variations of the experts' judgements yielded by the Simos preference elicitation differed considerably. The most constant (robust) judgement of the importance of a criterion, in the case of non-hierarchical criteria arrangement, yielded the only social criterion – the "No. of days with restricted domestic supply", followed by "economic efficiency" and "D/S agriculture". The environmental criteria (especially "global quality") showed the most varying preference judgements across the experts. In the case the criteria were organised hierarchically, “D/S agriculture” yielded the most stable judgement across the economic criteria, followed by “economic efficiency” and “D/S tourism”. The “D/S industry” did worst. Among the environmental criteria, once again “D/S environment” criterion yielded more stable judgements.

These inconsistencies had no impact on the further comparative analysis across the case studies since only the criteria weights elicited in the hierarchical way (ws in the table 3) were applied to evaluate policy performance.

3.2.3 Correlation

Both Spearman's rank correlation and Kendall's tau coefficient have been applied to analyse the relations between the criteria. A significant correlation was revealed only between four pairs of criteria. A negative correlation was revealed between some economic and environmental criteria, meaning that participants who assigned a high rank position (and resulting weight) to economic aspects of the problem, generally tended to see environmental issues as less relevant and vice versa. However, this could not be generalised for all the criteria in these sub-groups, indicating a rather complex preference system hardly reducible to stereotypes such as antagonism between economically and environmentally oriented people.

The only significant correlation of this type was between criteria “D/S tourism” and “D/S environment”. A negative correlation was also found within economic sub-groups, namely between the criteria “D/S industry” and “Economic efficiency”. More complex is the situation between the only social criterion and the other criteria. A significant positive correlation was revealed between “D/S tourism” and “No. of days of restricted domestic use”. On the other hand a negative correlation characterised the relation between “D/S agriculture” and “No. of days”. In the case of the criteria with significant correlation the coefficients varied between 0.34 and 0.41.

The correlations between the experts’ judgments of criteria importance give an insight into the within-group variability of experts’ preferences. The correlation between the single experts ranges between -.48 (in the case of experts p4 and p13) and 0.9 (experts p12 and p14). Given the small sample size only 18 pairs of experts (out of n(n-1)/2 = 91) show a statistically significant correlation. The correlation in order to be statistically significant in our case must exceed 0.52, meaning that only positive correlations are statistically significant. Again, the correlation analysis does not allow a simple conclusion regarding the further differentiation of experts’ preferences.

3.3 Aggregated performance

The multi-criteria decision functionality implemented in mDss allows the system to model users’ preferences and to aggregate the performances of considered options with regard to the decision criteria. All the information collected during the various phases of the analysis are suitable to be inserted in this too; this simplifies the comparative analysis of the indicators as it allows to insert the DPSIR conceptualisation, vary the

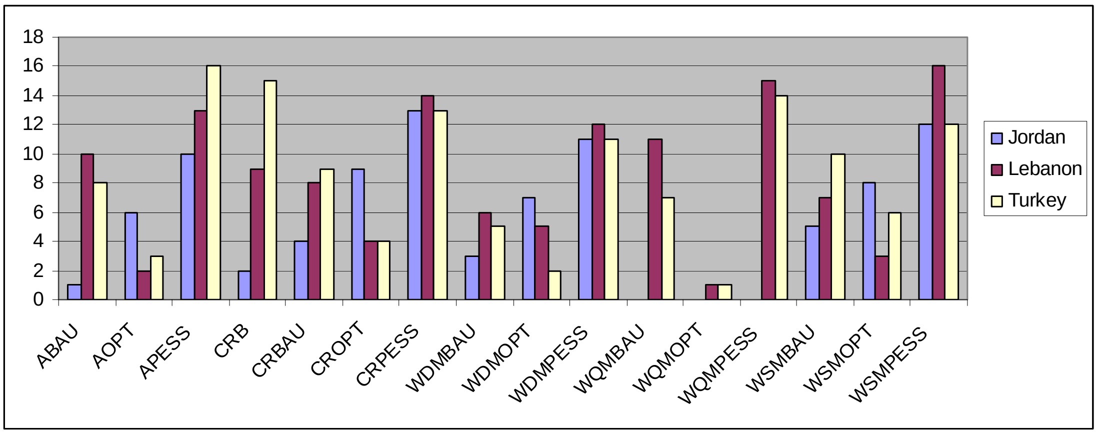
parameters of the analysis, rank the options, and perform a sensitivity analysis on the results in a manner that is suitable to communicate intermediate and final results also to the interested parties outside the scientific sphere.
The total performances yielded by applying the additive averaging method based on the VF and weights described earlier are shown in Table 4.

Table 3: Final results of the CA

	Jordan		**Lebanon**		**Turkey**	
Options	**Score**	**Rank**	**Score**	**Rank**	Score	**Rank**
ABAU	**0,6653**	**1**	0,5496	10	0,8297	8
AOPT	0,5737	6	**0,7723**	**2**	**0,896**	**3**
APESS	0,5269	10	0,4262	13	0,6356	16
CRB	**0,6563**	**2**	0,5626	9	0,6873	15
CRBAU	0,617	4	0,5642	8	0,7846	9
CROPT	0,5362	9	0,7543	4	0,8704	4
CRPESS	0,4476	13	0,4258	14	0,7285	13
WDMBAU	**0,6466**	**3**	0,613	6	0,8363	5
WDMOPT	0,5636	7	0,753	5	**0,9092**	**2**
WDMPESS	0,5264	11	0,4279	12	0,7437	11
WQMBAU			0,5242	11	0,8308	7
WQMOPT			**0,8283**	**1**	**0,9169**	**1**
WQMPESS			0,42	15	0,7266	14
WSMBAU	0,6031	5	0,5802	7	0,771	10
WSMOPT	0,5511	8	**0,7678**	**3**	0,8356	6
WSMPESS	0,5025	12	0,4067	16	0,7326	12

The situation in each case study is unique, nevertheless the same preferences – internalised in the value functions applied to transform the expected outcomes of the policy options and the criteria weights – were the same in all case studies. Concerning the correlations between the rankings obtained in each of the case studies, Kendall's tau coefficients (ranged between 0.18 and 0.63) are generally smaller than the Spearman Rank Correlations (0.28 – 0.83). In Lebanon and Turkey the results show higher similarity. This is also the only statistically significant correlation regardless of the type of correlation coefficient used. Both case studies share the same policy option as the best preferred one – WQMOPT. It should be noted that this option could not have been considered in the Jordan case study and thus this comparison is limited to the common policy options. The second best option in Lebanon CS is AOPT, whereas this option is ranked third in Turkey. The second best option in Turkey is WDMOPT which is in position 5 in Lebanon. Likewise, the lowest ranking options are similar, the differences in their rank positions are rather small and in any case do not exceed 6 rank positions. This explains the high correlation between both case studies.
In the Jordan case, the most preferred option is ABAU which ranks very low in other case studies. Similarly, the second best option (CRB) is the second worst in Turkey. The low ranked options on the other hand yield equally poor results in the other cases. Interestingly, the best results in the Jordan CS are related to the BAU scenario, followed by the OPT scenario.

Figure 3: Final ranking of the options



4. Conclusions

The methodology originally developed for the Comparative Analysis was shown to be fully operational, providing a comprehensive assessment of the different policy options available for each case study. This approach allows to share the whole assessment process of the different policy options also with non-experts of DSS tools (e.g. policy makers). Starting from the conceptualisation in the DPSIR framework, passing through the choice of the criteria, the elicitation of their relative weighting and value functions, the Mulino-DSS tool allows to process all the relevant information and finally to perform an MCA in a transparent and intuitive way.

The data set was limited in size and sub-optimal, as a result of the combination of missing data in the examined CS, therefore the results obtained should be considered only from the methodological viewpoint. Having pointed this out, the final result is a ranking of the preferred policy options for each of the case studies; this comparison moreover allowed a further analysis across CS, highlighting how similar policy responses were preferable in different CS.

Emphasis has been placed on supporting analytical thinking and exploring the problems. Several of the methods implemented allow the decision-maker to focus on various aspects of the decision problem and are useful to guide the decision process.

By simultaneously using a number of different decision methods and by reviewing the possible conclusions of each, decision-makers are enabled to better understand the problems and to explore the trade-offs offered by the various options (Bell et al., 2001). Since the approach is aimed at assisting decision-makers to become more familiar with analytical ways of decision-making, the methods have been kept simple to avoid discouraging inexperienced users.

The adopted methodology therefore represents an operational approach for bridging scientific modelling and policy making, by integrating the model outputs in a conceptual framework that can be understood and utilised by non experts. The methodology shows a concrete potential for participatory decision making since it uses simple methods not requiring hi-tech facilities (i.e. Simos for knowledge elicitation) and computer tools that are freely available through the Internet (i.e. Mulino-DSS).

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- *Mulino-dss* developed by the Mulino consortium (Contract n° EVK1-CT-2000-00082) http://siti.feem.it/mulino/

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