Experiences and case studies analysis on risk-based Decision Support Systems for contaminated water and land management

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DECISION PROCESS GENERALITIES

The decision making is the process of generating, evaluating and making choices of alternatives to solve a decision problem

(Simon, 1960)

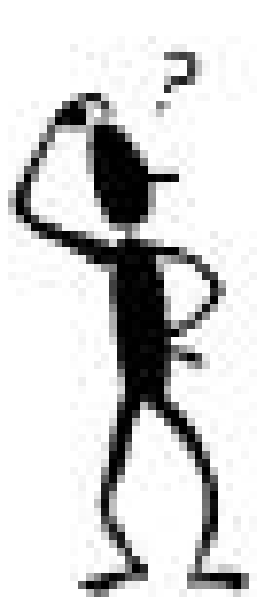
- Non structured problems, complex, non-routine, and difficult to define.
- Potential alternative solutions are often not known.
- Relevant decision makers are often not obvious.
- Data required to model the problem are usually not readily available.

GOALS TO BE ACHIEVED

Sustainability: considering all the involved issues in an integrated approach.

Efficiency: best use of available information.

Consensus building: transparent and wide-accepted decision process, public participation.



DECISION SUPPORT SYSTEMS: DEFINITION

computer-based tool that addresses integration and evaluation of economic, social and environmental information through multiple functionalities in the light of stakeholders' preferences and in a sustainable use and development perspective (Loucks, 1995; Shim et al., 2002)

A DSS can be designed that is:

- **very specific to a particular decision or component of a particular decision** (e.g., a watershed nutrient loading model built for a specific watershed, a brownfield revitalization model built for a specific industrial site)
- **a framework that allows a particular type of application** to be modeled (e.g., watershed management, site revitalization, sustainable land reuse)
- **a generic framework** for modeling any type of decision

information-based DSS

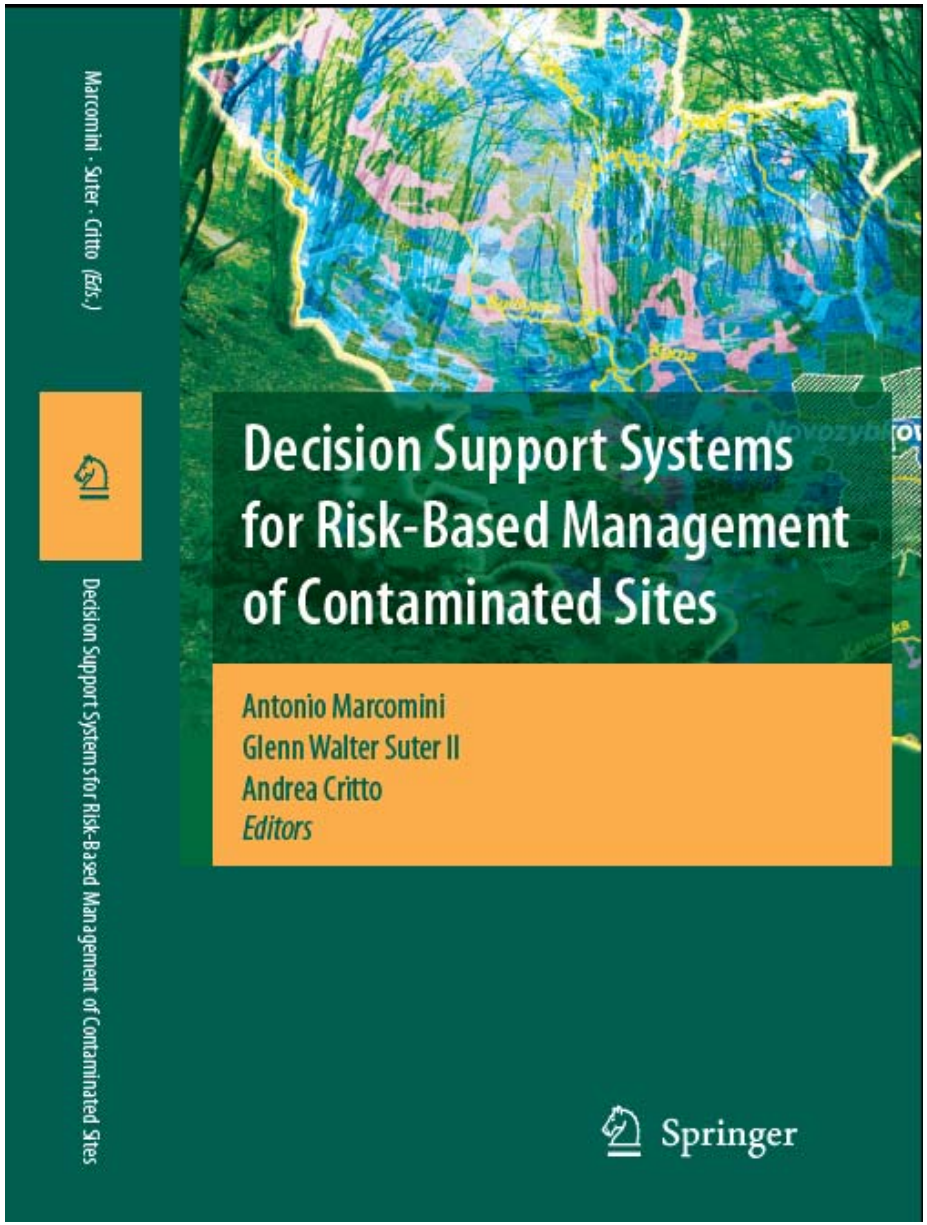
providing access to a knowledge base that contains only text, tables, and graphics

model-driven DSS

processing information to support quantitative analysis through an inference engine

Black and Stocton, *in* Marcomini et al. 2009

DSS BOOK



3 Sections:

1. STEPS AND TOOLS FOR THE DEVELOPMENT OF DSSs
2. DSSs FOR CONTAMINATED LAND MANAGEMENT
3. DSSs FOR INLAND AND COASTAL WATERS MANAGEMENT

9 analyzed DSS:

DESYRE (EU)

SMARTe (USA)

ERA-MANIA (EU)

SADA (USA)

DECERNS (USA)

MODELKEY (EU)

CADDIS (USA)

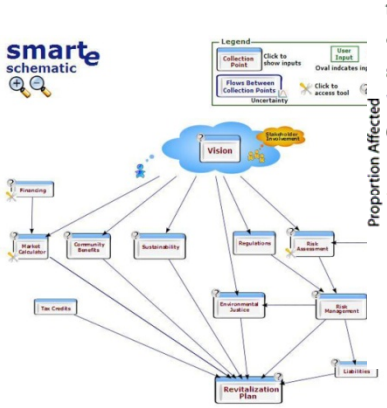
BASINS (USA)

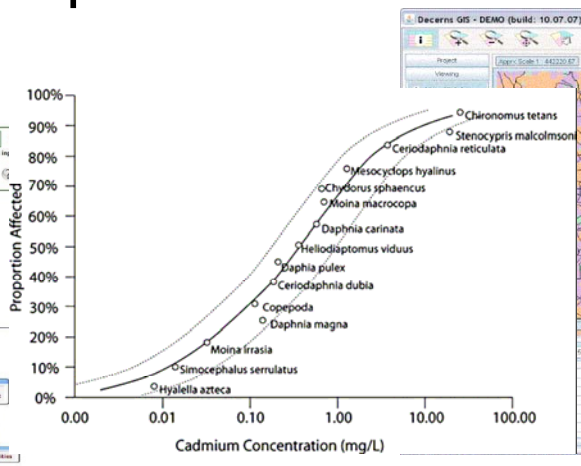
DITTY (EU)

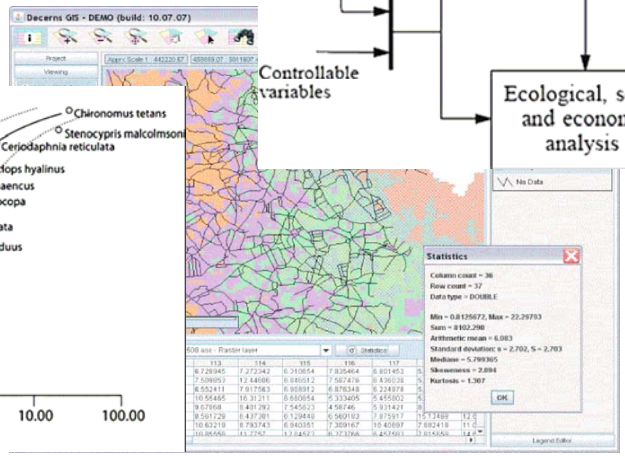
DSS BOOK

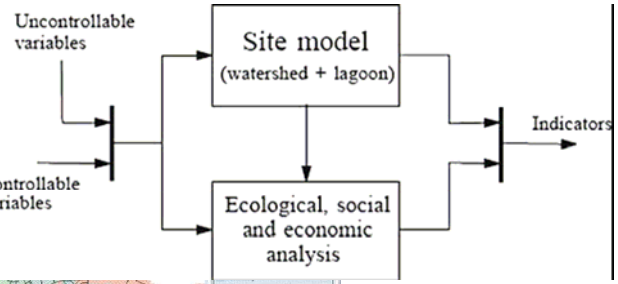
All 9 DSS are presented in the following aspects:

- ✓ Conceptual framework and main functionalities
- ✓ Structure (database management, main modeling functions, spatial applications, interfaces)
- ✓ Decision aspects and involvement of stakeholders
- ✓ Case-study application
- ✓ Future development









DSS BOOK: SECTION 2

Chapter 6
Contaminated land: a multi-dimensional problem (Carlon, Hope, Quercia)

Chapter 7
Decision support systems for contaminated land management: a review (Agostini, Critto, Semenzin, Marcomini)

Chapter 8
A Spatial Decision Support System for the Risk-based Management of Contaminated Sites: the DESYRE DSS (Pizzol, Critto, Marcomini)

Chapter 9
SMARTe: an MCDA approach to revitalize communities and restore the environment (Vega, Argus, Stockton, Black P, Black K, Stiber)

Chapter 10
DSS ERA-MANIA: decision support system for site-specific ecological risk assessment of contaminated sites (Semenzin, Critto, Rutgers, Marcomini)

Chapter 11
SADA: ecological risk-based decision support system for selective remediation (Purucker, Stewart, Welsh)

Chapter 12
Decision Evaluation for complex risk network systems (DECERNS) software tool (Sullivan, Yatsalo, Grebenkov, Linkov)

Chapter 13
Decision Support Systems (DSSs) for Contaminated Land Management – Gaps and Challenges (Agostini, Vega)

DSS BOOK: SECTION 2

Chapter 10

DSS ERA-MANIA: decision support system for site-specific ecological risk assessment of contaminated sites (Semenzin, Critto, Rutgers, Marcomini)

ERA-MANIA DSS supports the site-specific Ecological Risk Assessment (ERA) of contaminated sites in order to guide decision makers and experts in remediation actions and monitoring plans

PROJECT PARTNERS

APAT
National Environmental Protection Agency (Italy)

National Institute of Public Health and Environment (Netherlands)

Consorzio Venezia Ricerche

Project funded by the Italian Government Commissary for the rehabilitation of the Bormida Valley

ERA-MANIA: GENERALITIES

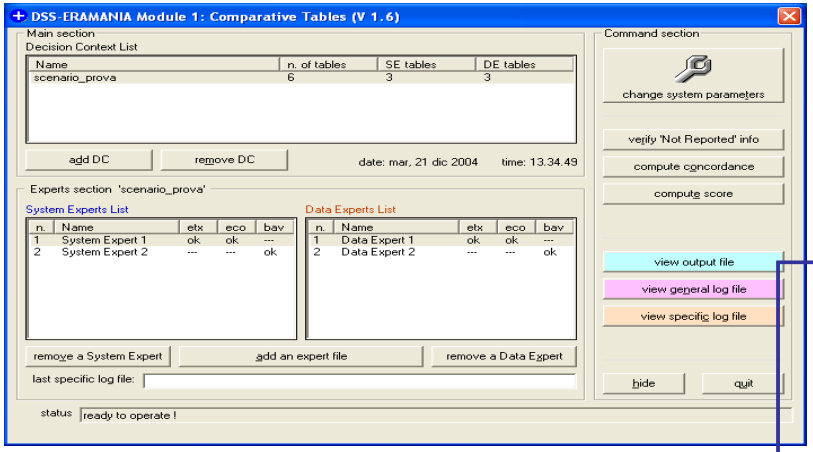
Objectives

- ✓ Selection of the most suitable set of bioavailability, ecotoxicological and ecological tests to be applied at different risk analysis tiers.
- ✓ Integrated Effect Indexes calculation.
- ✓ Quantitative and qualitative evaluation of the impairment occurring on the terrestrial ecosystem, taking into account both biodiversity and functional diversity.

Methodologies

- ➢ Based on an **integrated risk analysis tiered framework.**
- ➢ For each tier combination of **chemical, ecotoxicological and ecological Lines of Evidences (LoE) in a TRIAD approach.**
- ➢ Inclusion of **Weight of Evidence approach** to support indices formulation.
- ➢ Inclusion of **MCDA methodologies** to support indices calculation

ERA-MANIA: STRUCTURE



MODULE 1: ranking of bioavailability, ecotoxicological and ecological tests, according to their suitability for each TRIAD tier, to **select the most suitable set of tests** of each TRIAD LoE

TRIAD leg: ECOTOXICOLOGY
TIER n

TEST NAME	SCORE	COST (euro)	TIME (days)	ECOLOGICAL RELEVANCE
Test 10	0.943	20	1	99
Test 02	0.900	40	1	80
Test 23	0.888	100	1	76
Test 14	0.887	110	1	70
Test 09	0.823	120	1	78
…	…	…	…	…
Test 08	0.125	1100	14	15

MODULE 2: comprehensive (quantitative and qualitative) evaluation of the impairment occurring on the terrestrial ecosystem aggregating the different lines of evidence results to **derive integrated ecological risk indexes** which are able to characterise different risk scenarios and **support the definition of suitable remediation and monitoring plans**

EVALUATION METHOD	Ecosystem Impairment Matrix (EcoIM) evaluation																	
	Biodiversity			Functional diversity														
				Organic matter degradation			Recycle of nutrients			Soil detoxification			Water cycle			Formation of soil structure		
TRIAD legs	chem	eco	etx	chem	eco	etx	chem	eco	etx	chem	eco	etx	chem	eco	etx	chem	eco	etx
SAMPLING SITES: sample 1																		
SAMPLING SITES: sample 2																		
SAMPLING SITES: sample k																		

IEI summary module

TRIAD legs		chem		eco		etx	
		value	SD	value	SD	value	SD
SAMPLING SITES	sample 1	1.00	0.12	0.77	0.10	0.93	0.08
	sample 2	0.82	0.11	0.48	0.20	0.90	0.11
	sample k	0.34	0.07	0.74	0.01	0.55	0.09

Global impairment evaluation module

TRIAD legs		expert judgement
SAMPLING SITES	sample 1	
	sample 2	
	sample k	

ERA-MANIA: CASE-STUDY

ACNA di Cengio contaminated site, Savona province (Italy)

- one of 14 contaminated sites of national interest (Dec. 1998)
- extending over ca 550000 m^2
- production of dynamite and tri-nitrotoluene, lighting gas, chemical products (e.g. nitric acid, phenol, sulphuric acid), dyes and pigments, β-naphthol and phtalocyanine)
- for the application, reference sampling station A and the contaminated sample C were used

a. EcoIM summary sub-module

	Biodiversity				Functional diversity															
					Organic matter degradation				Recycle of nutrients				Soil detoxification				Water cycle				Formation of soil structure			
TRIAD LOE	chem tot	chem bav	eco	etx	chem tot	chem bav	eco	etx	chem tot	chem bav	eco	etx	chem tot	chem bav	eco	etx	chem tot	chem bav	eco	etx	chem tot	chem bav	eco	etx
SAMPLING SITES: site C																								

b. IEI summary sub-module

TRIAD LOE		chem tot		chem bav		eco		etx	
		value	SD	value	SD	value	SD	value	SD
SAMPLING SITES	site C	1.00	0.00	0.00	0.00	0.11	0.19	0.19	0.28

c. Global impairment evaluation sub-module

		Expert judgement
SAMPLING SITES	site C	Globally slightly impaired by soil contamination. Chemical (total concentrations) LoE discordant compared to the others. Need for investigating bioavailability of organic compounds and for completing the ecological LoE.

Main results

Module 1 allowed the **ranking of 40 ecotoxicological tests and 21 ecological observations and 14 bioavailability assessment tools** for the three considered tiers.

For Module 2, the obtained indexes, and specifically Global impairment evaluation sub-module, showed sample C to be **globally slightly impaired** compared to reference conditions A, with higher impairment for the chemical LOE compared to the others (because of low contaminants' bioavailability in soil)

DSS BOOK: SECTION 2

Chapter 11

SADA: ecological risk-based decision support system for selective remediation (Purucker, Stewart, Welsh)

U.S. Environmental Protection Agency, Athens USA

Department of Ecology and Evolutionary Biology, University of Tennessee, USA

http://www.tiem.utk.edu/~sada/download.shtml

SADA: GENERALITIES

Objectives

- ✓ Integration of the GIS with ecological risk assessment to allow the spatial visualization of data.
- ✓ Development of movement-based exposure models.
- ✓ Exposure modelling in a spatial context.
- ✓ Comparison of model results to ecological benchmarks.
- ✓ Implementation of screening-level hazard quotient (HQ) approaches.

Methodologies

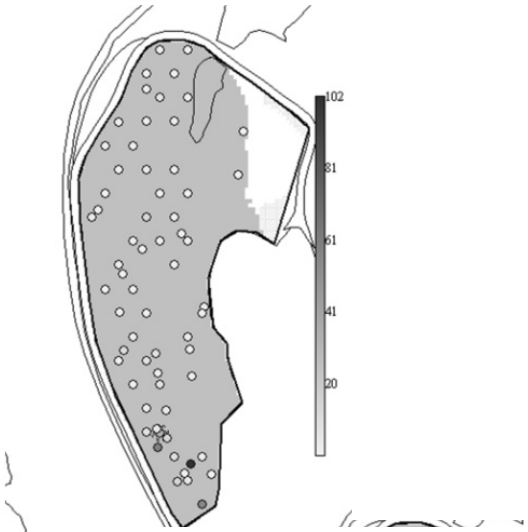
- ➢ **Terrestrial dose exposure models** to estimate the daily doses of contaminants at a site.

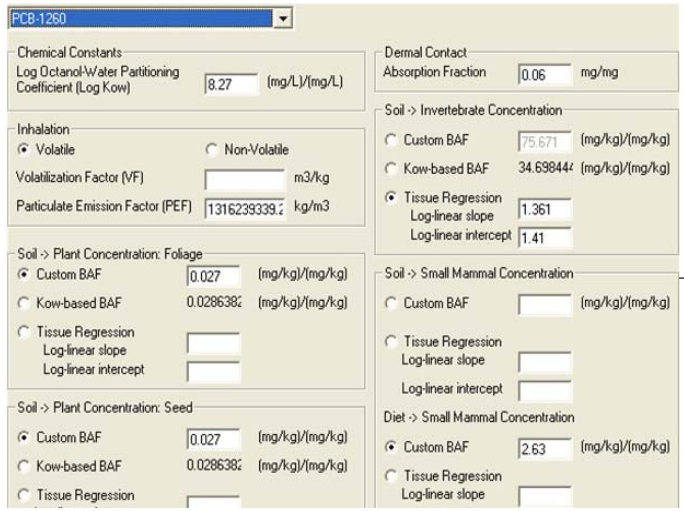
- ➢ **GIS platform**

SADA: CASE-STUDY

Powerhouse Peninsula at East Tennessee Technology Park, Roane County, Tennessee, USA

- K-770 Scrap Metal Yard less than 8 hectares
- during the 1940s an oil storage area and since the 1960s operated as a scrap facility, currently inactive
- Tens of thousands of tons of metal were stored in piles at the site, removed





Main results

SADA's spatial features allowed study of a **selective remediation design** by discretizing the site into a grid and identifying cleanup areas by remediating individual grid blocks in inverse order of risk magnitude (worst to least) until the cleanup objective

DSS BOOK: SECTION 3

Chapter 14
Use of Decision Support Systems to Address Contaminated Coastal Sediments: Experience in the United States
(Menzie, Booth, Law, von Stackelberg)

Chapter 15
Review of Decision Support Systems devoted to the management of inland and coastal waters in the European Union (Agostini, Torresan, Micheletti, Critto)

Chapter 16
MODELKEY: a decision support system for the assessment and evaluation of impacts on aquatic ecosystems
(Gottardo, Semenzin, Zabeo)

Chapter 17
CADDIS: The Causal Analysis/Diagnosis Decision Information System (Norton, Cormier, Suter, Schofield, Yuan, Shaw-Allen, Ziegler)

Chapter 18
BASINS: Better Assessment Science Integrating point & Nonpoint Sources (Kinerson, Kittle, Duda)

Chapter 19
A Decision Support System for the management of the Sacca di Goro (Italy) (Mocenni, Casini, Paoletti, Giordani, Viaroli, Comenges)

Chapter 20
Decision Support Systems (DSSs) for Inland and Coastal Waters Management – Gaps and Challenges (Semenzin, Suter)

Chapter 16

MODELKEY: a decision support system for the assessment and evaluation of impacts on aquatic ecosystems

(Gottardo, Semenzin, Zabeo)

The MODELEY project aims at developing diagnostic and predictive modeling tools as well as analytical methods generally applicable to European freshwaters and marine ecosystems to be integrated within a Decision Support System

Project N. 511237-GOCE

http://www.modelkey.org

MODELKEY: GENERALITIES

Objectives

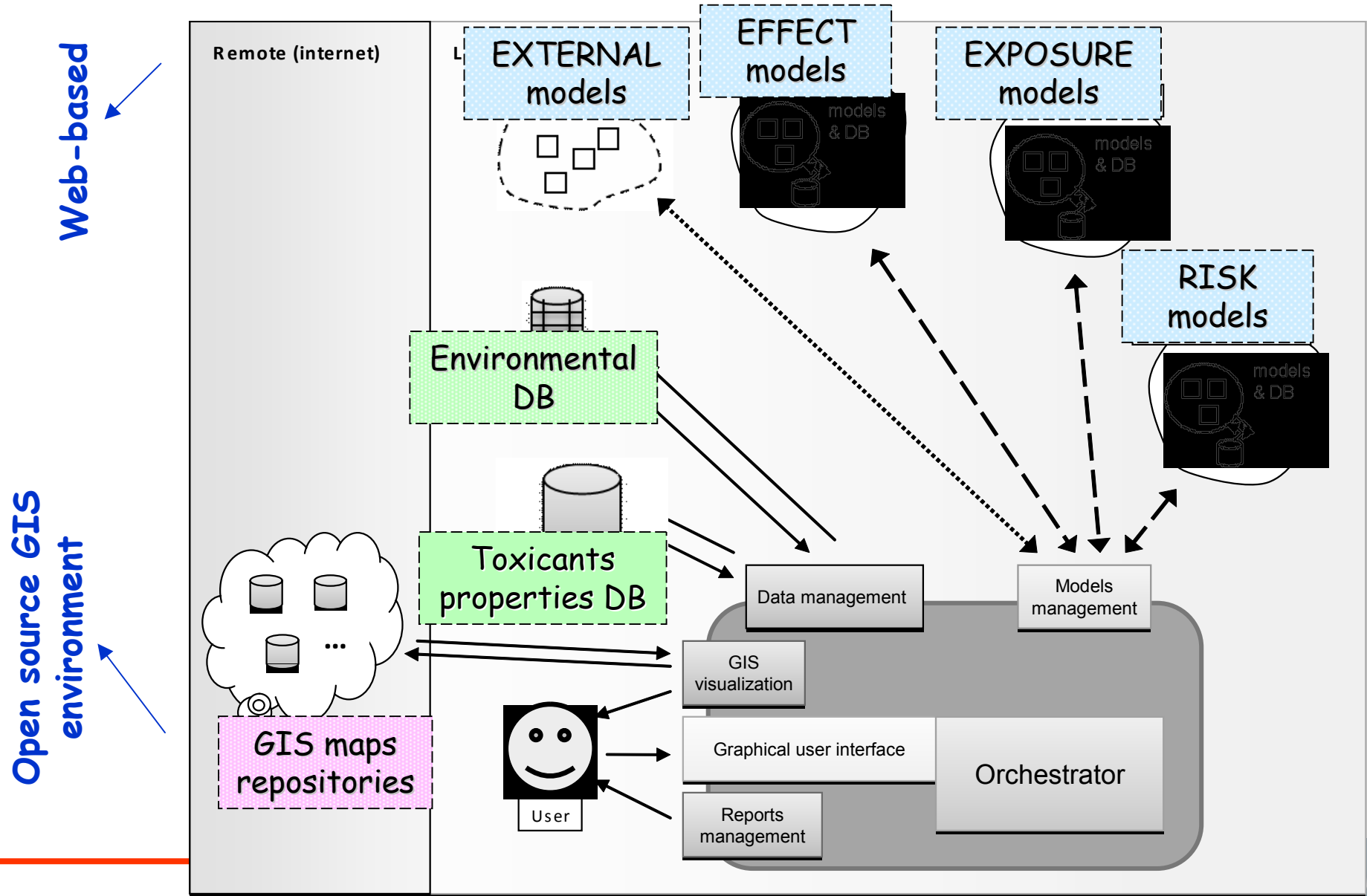
- ✓ Assessment and classification of the overall environmental quality (i.e. both ecological and chemical status) of water bodies.
- ✓ Identification of the most impaired biological communities (i.e. key ecological endpoints) and of the most responsible causes of impairment (i.e. key stressors and toxicants).
- ✓ 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.

MODELKEY: STRUCTURE

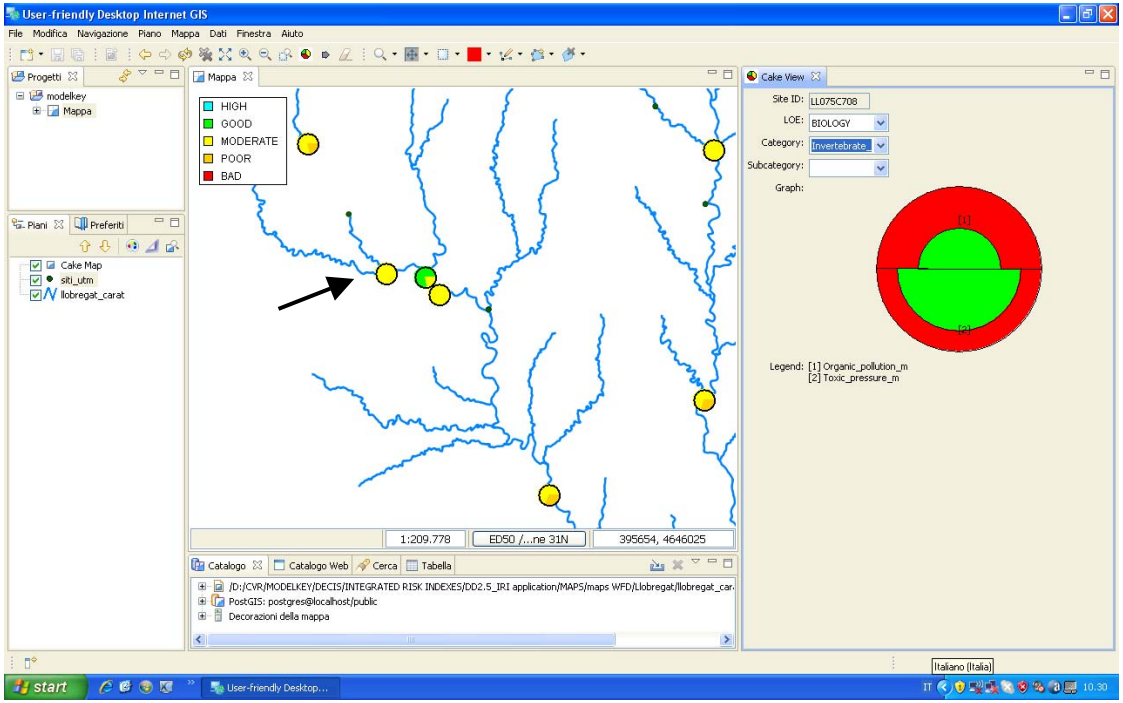
MODELKEY is composed of several tools that can also be connected with external resources, i.e. models, databases, GIS maps repositories



MODELKEY: CASE-STUDY

Scheldt (France, Belgium, The Netherlands) and Llobregat (Spain)

- one of the most complex international Pilot River Basins with long stretches canalized and a number of tributaries subjected to the tides; highly urbanized and heavily built-up
- a typical Mediterranean regime river basin, where industrial & urban waste waters as well as surface runoff from agricultural areas are main problems



MODELKEY's spatial features allowed **data analysis, indicators aggregation** and **GIS-based visualization of ecological and chemical status** in support to WFD provisions, facilitating identification of the most affected biological communities and the most responsible causes of impairment at the sampling site of interest.

Chapter 17

CADDIS: The Causal Analysis/Diagnosis Decision Information System

(Norton, Cormier, Suter, Schofield, Yuan, Shaw-Allen, Ziegler)

CADDIS is an on-line decision support system to help scientists identify the stressors responsible for undesirable biological conditions in aquatic systems

National Center for Environmental Assessment,
U.S. Environmental Protection Agency, USA

http://www.epa.gov/caddis

CADDIS: GENERALITIES

Objectives

- ✓ CADDIS is designed to help practitioners find, analyze and use information to produce causal evaluations in aquatic systems. It contains an inferential process and information needed to apply that process.
- ✓ The Step-by-Step Guide to Stressor Identification provides a formal process for making decisions about causation at specific sites

Methodologies

- ➢ A series of **conceptual models** illustrates connections between sources, stressors and effects.
- ➢ Other tools are used for analyzing data and interpreting results as causal evidence. Practitioners are guided through fifteen different types of evidence.
- ➢ A consistent **system for scoring the evidence**, through assignment of up to three plusses (+++) or minuses (---) for strongly supportive or extremely weakening evidence, respectively.

CADDIS: CASE-STUDY

Little Scioto River, Ohio, USA

- a 15-km reach of a river in north-central Ohio
- many point and non-point sources of pollutants, including a wastewater treatment plant and runoff from agricultural land uses and from the city of Marion, and from several contaminated industrial,including an abandoned wood treatment plant, a landfill, an appliance plant, and a rail facility

Candidate Cause	Result	Score
Sediment	Elevated sediment co-occurs with impairment	+
Pool/riffle	Poor pool/riffle condition co-occurs with impairment	+
Dissolved oxygen	Reduced DO co-occurs with impairment	+
Ammonia	Elevated ammonia not detected at site	---
Metals	Elevated metals concentrations observed at impairment	+
PAHs	Elevated PAHs not detected at Site A	**R**

Main results

Three general geographical segments were separately considered—upper, middle, and lower—based on the biological conditions and causal analysis results. The upper section was impaired by channelization and associated stressors, the middle section was extensively contaminated from a wood treatment site, and the lower part was affected by all of the upstream contaminants and metals.

CONCLUSIONS

Chapter 13

Decision Support Systems (DSSs) for Contaminated Land Management – Gaps and Challenges (Agostini, Vega)

Chapter 20

Decision Support Systems (DSSs) for Inland and Coastal Waters Management – Gaps and Challenges (Semenzin, Suter)

GAPS

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

CHALLENGES

- Effective presentation of DSS 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

Thank you for attention!

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