Decision Support Systems as useful and effective tools for watershed management

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1. Regulatory and frameworks for assessing and managing waters in Europe
2. Role of DSSs for the risk-based assessment and management of inland and coastal waters
3. DSSs developed by University Ca’ Foscari Venice and Consorzio Venezia Ricerche
   1. MODELKEY
   2. EQUALITY
   3. DESYCO
4. Conclusive remarks
REGULATORY FRAMEWORKS

✓ Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for Community action in the field of *water policy*;


✓ National legislations, e.g.:
  ✓ Shoreline Management Planning (SMP) in the United Kingdom
  ✓ Hazard Emergency Management (HEM) in the United States
  ✓ Groundwater Resources Management (GRM) in Bangladesh and India
REGULATORY FRAMEWORKS

River Basin and Coastal Zone Planning

Many of the problems facing the coastal zone can only be solved through an integrated approach considering different sectors (water, forestry, agriculture, urban development, environmental protection, etc.) across the land/sea (and freshwater and marine) interface.

The implementation of Integrated Coastal Zone Management (ICZM) in Europe is based on the ECOSYSTEM APPROACH preserving the integrity, functioning and sustainable management of the natural resources of both the MARINE and TERRESTRIAL components of coastal systems (2002/413/EC; ICZM, 2008).

River basins and coastal sectors are intimately linked in the ecosystem approach through their physical and ecological structure and related physical and biological processes.

The implementation of the WFD and of ICZM principles in the development of River Basin Planning will provide a new opportunity for more integrated management in estuaries, transitional waters and freshwater environment.
REGULATORY REQUIREMENTS AND ISSUES

✓ Integrated assessment strategies
✓ Definition of sustainable goals
✓ Socio-economic assessment
✓ Site characterization
✓ Assessment and management of risk
✓ Suitable technological choices
✓ Participatory and consensus-based decision-making process
✓ Consideration of different legislative frameworks
✓ Inventories of contaminated sites at the European level
✓ Standardization of procedures (common criteria for risk assessment and site management)
The decision making is the process of generating, evaluating and making choices of alternatives to solve a decision problem (Simon, 1960).

Non structured problems tend to be complex, non-routine, and difficult to define. Potential alternative solutions, objective(s) associated with solving these problems, and the relevant decision makers and stakeholders, are often not obvious. The data required to model the problem are usually not readily available.

GOALS TO BE ACHIEVED

Sustainability: considering all the involved issues in an integrated approach (environmental, social and economic aspects)

Efficiency: best use of available information

Consensus building: transparent and wide-accepted decision process, public participation
DSS is as an integrated, interactive computer system, consisting of analytical tools and information management capabilities, designed to aid decision makers in solving relatively large, unstructured problems.

( Watkins & McKinney, 2001)

DSS can be defined as computer-based tool used to support complex decision-making and problem solving

Conventional DSSs consist of components for database management, powerful modeling functions and powerful (but simple) user interface designs.

(Shim et al., 2002)
# Approaches and Tools for Decision-Making

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## Integration

**Decision Support –**

Risk-Based Decision Support Systems
BENEFITS OF USE OF DSSs

- Structured approach to problem solving
- Enhancement of effectiveness of decision process
- Summary & integration of many information sources
- Improvement of interpersonal communication, active participation and consensus building
- Identification of preferred options for further discussion
- Dealing with trade-offs: social, economic, biophysical, legislation
- Flexibility and adaptability to accommodate changes in the environment and in the decision making approach
- Promoting learning
STATE OF THE ART OF RISK BASED DSSs

470 pages, 20 chapters

53 Contributors from 6 countries in Europe and USA

Experts of DSSs, MCDA (Multi-criteria Decision Analysis), GIS (Geographic Information System), Informatics, Human Health and Ecological Risk Assessment, Indicators, Regulatory frameworks in USA and Europe

2 reviews of DSSs for land and water management

2 introductions to the problem in Europe and USA

9 analyzed DSSs for contaminated land and inland/coastal waters
STATE OF THE ART OF RISK BASED DSSs

✓ It is still an emergent topic in the field of Environmental Sciences
✓ It is highly interdisciplinary (integrating environmental and socio-economic aspects; making use of different mathematical and spatial analysis method, etc.)
✓ There are only few international conferences specifically targeted to DSSs for environmental issues (e.g. IEMSs)
✓ There have been some specialized workshops, mostly project-oriented (e.g. NoMiracle, MODELKEY)
✓ Recent review papers:


DSSs for inland and coastal waters

**GAPS**

- DSSs addressing liability issues and more integrally socio-economic aspects
- Spatial analysis
- Perception of “black boxes”

**CHALLENGES**

- Effective presentation of DSSs balancing complex/technical information with user friendly interfaces
- Active involvement of users in development
- Group decision support
- Flexibility and adaptability
- Continued operation & maintenance
- Degree of automation
- Data accuracy and quality
- Management of scale issues
DSSs developed by University Ca’ Foscari Venice and Consorzio Venezia Ricerche

✓ MODELKEY → Site-specific scale and Ecological Risk (inland waters)
✓ E-QUALITY → Site-specific scale and Ecological Risk (lagoons)
✓ DESYCO → Regional scale, Climate change impacts (coastal, inland and ground waters)

MAIN CHARACTERISTICS

• Integration of disciplines (risk assessment, socio-economic analysis, multi-criteria decision analysis)
• Variety of environmental problems assessment and management
• GIS-based
• Different case-studies application
• International partnership
• Participation of public authorities and end-users
MODELKEY

DECISION SUPPORT SYSTEM FOR THE ASSESSMENT AND EVALUATION OF IMPACTS ON AQUATIC ECOSYSTEMS

European Project under FP6

Project N. 511237-GOCE

http://www.modelkey.org
MODELKEY DSS: GENERALITIES

Objectives

✓ Assessment and classification of the overall environmental quality (i.e. both ecological and chemical status) of water bodies.

✓ Identification of the most impaired biological communities (i.e. key ecological endpoints) and of the most responsible causes of impairment (i.e. key stressors and toxicants).

✓ Prioritization of the most critical sites in need of immediate and consistent management measures (i.e. hot spots).

Methodologies

➢ Developed according to a risk-based DPSIR framework.

➢ Combination of chemical, ecotoxicological, ecological, physico-chemical and hydromorphological LoE in an extended TRIAD approach.

➢ Inclusion of a Weight of Evidence approach to support indices formulation

➢ Inclusion of MCDA methods and Fuzzy Logic to support indices calculation

➢ GIS-based integration of environmental and socio-economic perspectives for prioritization of hot spots.
Integrated Risk Assessment

PROBLEM FORMULATION

PRELIMINARY ASSESSMENT

Existing data evaluation

Environmental data
Socio-economic data

ENVIRONMENTAL STATUS AND IMPACTS ASSESSMENT

WOE
MCDA

Causes of impairment
Quality Status Index

DRIVING FORCES AND PRESSURES ANALYSIS

RRA
MCDA

Hazard Index

INTEGRATED ASSESSMENT

New data collection and evaluation

ECONOMIC ANALYSIS OF WATER USES

Market and no-market valuation methods

Socio-economic Indices
Socio-economic characterization

HOT-SPOTS SELECTION

GIS-based selection

Hot-spots

INTEGRATED ASSESSMENT

Environmental data

Causes of impairment
Quality Status Index

MANAGEMENT

monitoring

Gottardo et al.,
Sci. Tot. Env., in press
Ecological status expression of the structure and ecological function of aquatic ecosystems of superficial water bodies, classified according to the annex V of WFD.

5 QUALITY CLASSES

- HIGH
- GOOD
- MODERATE
- POOR
- BAD

3 QUALITY ELEMENTS (QE) GROUPS

- Biologic QE ➔ dominant
- Physico-chemistry and chemistry QE ➔ supporting
  - T, pH, transparency, nutrients, salinity, …
- Hydromorphology QE ➔ supporting
  - Substrate, riparian zone, flow velocity, …

Comparison with ‘reference conditions’
1. Integration process recommended by the CIS ECOSTAT wg (EC, 2005), modified by adding ecotoxicological QE and two compliance level for each supportive LOE

2. Results obtained from LOE Biology represent the input to the integration process

3. Other LOE confirm or modify the Biology LOE quality judgment

4. Final classification is expressed as probability distribution on one or two WFD status classes

Ref: Gottardo et al., Sci. Tot. Env., in press
Objective: to focus further investigation and to target remedial efforts to those sites where poor environmental conditions could compromise current or future important socio-economic uses of water resources.

GIS maps will help decision-makers in discriminating among sites/water bodies characterized by similar water quality by showing a different socio-economic usage of water resources.
MODELKEY: STRUCTURE

MODELKEY is composed of several tools that can also be connected with external resources, i.e. models, databases, GIS maps repositories.
MODELKEY DSS: OUTPUTS

SINGLE L.O.E. EVALUATION
Spatial distribution of the pie-chart representing the quality status of each site according to distinct L.o.E. (e.g. biology, chemistry)

INTEGRATED RISK ASSESSMENT
Spatial distribution of the pie-charts representing membership to WFD quality classes for each site according to 5 L.o.E.

HOT-SPOT PRIORITIZATION
Visualization of the priority level of each sites according to environmental conditions and socio-economic uses of water resources

SOCIO-ECONOMIC ASSESSMENT
Visualization of socio-economic indices for different administrative areas.
A GIS-based tool for the assessment of the environmental quality of the Lagoon of Venice
E-QUALITY: OBJECTIVES

✓ To develop a risk-based DPSIR approach based on a weight-of-evidence procedure

✓ To estimate the environmental quality of the lagoon water bodies according to the WFD, and to evaluate the relevance of the chemical contamination for ecological (i.e. biodiversity) and overall quality status, supporting management decisions

✓ To identify reference conditions for the lagoon of Venice water bodies in relation to different habitat typologies

✓ To develop a comprehensive environmental database including all parameters to characterize WFD Quality Elements and available additional data (e.g. toxicological data)
E-QUALITY: ENVIRONMENTAL DATABASE

Environmental database

Data entry from several recent monitoring projects (“studio Artista”, MELa 2 and 3, ICSEL, MAPVE1, SIOSED, HICSED, CORILA project)

- Biological parameter (Fish, algae, phytobenthos, and zoobenthos)
- Chemical parameters in different environmental matrices (metals and organics in sediment, water and biota)
- Physical-chemical parameters (nutrients, turbidity, pH, Temperature, TSS, TOC, OD, Eh, salinity and organic matter)
- Toxicological parameters (toxicological bioassay)
The risk-based DPSIR approach proposed for the lagoon of Venice supported the identification and the integrated application of assessment tools providing useful results for decision makers.

The environmental quality assessment procedure is effective to summarize data and results at different information levels (from index to QE) and spatial scales (from sampling site-scale to water body scale), avoiding the loss of information.

The selection of reference sites at local level represents a delicate step toward an environmental quality classification.
Investigation of impacts of climate change, which are:

- far reaching effects on different sectors (e.g. water, forest, agriculture, health, coasts, species);
- not uniform throughout the globe;
- may be both beneficial and adverse.

**NEED OF SUITABLE DECISION SUPPORT SYSTEMS**
DEcision support SYstem for COastal climate change impact assessment
- Provide Source-Pathway-Receptor-Consequence risk scenarios;
- Provide regional scale scenarios using the output of numerical models simulations, downscaling techniques and time series analysis;
- Transfer information about climate change impacts and risks for responding to stakeholders needs and challenges;
- Enable various stakeholders, governmental and non-governmental bodies and communities to start the implementation of appropriate adaptation actions;
- Use GIS tools to facilitate the visualization and the identification of coastal areas and receptors exposed to the risk of Climate Change;
- Provide a base for coastal zoning and land use planning considering long-term scenarios in a ICZM perspective.
The structure of DESYCO consists of 3 main components:

• A GEODATABASE with bio-physical and socio-economic data for the investigated coastal area.

• Multi-scale SCENARIOS Module, provided by numerical models simulations or time series analysis.

• A Relative Risk Model (RRM) for the application of the Regional Risk Assessment (RRA) methodology.
DESYCO: OUTPUTS

HAZARD METRICS

PATHWAY FACTORS

VULNERABILITY FACTORS

SUSCEPTIBILITY FACTORS

VALUE FACTORS

Exposure maps

Risk maps

Susceptibility maps

Value maps

Damage maps

Exposure map

Susceptibility map

Risk map

decision support tools useful to guide the impact/risk management phase.

Adapted from: http://www.adrc.or.jp/publications/Venten/HP/herath4.jpg
✓ Application of the developed DSS to inland and coastal waters located also in non-European countries in order to further develop and target it to specific end users needs.

✓ The European 7th Framework Program for Research offers good opportunities to use the results of the presented projects as a starting point for new research activities towards the Integrated Coastal Zone Management (ICZM) implementation. Specifically, main research areas for effective cooperation include:

  i) methods to improve sustainable and integrated management of coastal lagoons;

  ii) methodologies and tools for the assessment of the relevant pressures and their combined effects on water resources, including the analysis of impacts of chemical substances and pollutants in the context of environmental changes (e.g. climate changes);

✓ Cooperation can be stimulated focusing on systemic approaches for governance in the Mediterranean and Black Sea basins.
The research group at CVR and Ca’ Foscari University Venice

(www.unive.it/nqcontent.cfm?a_id=88009):

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RELEVANT PUBLICATIONS


Thank you for attention!

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