EnviroInfo 2001: Sustainability in the Information Society

A system representation and evaluation model based on object-oriented design

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Abstract

Real environmental problems cannot be simply solved by system modelling. On the one hand, an evaluation under several perspectives is necessary, for instance by different agents. But, on the other hand, evaluations, such as multi-criteria evaluations, cannot rely simply on information about the values and priorities of the agents. Reliable evaluations, which may be shared by several agents, have to rely on system knowledge and its proper representation. This is even true for the evaluation by scientific experts, who discuss both the underlying (uncertain) system knowledge and the applicable evaluation criteria. Therefore an evaluation model must be related to a flexible system representation, which is capable to change and improvement, and a corresponding set of evaluation criteria, which can be interactively tested, improved and completed. The object-oriented design consists of

- A hierarchy of system objects
- An evaluation object and its inheritors and
- A corresponding interface.

The system representation inherits the land use, soil, and plant properties to the land object, which is going to be evaluated. The evaluator object has several groups of criteria (social, economic, and ecological). The methods include the presentation of the land system, its remediation based on the system specification and the available knowledge, the acquisition of the system knowledge by the evaluator, the acquisition of values and priorities, and the preliminary evaluation. The main task is the analysis of the evaluation, which continuously leads to a refinement of the preliminary evaluation until a further refinement of the system representation is necessary or until the evaluation is considered final.

A Java implementation of the System Representation and Evaluation Model (SREM) is presented for the evaluation of remediation options for soil contaminations with heavy metals Cadmium, Zinc, and Copper. The SREM is not merely another soil evaluation model, which are numerously available, but a prototype of an evaluation tool, which can be used for practical evaluation tasks, because it combines the structural aspects (system

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representation and a hierarchy of evaluation criteria) and the procedural aspects (interface of the representation and evaluation objects) of evaluation.

Goal and Scope

Evaluation is a very crucial issue for environmental planning and management. Many times there is a question, how to combine scientific knowledge and practical management. This relates to the fact, that evaluation and decision models from managerial science in general do not include specific system representation models. As prescriptive approaches only intuition, linear rules, bootstrapping, decision support systems, mathematical programming, and decision-analysis are included (Kleindorfer, Kunreuther, & Schoemaker, 1993). Perhaps one expects too much when requesting such a general evaluation model. But it is worth considering a formal evaluation tool for an important example of evaluations, namely the environmental evaluation of soil remediation alternatives for heavy metal contaminated soils.

A simple methodology to represent real objects in a formative procedure can be found in computer science: the object model (see, for example, Booch, 1991). Hence this model is investigated whether it is appropriate for the formative system representation used in the above-specified evaluations. As an example to illustrate the advantages, the evaluation of different remediation methods to reduce heavy metal content in soils is used.

Methods

A formative evaluation model is a two level model. On the first level it is a model for the evaluators' process of evaluation, which is a model for a task of mind. On the second level, within the process model, the evaluator employs a model of his environment, which is a model of physical reality (Tietje, Scholz, Heitzer, & Weber, 1998).

My formative evaluation model is called *value agent*, which is a – prescriptive or descriptive – model for someone who evaluates. Value agents are (sometimes non-) autonomous, reactive and proactive agents for the control of dynamic systems. But one has to be aware, that the *value agent* in its current state presented here is not more than a prototypical model, a constructed representation of a system. A validation of this model is hardly possible, an indication for that can be, if several individuals do an evaluation applying this concept and if they are some sort of satisfied with this evaluation. This will be left for further investigation. Please note that a valuation model will never be unique. But a knowledge basis, which consists of a specific system representation and an evaluation model, might be capable to realize

a large number of individual evaluations, at least in the field of environmental evaluation.

In Switzerland, large areas are contaminated with heavy metals. The investigated region mainly exhibits heavy metal concentrations of Cadmium, Copper, and Zinc (see Table 1). Several remediation options are still being discussed: soil exchange, phytoremediation, mobilization, immobilization, or a combination. An evaluation tool is, for example, available on http://www.phytomine.co.nz/, but it is not for a specific evaluation by an owner rather than specifically for the assessment of phytoremediation and for soil experts and consultants, who have to give a recommendation to phytoremediate or not.

	Cd	Cu	Zn
Geometric mean	0.93	88.91	232.86
Geometric stdev	2.22	3.62	2.39

Table 1: Geometric mean and standard deviation (Limpert et al., 2000) of Cadmium, Copper, and Zinc within the investigated region (data from Geiger & Schulin, 1992).

Due to (Kleindorfer et al., 1993) the context of an evaluation, the identification of the problem, the problem solving options and the legitimation of valuation are specifically important. This renders the current evaluation task difficult:

- Context: The role of the causer and the administration remains unclear, because it is not known, how they treat the problem exactly.
- Problem finding: The identification of the problem is difficult, because individuals have their own evaluation model, their own risk acceptance and their own system representation (model),which to a large extent determines the problem finding.
- Problem solution: The variants of phytoremediation are still under development. A large part of those, who have to evaluate, have not not yet developed the values which guide the treatment of ecological and human health risks.
- Legitimation: The consequences of the choice of an remediation procedure for other evaluators or regional stakeholder remain unknown.
- Therefore any help in structuring the system and its evaluation is greatly appreciated.

Results and Conclusions

The system representation consists of an activity model (in this case consisting of different land uses) and an inventory (in this case the material fluxes into or from the soil). The evaluation model is a procedural model including:

- The selection of criteria
- The evaluation of criteria
- The definition of utility
- The definition of weights
- The definition of the composition
- The estimation of sensitivities, biases, fallacies, double counting

The *value agent* conducts this evaluation. He might take the role of the causer, the administration, remediation companies, public, consultants, or the concerned people. The interface between the activities, the soil inventory variables, and the evaluation criteria is a matrix. This matrix contains for each activity the resulting material fluxes in soil and the resulting levels of the selected evaluation criteria.

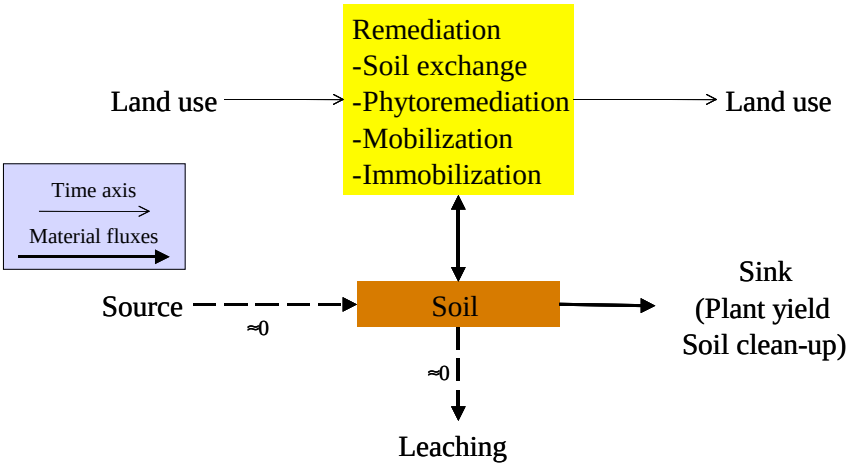

Figure 1 System representation divided into the *activity model* (land use) and the *inventory* (material fluxes in soil).

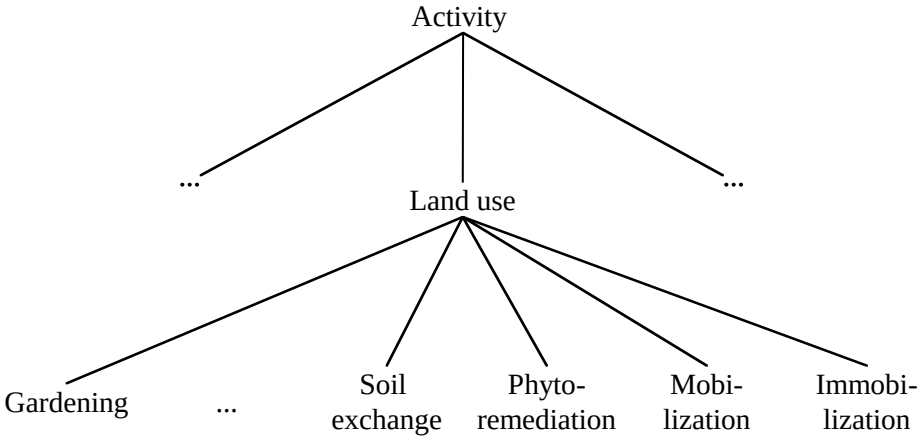

Figure 2: Object hierarchy of the activities. For the ordinary land uses on the left only the example of gardening is given. Of course other activities than land use could be elaborated.

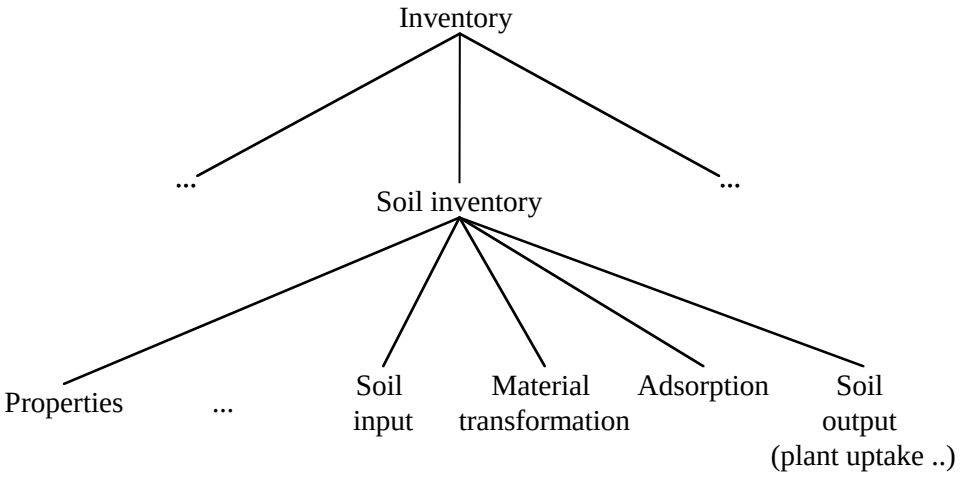

Figure 3: Object hierarchy of the inventory. The soil properties are indicated on the eft, on the right the remediation options result in specific matrial fluxes in the soil. Of course, other inventories than soil inventories can be elaborated.

The *value agent* exists currently only as a prototypical model. Therefore the resulting evaluation cannot be shown yet. But the object orientation induces thinking in small cognitive units, which are related to the environment of the agent (cognitons,

see Ferber, 1999). Therefore the object-oriented system representation and evaluation has lead to a robust structure, which is an appropriate basis for a database of evaluation criteria.

Recommendations and Outlook

The evaluation of heavy metal remediation measures is still an uncertain task shaped by individual knowledge and preferences. The discussion of quantitative evaluation criteria and their use and combination for an integral evaluation can be supported by their formal and intentional characterization within the object hierarchies presented. Probably the choice of alternatives by individuals or groups can be enhanced. The objective is to leave the evaluator with the most flexible presentation of criteria but with the most reliable and criteria related information. The evaluator should be able to adapt the criteria to his own thinking as flexible as possible. At the same time he shall be provided by the relevant information on the case.

The system representation and evaluation model will be further elaborated within the concept of *value agent system dynamics*.

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