Long abstract

From the DPSIR reporting framework to a system for a dynamic and integrated decision making process

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Abstract: This paper briefly presents the theoretical and methodological background of the development of a dynamic and integrated decision support system (DSS) based upon the DPSIR framework. First the DPSIR framework is presented, and then the evolution from a static reporting framework to a dynamic modelling environment and from an environmental to an integrated multi-disciplinary approach is discussed. Finally the implementation of such approach in the DSS tool developed by the MULINO (Multi-sectoral, integrated and operational decision support system for the sustainable use of water resources at the catchment scale) Project (mDSS) is briefly reported.

Keywords: Integrated Assessment Modelling, Decision Making, DPSIR

1. INTRODUCTION

Environmental reporting has been gaining momentum over the past decade as an important tool for monitoring and evaluating environmental resources and their changes over time. Examples are the State-of-the-Environment reports published every year by national and international environmental agencies.

A prerequisite for the assessment and reporting on the state of the environment and its evolution as affected by human activity is the identification of adequate sets of indicators to be surveyed and the definition of a functional scheme to describe cause-effect linking the state of the various – ecological, economic, social, technological– indicators. Relevant examples in this field are the PSR scheme (Pressure – State – Response), adopted by the Organisation for Economic Co-operation and Development (OECD, 1994), and the DSR (driving force – State – Response) of the UN Commission on Sustainable Development (UN, 1997). More recently the DPSIR framework (Driving Force – Presuure – State – Impact – State – Response), was proposed by the European Environmental Agency (EEA, 1999) and adopted by many national and European institutions, EEA and Eurostat among others.

Despite the broad use of the DPSIR framework, a reference document with thorough theoretical and methodological presentation of such an approach is lacking. This fact contributes to diversified interpretations such as inconsistent attributions of the same indicators to the five components.

This paper briefly presents how the European Project MULINO (EVK1-2000-00082) has developed a theoretical and methodological framework for designing an operational Decision Support System (DSS) for sustainable management of water resources at the catchment scale, built upon the DPSIR framework.

2. THE DPSIR FRAMEWORK

The framework was originally developed by the EEA for environmental reporting purposes and structures the description of the environmental problems, by formalising the relationships between various sectors of human activity and the environment as causal chains of links. The

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environmental management process may thus be described as a feedback loop controlling a cycle consisting of five stages (see Figure 1).

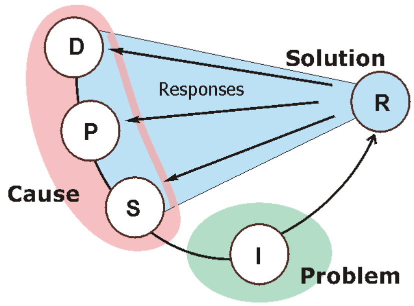

Figure 1: The DPSIR framework, in a decisional context

Driving forces are the underlying causes, which lead to environmental pressures. Examples are the human demands for agricultural land, energy, industry, transport and housing. These driving forces lead to ***Pressures*** on the environment, for example the exploitation of resources (land, water, minerals, fuels, etc.) and the emission of pollution. The pressures in turn affect the ***State*** of the environment. This refers to the quality of the various environmental media (air, soil, water, etc.) and their consequent ability to support the demands placed on them (for example, supporting human and non-human life, supplying resources, etc.). Changes in the state may have an ***Impact*** on human health, ecosystems, biodiversity, amenity value, financial value, etc. Impact may be expressed in terms of the level of environmental harm. The ***Responses*** demonstrate the efforts by society (e.g. politicians, decision makers) to solve the problems identified by the assessed impacts, e.g. policy measures, and planning actions.

3. DPSIR AND DECISION MAKING

Within this framework the task of decision makers (DMs) is therefore that of analysing the territorial system and assessing the acting Driving forces, their Pressures, the consequences on State variables and their ultimate Impact, i.e. their negative externalities, if any. From the assessment of Impacts they should determine appropriate Responses, in order to direct the final effect in the desired direction (a reduction in environmental harm). Therefore in a decisional context related to natural resource management, Impacts describe the existing problems arising from the change detected in State variables, which reduces the value (either in quantitative, economic, or qualitative terms) of the natural resource.

DMs who could potentially take advantage of the DPSIR approach, range from high level (national and international) policy makers to local managers and administrators. Driving forces, Pressures and States are the possible levels of intervention, as depicted in Figure 1: a DM chooses one of them (or a combination of them) as a concrete object for his response depending on his/her responsibilities and capabilities. In general, local managers may not be able to intervene on the main socio-economic Driving forces, but within their specific jurisdictions may effectively deal with the State of the environment, or with some of the Pressures. Conversely, the higher level policy making bodies act on Driving forces and Pressures, having instead fewer possibilities to deal directly with environmental conditions or State.

From the above, the potentials of the DPSIR approach for decision making in the field of natural resource management should result clear. Nevertheless the methodology for an effective implementation of a decisional process in the DPSIR framework is far from being clear, nor unique, as demonstrated by the substantial lack of implementations outside the field of environmental reporting. The adoption of the DPSIR scheme in the operational DSS tool developed by the MULINO Project (mDSS) required the development of innovative theory and methodologies aimed at transforming a static reporting scheme in a framework for dynamic integrated assessment modelling (IAM) and evaluation procedures.

4. IAM IN THE "DPS" FRAMEWORK

The implementation of IAM in the DPSIR framework was approached in mDSS by focusing on the DPS part of the framework. Those three elements were thus considered as explicit formalisations of forcing (i.e. driving) variables, model parameters and outputs, respectively. In the case of water pollution models, for instance, D's represent the forcing variables ruling the behaviour of the simulated system- the catchment. P's may be expressed as parameters expressing the rate of pollution processes and S's are the output variables quantifying the dynamic evolution of the catchment system as affected by the considered pollution sources and processes. Integration of models may occur at various levels and in different ways and thus relationships along the chains could be expressed by parallel one-to-one flows, or one-to-many (e.g. one activity affecting various environmental compartments), or many-to-one (e.g. various sectors affecting the same environmental indicator), or even many-to-many, in the case of multi-sector integrated models.

In the context of environmental decision making, IAM can thus support the identification of the correct Responses by providing sets of indicator values deriving from subsequent simulation runs in which model(s) are parameterised to represent the expected consequences of a set of possible alternative responses. However, a crucial step is needed: the development of a set of evaluation indices, targeted in particular to identify Impacts deriving from the State indicators provided by IAM. Such disciplinary context is commonly dealt with by Multi-Criteria Analysis (MCA) methods.

5. MCA IN THE "IR" FRAMEWORK

Evaluation procedures in mDSS were implemented by focusing on the link between S and I and between I and R and by adapting concepts and methods derived from the MCA literature and Multi-Attribute methods in particular (Hwang and Yoon, 1981). Within this disciplinary context a preliminary phase of Problem Structuring is targeted to the identification of the factors or criteria to be considered for choosing among previously defined alternative response options, taking to the delineation of the structure of the Analysis Matrix (AM). Those factors are expressed by output variables deriving from IAM or monitoring activities and used to fill the cells of the AM. The step between the quantification of State variables in the AM and the identification of Impact evaluation indices can be conceptualised according to the MCA theory as the conversion of the AM into an Evaluation Matrix (EM), which expresses the estimated impacts (see Figure 2). This step is realised by means of normalisation procedures and value or utility functions, allowing respectively the comparison of multidimensional variables and the expression of judgements to convert the scales of state indicators into evaluation criteria specific for the decision in question. The standardisation procedure simply transform any arbitrary data range to a standard interval which represents the degree to which a decision objective is matched. The value function represents an effort for mathematical representation of human judgements. The way the performances of the alternatives are translated into value score is controlled by decision maker's preferences. Weights are usually applied to evaluation criteria to contribute to making explicit the preferences of the DMs.

Having identified the impacts as they vary under the effects of alternative response options, the DM –and thus the DSS– has to apply decision rules to the values stored in the EM to identify the preferred option, then filling the gap between I and R. In the simplest case the rule can be expressed by the weighted sum of values stored the columns of the EM. Various iterations are possible at this step to refine the selection of the preferred response, by considering the results of the sensitivity analysis, refining the weights, or choosing alternative decision rules, parallel procedures are also possible in multi-stakeholders group decision making.

6. A DYNAMIC AND INTEGRATED DPSIR-DSS

The main objective of the MULINO project is contributing to improve decision making in sustainable water resource management at the catchment scale, in compliance with the recently released Water Framework Directive, WFD (EC, 2000). According to the WFD, the DSS under development should integrate hydrological and socio-economic approaches in order to assist water authorities in the management of water resources. Sustainable development is one of the main keys of the WFD and requires the integrated analysis of at least three disciplinary approaches: economic, social and environmental.

The development of an innovative approach to convert the DPSIR framework in a dynamic environment through the implementation of IAM procedures did not raise relevant theoretical issues until the problem of multidisciplinary integration was touched on. But when social and economic considerations are brought into the IAM environment, some problems emerge, deriving from the origin of the DPSIR approach, which is limited to environmental monitoring and reporting. In theory it considers socio-economic aspects, by analysing the driving forces, i.e. human activities influencing environmental systems, but the problem arises when those aspects should be included in cause effect links and models.

Two main alternative solutions were examined in order to expand the DPSIR context to social and economic issues. The first hypothesis was to reconsider the definition of State by broadening its meaning to include socio-economic indicators describing the state of the territorial system under consideration. The second was to maintain the more restrictive environmental meaning and locate socio-economic analyses within the D component. Pros and Cons were evident for both solutions. The first allowing more explicit representation of causal links and processes within the catchment, but loosing coherence with the original –or at least the usual– terminology, while the second being more coherent but probably less effective in representing and communicating the territorial system and the decisional process.

The adopted solution was the second, because it was considered sound from a theoretical viewpoint to represent causal links between social and economic drivers and the state of the environment through the DPS chains, restricting thus socio-economic aspects to the origin of the chain, i.e. social indicators of driving force such as "Unemployment rate" could be included in a model assessing environmental impacts in a given territorial context. This being valid in particular for analysis conducted at broad territorial scale. With this in mind, in contrast with some interpretations of the DPSIR framework, it was also considered useful to include within D indicators non socio-economic drivers such as climate change. This solution required an expansion of the IAM environment to deal not only with D-P-S chains, but also with "within D" modelling, in the cases where the responses to be evaluated may determine dynamic processes to be modelled within the socio-economic systems. This is true once more in particular for applications conducted at broader scales where typically responses at the D level are considered, as mentioned above, in the form of new policies or regulations. Feedback effects of environmental changes in this context are possible in two ways: (i) by closing the DPSIR cycle, or (ii) by internal DPS loops. Both are coherent with the methodological framework presented herein.

A key issue from a methodological viewpoint is to guarantee the possibility of feeding decisional matrices with social, economic and environmental criteria, to allow decisions to be taken in a perspective of sustainable development. This aspect was tackled by also allowing D and P indicators to be considered as decisional factors to build the AM.

7. CONCLUSION

The DPSIR scheme proved to be sufficiently broad to allow the formalisation of the whole procedure of decision making in the context of sustainable water management, but a great deal of theoretical and methodological analyses was necessary to develop an integrated and dynamic DSS tool upon that basis. The resulting methodology and the application tool combine thus the innovative potentials of IAM and MCA approaches, with the effective communication potential of the well known DPSIR approach.

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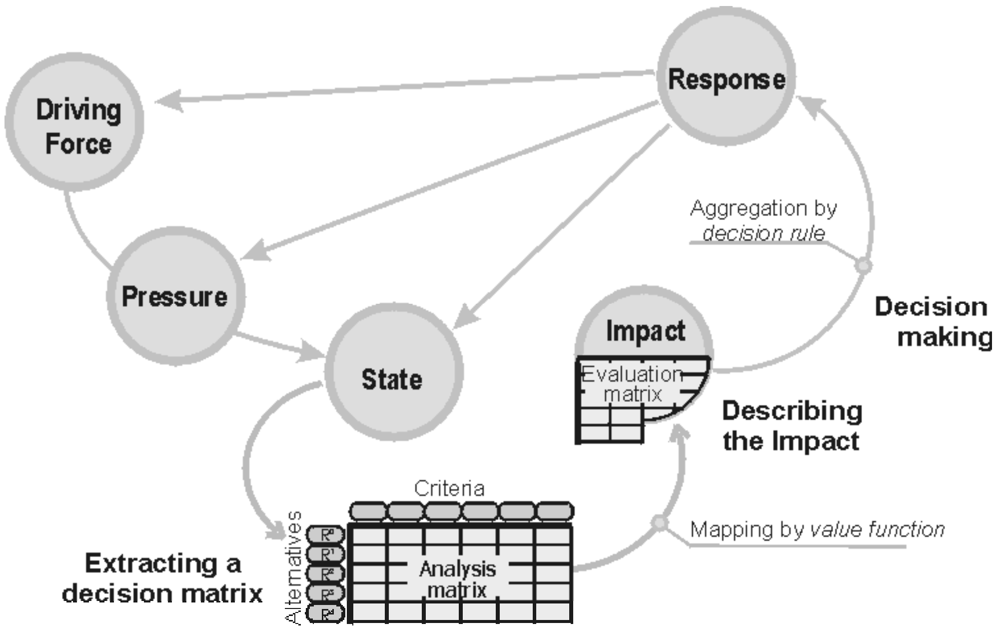

Figure 2: Multi-Criteria Analysis in the DPSIR framework