PERCEIVED DIVERSITY of WATER MANAGEMENT in MEDITERRANEAN WATERSHEDS: A CASE STUDY

Ugo Gasparino, Barbara Del Corpo
FEEM - Fondazione Eni Enrico Mattei, Corso Magenta, 63, 20123 Milano, Italy
Tel. +39 02 520 369 89 - Fax: +39 02 520 369 46;
e-mail: ugo.gasparino@feem.it, barbara.delcorpo@feem.it

Keywords: Cognitive Map, Factor Analysis, Indicators and indices of Sustainability, Participative Approach, Water Management

Abstract *The general attitude towards the sustainable management of environmental resources is evolving towards the implementation of 'participatory' (as opposed to the classical 'command and control') and, especially at local scale, 'bottom up' (as opposed to the classical 'top down') approaches. This progress pushes a major interest in the development and application of methodologies able to 'discover' and 'measure' how the same environmental systems tend to be perceived by different (groups of) Stakeholders. In the present paper an approach, typical of social sciences, is presented and applied to the analysis of the sustainable water management in seven Southern and Eastern Mediterranean Watersheds. The methodology is based on the development and analysis (explorative factor analysis) of a questionnaire aiming at the 'discovery' and 'measurement' of eventual latent multidimensional 'underlying structures' ('conceptual maps'). It is the opinion of the authors, that the identification of a set of 'consistent', 'independent', 'bottom up' and 'shared' synthetic indicators (aggregated indices) could be strongly facilitated by the interpretation of the emerging dimensions of the such 'underlying structures'.*

1 INTRODUCTION

Environmental sciences have typically to assess the impact of human activities on complex natural systems (e.g., complex webs of linear or non-linear interactions containing difficult to define pathways and multiple feedback loops). Furthermore, in the framework of sustainable development, environmental compatibility has to be complemented by economic efficiency and social equity. This makes any 'consistent' deterministic mathematical formulation hardly feasible. Furthermore, in order to 'optimise' the management of natural resources one has, as a matter of facts, to analyse and frequently to reconcile conflicting demands (often by different Stakeholders). Recent EU legislation (e.g., 2001 White Paper on 'European Governance' or, in relation to environmental legislation, the 'Water Framework Directive' - 2000/60/EC) tends to force the implementation of 'participatory' approaches, where different Stakeholders are not only informed, but also directly involved in different phases of the decision process. This concern is variously articulated using the language of public participation, community empowerment, decentralised decision-making, and democratic governance. It becomes therefore mandatory, especially at local level, the development of efficient approaches aimed at the 'discovery' and 'measurement' of how complex environmental systems tend to be perceived by different Stakeholders.

The present paper presents a methodology aiming at 'bringing to the surface' the underlying multidimensional structure, as perceived by the Stakeholders (the so-called 'conceptual map'). The application is part of OPTIMA (Optimisation for Sustainable Water Management), a Project using both a participative approach as well as detailed numerical modelling, where seven independent Middle East and North African Mediterranean Watersheds are modelled and investigated. OPTIMA is financed by the European Union in the INCO-MPC - 6th Framework Programme. Detailed information about the project can be found in Internet, at http://www.ess.co.at/OPTIMA.

2 METHODOLOGY

The methodology is based on interviewing Stakeholders (i.e., compilation of a Questionnaire). Schematically, the applied procedure is as follows:

- generate and submit to Stakeholders of concern a Questionnaire, containing a list of Issues thought to comprehensively cover the topics inherent to the system under investigation, and ask them to score the perceived criticality of each single Issue (e.g., by means of a scale, anchored to: 'Extremely Unimportant' and 'Extremely Important');
- analyse the Questionnaires (e.g., explorative factor analysis) aiming at the 'discovery' of any latent multidimensional 'underlying structure'. The procedure allows the extraction of an 'optimal' number of orthogonal (i.e., independent) dimensions (typically, expressed as weighted sums of subgroups of Issues).
- interpret the discovered 'underlying structure' and use this reduced set of new dimensions in further analysis (e.g., cross-comparisons, construction of 'synthetic indicators'). Analyze, compare and rank the Watersheds and/or the classes of Stakeholders in the framework of the extracted factors.

3 RESULTS

The approach selected in OPTIMA in order to prepare an 'holistic' Questionnaire, was based on a relatively pragmatic framework that tends to reflect directly the 'Water Budget' at 'River Basin Scale'. The Water Issues Questionnaire is structured in three main Sections: Water Management. Demand and Supply. The details of the three sections (adding up to 57 Issues) are reported in Ref. /1b/. Stakeholders were invited to score the significance (in reference to the Watershed of concern) of each Issue making use of a 7-point symmetric semantic differential scale, anchored to: 'Extremely Unimportant' and 'Extremely Important' (the intermediate levels had been labelled, respectively, as 'Very Unimportant', 'Unimportant', 'Neutral', 'Important', 'Very Important'). Alternatively, the answer 'don't know' could be selected (e.g., when the question - or its formulation - was found not sufficiently understandable/unambiguous or when the interviewed perceived himself/herself 'too incompetent' on that specific Item). The compilation of the Questionnaires was carried out by means of Interviews with trained Interviewers.

3.1 Data Collection

The OPTIMA dataset consists of 75 questionnaires, related to 7 Case Studies: Dhiarzos (Cyprus), Gediz (Turkey), Litani (Lebanon), Martil (Morocco), Melian (Tunisia), Wadi Zeimar/Alexander (two branches of the same river, flowing in Palestine and Israel, respectively) and Zarqa (Jordan). These basins offer an heterogeneous selection of Mediterranean Watersheds ranging from minor (e.g., Dhiarzos River basin, characterized by a size of 260 km^2 and a population of 3,550 inhabitants) to major Basins (e.g., Gediz River basin, 17,600 km^2 and nearly 2 millions residents).

3.2 Multivariate Statistical Analysis

Principal factor analysis suggests the presence of four orthogonal (*varimax* rotated) factors that explain about 50% of the variation of the original data in (i.e., 57 variables). Solutions obtained treating the ordinal variables as continuous or more consistent (and complex) treatments (estimation of *polychoric* correlation and MINRES factoring method) bring to practically identical results /1b/. One has to notice that being orthogonal (*varimax* rotated), the four factors are uncorrelated (i.e., 'independent'). Based on factor loadings, the following interpretation is proposed /1b/:

1st factor:	'Pressure' and 'impact' on water demand and quality, mainly related to non-agricultural 'driving forces' (tourism, household, industry)
2nd factor:	Deficiencies in the regulatory and institutional 'response' (DPSIR Framework), mainly in relation with Agriculture
3rd factor:	Techno-economical barriers and (industrial) impact on water quality
4th factor:	'Subventioned' water price (agriculture and household)

While extracting the factors, no use is done of the fact that the Questionnaires refer to seven independent Case Studies. The set of Questionnaires is treated as a single (heterogeneous) dataset. It is therefore interesting to analyze 'post hoc' if different Case Studies tend to present significantly different behaviours. This is also of primary importance with respect to the objective of using the 'conceptual map' extracted by factor analysis to support the construction of consistent aggregated indicators. The result of such a kind of analysis, in relation to the 1st factor, is reported in Figure 1.

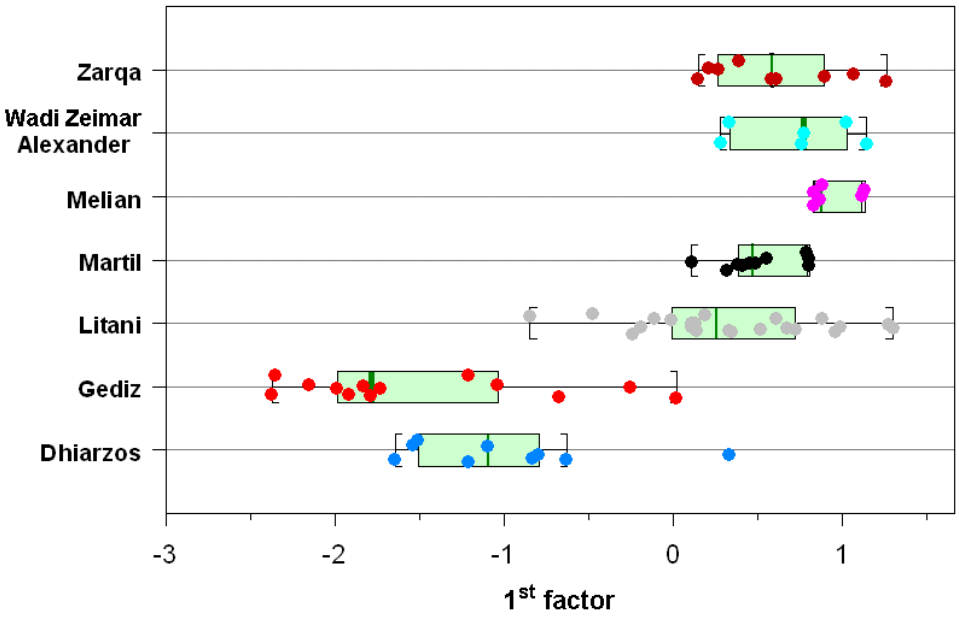

Figure 1: Factor scoring on the 1st factor. Respondents are aggregated by Case Study. In the plot, the points are randomly 'jittered' on the y-axis in order to prevent overlapping.

As emerges from Figure 1, the 1st factor offers a rather clear discrimination among the different Case Studies. The Gediz (Turkey) and the Dhiarzos (Cyprus) basins tend to show systematically lower scorings. On the opposite, the most critical situation appears to be related with the Melian (Tunisia), the Wadi Zeimar/Alexander (Palestine/Israel) and the Zarqa (Jordan) rivers. One has to remember that this factor has been interpreted as mainly reflecting the Pressure (prevalently related to non-agricultural 'driving forces') on water quantity and quality.

The scorings on the first two factors are graphically shown in Figure 2. To highlight the distributional properties of the data (as well as the possible presence of 'outliers'), the scatterplot is enhanced by representing the *bivariate boxplots* (i.e., the 'two dimensional analogue' of the familiar boxplots for univariate data, see, e.g., /2/) associated to each Case Study. The *bivariate boxplots*, based on the calculation of 'robust' measures, consist essentially of a pair of tilted concentric ellipses, one of which (full line) includes 50% of the data and the other (dotted line) which should delineate potential troublesome outliers. It is evident from Figure 2 that, even if only the 'global dataset' of compiled Questionnaires has been given as input to factor analysis (i.e., without specifying to which Case Study a single Questionnaire belongs), the results on the first two factors can discriminate relatively well among most of the Case Studies under investigation. The 'between-Case Study' variation tends generally to overcome the 'within-Case Study' variation (related to the discrepancy in the point of view of different respondents) reflecting therefore some 'specific characters' of the different Case Studies.

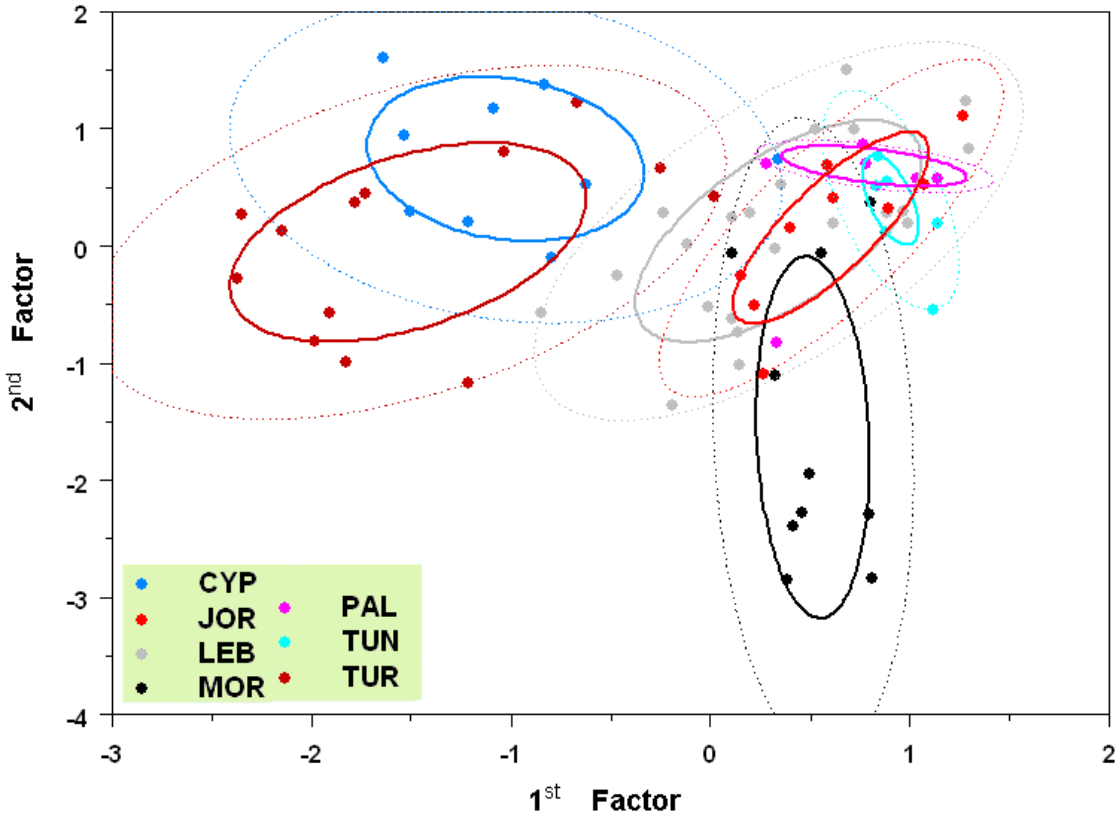

Figure 2: representation of the scores on the first two factors

A further analysis was dedicated to the investigation of whether distinct classes of respondents (Stakeholders) tend to score in a significantly different way (in the factor space). In order to *demean* the data from the systematic differences observed in the different Case Studies, the analysis was not done on the original scorings but on their deviations from the average value observed in the corresponding Case Study. Four different aggregations of the Stakeholders (by 'scope', by 'size', by 'category' and by 'type' – see Ref. /1a/, for definitions) were analyzed, in order to test if the (demeaned) average scorings assigned by different classes of Stakeholders to each of the four factors differed in a significant way. The analysis was done by means of the method of analysis of variance (ANOVA) and of its alternative non-parametric equivalent: Kruskal-Wallis rank sum test.
The two methods agreed in selecting as '*highly significantly*' different (p-value < 0.01) the scoring on the 1st factor, when the responses were aggregated by 'category', by 'type' and by 'scope'. A further '*highly significantly*' difference was found for the 4th factor, aggregating the Stakeholders by 'scope'. No significantly different scorings (even at the p-value < 0.05 level) were instead observed for the 2nd and 3rd factors (for the 4 types of aggregation being tested).
As an example, the results on the 1st factor for the aggregation by 'scope' are shown in Figure 3. Multiple comparisons identify the following pairwise combinations as significant sources of the discrepancies: 'local' vs. 'national' and 'local' vs. 'international' ('local' tends to assign lower scorings). The 1st factor ('pressure and impact on water demand and quality - mainly related to non-agricultural driving forces') seems to be perceived as 'less critical' by locally based Stakeholders than by national/international ones.

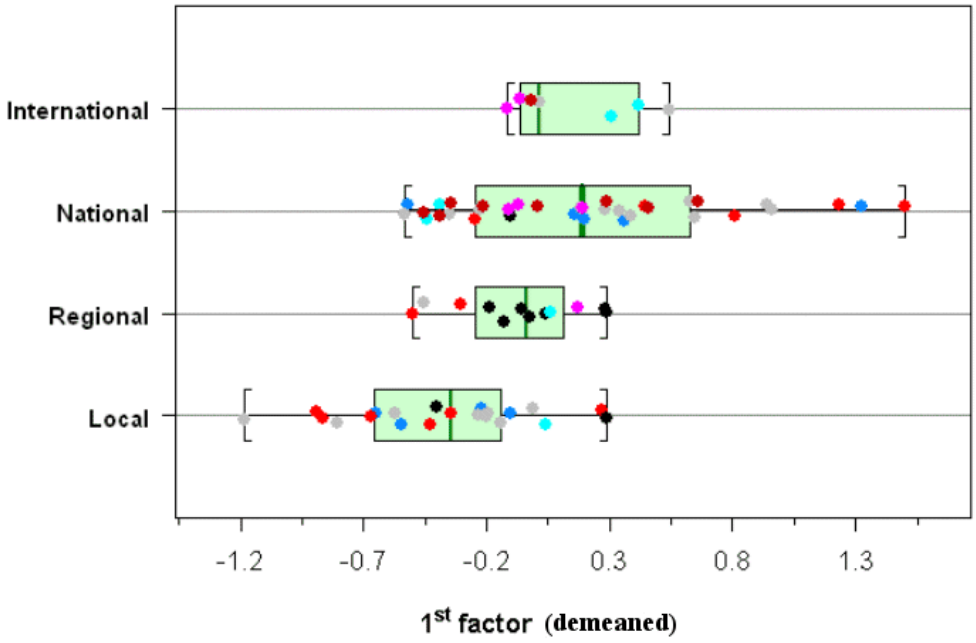

Figure 3: same as Figure 1 but discriminating for 'Scope of Stakeholder'. Local Stakeholders tend, on average, to assign lower scoring to the 1st factor (i.e., to perceive it as 'less critical').

CONCLUSIONS AND FUTURE WORK

An application of a Questionnaire-based methodology to the Sustainable Water Management in seven Mediterranean Basins tends to suggest a four-dimensional orthogonal 'latent structure' (indicating, for each dimension, a set of correlated Issues /1b/). This 4-dimensional structure allows to discriminate among different Watersheds and/or different classes of Stakeholders. However, due to the relatively small sample size of the available data, the generality of the result cannot be 'guaranteed' (i.e., it could be, at least partially, 'data specific' and not emerge in other 'equivalent samples'). The major future work is therefore related to the following steps:

- a validation of the results on an independent dataset (or a further increase in the number of compiled questionnaires);
- the improvement of the Questionnaire (decreasing 'redundancies' through the creation of 'sum scales');
- the 'translation' of the perceived factors in quantitative composite indices (using the linear combinations defining the factors in terms of basic Issues).

ACKNOWLEDGEMENTS

The presented Methodology has been developed and applied in the Framework of the OPTIMA (Optimisation for Sustainable Water Management) Project, financed by the European Commission (6th Framework Programme of Research, INCO-MPC).
We would like to thank all OPTIMA partners for fruitful discussions and for taking care of the compilation of the Questionnaires, by Interviewing local Stakeholders.

REFERENCES

/1a/ OPTIMA Project, *for further information about the Water Issues Questionnaire, see project* '*Deliverable D01*' at http://www.ess.co.at/OPTIMA/FTP/D01.pdf

/1b/ OPTIMA Project, *for further information about the Statistical Analysis, see project* '*Deliverable D02*' at http://www.ess.co.at/OPTIMA/FTP/D02.pdf

/2/ Everitt, '*An R and S-plus companion to multivariate analysis*', Springer, 2005