EnviroInfo 2007 (Warschau)
Environmental Informatics and Systems Research
 ISBN: 978-3-8322-6397-3

DECERNS: Methodology and Software for Risk-Based Land Use Planning and Decision Support

Alexandre Grebenkov[1], Boris Yatsalo[2], Terry Sullivan[3], Igor Linkov[4]

Abstract

Decisions for environmental contamination problems are often complex due to the need to incorporate many differing measures and views. Strategies to support these decisions with a more systematic framework have evolved along with the development of computer capabilities and analytical tools. The decision process often involves incorporating subjective judgment that reflects public and stakeholder values, while also accounting for cost-benefit, toxicological health risk, and ecological risk assessment methods, along with methods to combine each of these measures. DECERNS (Decision Evaluation for Complex Environmental Risk Network Systems) has been developed as integrated decision support software for environmental problems. This tool combines multi-criteria decision analysis (MCDA) with geographic information system (GIS) components to frame practical solutions. By also incorporating cost/benefit and risk assessment tools into a common web-based platform, DECERNS permits an integrated analysis that frames effective environmental decision making.

1. Introduction

Environmental decision-making strategies over the last several decades have evolved into increasingly sophisticated approaches including expert judgment, cost-benefit analysis, toxicological risk assessment, comparative risk assessment, and many methods for incorporating public and stakeholder values. This evolution has led to an improved array of decision-making aides, including development of Multi-Criteria Decision Analysis (MCDA) tools that offer a scientifically sound decision analytical framework.

The existence of different MCDA methods and the availability of corresponding MCDA and Geographic Information Systems (GIS) tools both contribute to the possibility of practical implementation of these approaches/methods when investigating environmental problems. The objective of the DECERNS project is to develop the methodology, computer models and software tools that would facilitate the defensible, reproducible decision-making in the field of remediation and sustainable land use. This collaborative international project is funded by the U.S. Department of Energy (DOE) Initiatives for Proliferation Prevention (IPP) program.

2. Framework and Approaches

There are many tools in the western market and, to a lesser extent, in the former Soviet Union for evaluation of remediation alternatives based on a degree of human health risk, ecological risk and environmental quality. This study is to analyze these techniques, and develop a new one, which unites a wide range of ecological impact and land reuse scenarios in an integrated tool that evaluates decision criteria for many purposes, e.g., minimum damage to the environment, minimum risk for population health, minimum cost, and optimum land reuse.

[1] Joint Institute for Power and Nuclear Research, Minsk, Belarus.
[2] Obninsk State Technical University of Nuclear Power Engineering, Obninsk, Russia.
[3] Brookhaven National Laboratory, Long Island, New York, USA.
[4] Intertox, Cambridge, Massachusetts, USA.

The software will have the following major elements of a Spatial Decision Support System (SDSS): (i) several MCDA methods for defensible and sound decision-making support, this will include tools to incorporate value judgments in the decision process; (ii) a software tools with with basic and advanced GIS functions for spatial information analysis; (iii) environmental risk assessment models for ecological and human health; and (iv) cost-benefit or least-cost analysis tools (CBA) (.

The *DECERNS SDSS* being developed is considered as an MCDA-oriented SDSS (in spite of other existing SDSS which are mainly GIS-oriented systems). The basic MCDA methods (MAVT/MAUT, AHP, Promethe, and some others) are incorporated into MCDA subsistem, including possibility for sensitivity/uncertainty analysis, and both individual and group decision analysis.

Decision-making support is provided through presentation to the experts all necessary and required information about the territory under consideration (e.g., monitoring data, model assessments, and supplemental information) in the form of electronic maps, diagrams and tables, with implementation of CBA and MCDA methods. The tool will take into account different preferences expressed by stakeholders, experts and decision-makers, and will output information in a form to aid in decision making. GIS subsystem within the *DECERNS SDSS* allows examining a variety of decision-making tasks associated with spatial (geographic) information analysis and processing. Such tasks can often be found amongst those related to environmental protection, nature biodiversity conservation, improvement of endangered species habitat, sustainable land management and development, remediation of contaminated territories, and planning sustainable or optimal use of natural resources.

The software will contain a number of models (existing and new) that use different methods of environmental risk assessment, ranking of territories and environmental objects as to environmental value, techniques for remediation/rehabilitation of contaminated/disturbed territories, etc. For example, the models will cover (but will not be limited to) the following tasks:

(i) Contaminant migration in the environment;
(ii) Risk assessment for environmental receptors (human and animal) populations and communities in view of time and spatial factors and taking into account the behavior of a population and individuals (Linkov et al, 2002; Grebenkov et al, 2002; Linkov et al, 2004; Yatsalo and Bardos, 2002);
(iii) Evaluation of environmental value (environmental quality) of their habitats and ranking of territories using this parameter (Grebenkov et al, 2006); and
(iv) Evaluation of social and economic acceptability of proposed alternative analysis/ land use options (Yatsalo et al, 2007; Yatsalo, 2007; Grebenkov and Yakushau, 2007).

3. DECERNS Project Progress

Development of the *DECERNS SDSS* is based on the experience of Web-version of the *PRANA DSS* creation (Yatsalo et al, 1997; Yatsalo, 2007).

DECERNS SDSS is developed on the basis of Java technologies as a distributed application constructed on the classical three-tier architecture (information layer – application layer – client layer). This SDSS is considered as a mixed client and server application.

The information tier is operated through the DBMS (Database Management System) Interbase Firebird v.1.5. This DBMS has been chosen for several reasons, and the most important ones are availability, reliability and simplicity.

The application tier is located on the server. The key components of the application tier are: Model Block, Scenario Management Block, Data Representation Block, and Decision-Making Support Block.

The client tier is presented by a set of *html* pages, *java* applets and JavaScript modules that implement the user interface of the system. The structure of the user interface logically corresponds to the following (simplified) scheme: authorization – choice of the object(s) for subsequent analysis – assignment of the

evaluation criteria and alternatives – calculation – presentation and analysis of the results (as a step within decision making support). For high-grade work with the system on the user side it is necessary to use a web-browser with frame support and Java(TM) Plug-in v.1.4.2 installed.

The current *DECERNS SDSS* version includes MCDA subsystem (MAVT, AHP and Promethee methods, with extended possibility for sensitivity analysis to changing both criteria weights and value functions) and GIS subsistems with all basic and some advanced functions for spatial data processing and analysis (both for vector and raster maps).

A bridge for heterogeneous modular structure realization (taking into account implementation of various computer models) is built as a .NET-Java bridge software. This allows the use of previously developed and successfully realized models and existing codes, and creates robust computer programs through simultaneously using various existing software technologies. A bridge product architecture that places the bridge function on the client side preserves the existing Java software that resides in the client code. Through proper implementation, bridge architecture fulfills all of the interoperability requirements.

The following preliminary results have been achieved on the basis of developed models: (i) development of the territory ranking methods based on habitat quality evaluation, (ii) development of the more precise and efficient environmental risk assessment models for biota, which take into account spatially-explicit factors and temporal scale for different stressors and receptors, and (iii) improvement of the methods of multi-attribute strategic planning of remedial measures, which take into account ecological-economic parameters and utilizes GIS applications.

4. Next Steps

Insights gained from a number of remediation projects are being incorporated into the development of the *DECERNS* software to help direct experts through a systematic process that integrates many factors involved in environmental restoration decisions including human health, ecological resources and values, and socio-economic aspects. The ongoing project involves incorporating methods, models and databases developed into this cutting-edge software product with a user-friendly interface installed in a Web server.

Bibliography

Grebenkov, A., I. Linkov, G. Zibold, A. Andrizhievski, and V. Baitchorov (2002): Approaches to Spatially-Explicit Exposure Modeling and Model Validation / Radioactivity in the Environment, IUR, 1-5 September, Monaco, 2002.

Grebenkov, A., Lukashevich, A., Linkov, I., Kapustka, L. (2006): A Habitat Suitability Evaluation Technique and its Application to Environmental Risk Assessment/Ecotoxicology, Ecological Risk Assessment and Multiple Stressors, NATO Science Series IV: Earth and Environmental Series, – Vol. 6, Springer

Grebenkov, A., Yakushau, A. (2007): Ranking of Available Countermeasures Using MCDA Applied to Contaminated Environment / Proc. of NATO ARW, April 12-20, 2005, Greece, Thessalonici. – NATO Science Series, Series IV: Earth and Environmental Series,– (in press).

Linkov, I., A. Grebenkov, and V. Baitchorov, (2002): Spatially Explicit Exposure Models: Application to Military Sites / Journal of Toxicology and Industrial Health, 17

Linkov, I., A. Varghese, A. Grebenkov, A. Andrizhievski, A. Lukashevich, A. Trifonov, and L. Kapustka, (2004): Incorporating Habitat Characterization into Risk-Trace Software for Spatially Explicit Exposure Assessment / Comparative Risk Assessment and Environmental Decision Making, NATO Science Series IV, - Vol. 6, Kluwer Academic Publishers.

Yatsalo, B., O.Mirzeabassov, I. Okhrimenko, I. Pichugina, B. Kulagin (1997): PRANA - Decision Support System for Assessment of Countermeasure Strategy in the Long-term Period of

Liquidation of the Consequences of a Nuclear Accident (Agrosphere) - Radiat. Prot. Dosim., 73, 1-4: 291-294.

Yatsalo, B., and P. Bardos (2002): Decision Support on Risk Based Land Management and Sustainable Rehabilitation of Radioactively Contaminated Territories / Radioprotection – Colloques, 37, C1: 1087-1092.

Yatsalo B.I., Kiker G.A., Kim J., Bridges T.S., Seager T.P., Gardner K., Satterstrom F.K., Linkov I. (2007): Application of Multicriteria Decision Analysis Tools to two Contaminated Sediment Case Studies. - Integrated Environmental Assessment and Management, 3(2): 223-233.

Yatsalo B.I. (2007): Decision Support System for Risk Based Land Management and Rehabilitation of Radioactively Contaminated Territories: PRANA approach**. -** Int. J. Emergency Management, 4(3): 504-523.