From models to indicators: Ontology as a knowledge representation system

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Introduction

Evaluation of policies requires targeted and systematic approaches to assess their economical, environmental and social impacts at a wide range of scales. Integrated Assessment and Modelling (IAM) (Parker *et al.*, 2002) has been proposed as a method to *ex-ante* assess indicators for such policy impact assessment. In IAM these indicators have to be linked to model outputs and to user-relevant concepts, like scale and indicator framework and dimension.

Among the various IAM tools currently developed, SEAMLESS-IF has been built as a joint effort of thirty partners and their researchers (ca 150), each of them providing specific knowledge in his own discipline (Van Ittersum *et al.*, 2008). In the course of such tool development crossbreeding between different scientific knowledge is necessary as each discipline uses with its own way notions and concepts that sound similar, like resource efficiency, profitability, productivity, environmental soundness or social viability. For IAM projects, no explicit procedure was found in literature to homogenize meaning across concepts, scales and disciplines. To solve this problem of multitude of meanings for indicators and the related concepts, the SEAMLESS project developed an indicator ontology i.e. a finite list of concepts and the relationships between these concepts. This indicator ontology shared by all scientists from various disciplines and backgrounds working on an integration task, serves as a knowledge-level specification of the joint conceptualization (for more information on the ontology concept and objectives see Janssen *et al.*, 2009) and enabled implementing indicators in the IAM platform. The ontology supports and facilitates the communication of complex concepts needed to define, present, compute and displays social, economical and environmental indicators at the wide range of scales investigated by SEAMLESS-IF. This paper describes the ontology for indicators as developed in the SEAMLESS project and the process of ontology development.

Methods

Impact indicators in SEAMLESS are primarily based on modelling chain outputs. The development of such indicators necessitated a strong iterative and structured interaction between indicators, database, models and software developers as well as tool evaluators. The indicator development and implementation work started from a literature study on sustainability indicators and frameworks, evolved through the development of the indicator ontology, the definition of indicators that can be computed by the SEAMLESS modelling chains and the needed scaling procedures and other post-modelling processing. It resulted in implementing the SEAMLESS indicator tools offering all the services necessary to manipulate impact indicators for policy impact assessment focusing on the agricultural systems. The developed work steps were accompanied by a cyclical evaluation-improvement procedure involving most of the different type of developers.

Results and discussion

The specific SEAMLESS indicator ontology allows:

- To define ‘Indicator Group’ i.e. an indicator impact-oriented family grouping together a set of indicators providing information on the same impact but at different scales (Bockstaller *et al.*, 2009). This indicator group allows highlighting links between indicators presenting

different spatial and/or temporal extents but providing information on the same process (e.g., the nitrate leaching group brings together the Nitrate leaching in kg N-NO_3 ha^{-1} y^{-1} at field and farm level and the share of the area with nitrate leaching over a given threshold computed at landscape or regional level).
- For each indicator group to have a specific link to an indicator group fact sheet describing all the characteristics of the indicators (purpose, impact, described processes, scales, detailed description of calculation, information needed for interpretation, possibilities of up-scaling/aggregation and evaluation of the indicator).
- To establish the location within the so called Goal Oriented Framework (GOF) of each indicator (Alkan Olsson *et al.*, 2009). The GOF aims at guiding the user in the selection of indicators, preventing him from focusing on a single issue, and facilitating the communication between researchers and policy experts related to different sustainability dimensions.
- To define thresholds as reference value to interpret the indicator value.
- To highlight indicator tradeoff i.e. a relation of antagonism between different indicators.
- To define the model output used to compute the indicator and by this way the functional link between indicator and the modelling chains.
- To identify the list of intermediate variable of the modelling chain necessary to interpret and understand the causality chain lying behind the indicator values.
- To describe the spatial and temporal resolution and extent of each indicator (i.e the investigated process scales and the policy decision scales).

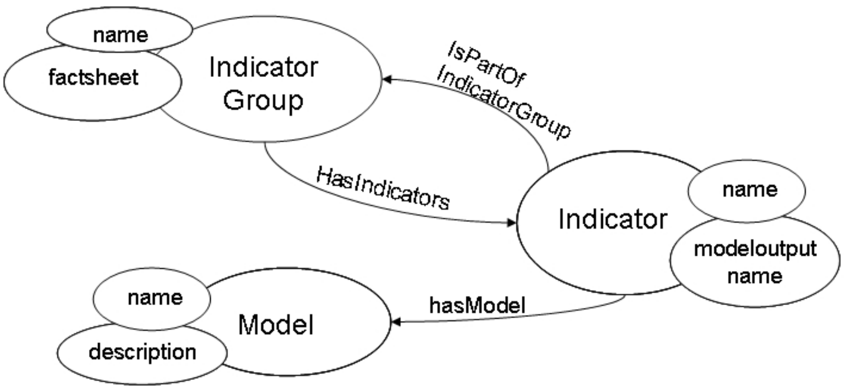

Figure 1. the concepts IndicatorGroup, Indicator and Model (large ellipses), with some of the attributes (small ellipses) and the relationships between them (arrows with name).

There are many indicators databases around the world[1] where indicator ontologies include metadata and semantic interoperability between the various indicators. The main specificity of the SEAMLESS indicator ontology is to allow implementing sustainability indicators in an IAM platform. This ontology structures all the knowledge and data in relation to indicators, so that an indicator, in a transparent and explicit way, can be linked to the relevant modelling chain outputs, be selected, assessed and displayed using the specific IAM tools and be enriched with all the user-oriented information necessary to perform well qualified policy impact assessment. The indicator ontology is a separate product of the SEAMLESS research project and can now be reused in other research projects working with indicators and models.

Reference:

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[1] For a recent survey and an operationalized ontology, see http://www.sdi.gov/