Linking Environmental Data Models to Ecosystem Services' Indicators for Strategic Decision Making

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Abstract: The quality of decision making mostly correlates with the quality of source data and data models. Aims of the decision making influence the decisions. In its turn, the sustainable land management is to ensure the growing of the humanity in a confined space without negative consequences to the environment and future generation. Uniting the existing environmental data models with Ecosystem Services assessment practices makes it possible to build Information System that supports decision making for territory planning specialists. The architecture of this Information System partially will be based on the Web Services technologies, which ensure the accessibility of input data from many sources/stakeholders and provides the availability of the output data in any stage of distributed decision making process's step. The purpose of the research is to highlight processes which make it possible to link the data from environmental data models with Ecosystem Services indicators. The task is to formulate proposal for facilitating data exchange process in distributed strategic decision making information systems for land management. This allows making Ecosystem Services' (Human benefits) assessment as an input using existing standardized (ISO/INSPIRE) and machine-readable (XML) data. Moreover, these assessments ensure feedback for strategic/sustainable land management which is based on distributed decision making.

1 INTRODUCTION

Most countries are building national data infrastructures, including spatial data infrastructures (SDI). In Europe, this infrastructure is being built using united regulations for all EU countries (EU Directive, 2007). Technical regulations are described in '*Implementing rules*', where United Data model is introduced. Information about data specification is available in '*Technical guidelines*' as Data specification for each theme and is available as:

- human readable text in Feature catalogue;
- diagram in Unified Modelling Language (UML);
- and in machine readable format – as Extensible Markup Language (XML) schemas (XSD) in schema repository (https://inspire.ec.europa.eu/schemas). These schemas can be used by any data holder to harmonize/reclassify own data.

This standardized and decentralized approach ensures efficient information exchange between stakeholders, including decision makers.

On the other hand, the idea from "Brundtland's" report about sustainable land development strategy, where the mankind must evolve with a perspective for the future, using resources in a way that does not negatively affect future generations (UN, 1987) receives recognition. Sustainable land development models gain popularity; there is implemented land development strategy that tries to decrease negative impact on human well-being in long term. Ecosystem Services (ES) approach helps us to classify and valuate nature phenomena and helps us understand – how our decisions affect the ecosystem. ES approach is just one of the hundreds of possibilities to describe the real world. The world where Economy exists only within Society, and Society within Biosphere (Environment) – Humanity and our economy depends on the environment (Folke et al., 2016). Planning the future, it is necessary to take this into account. Basics of ES are clearly described in 'Ecosystem and Human Well-being: Synthesis' – Ecosystem Services are potential gains or losses which a person can receive from ecosystem, while ecosystem – is a plant, animal and microorganism dynamic interaction with inanimate

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objects like soil, terrain, weather conditions. Ecosystems can be divided in two major categories: subsistence ecosystems – not affected or almost not affected by human and modified ecosystems, which are intensively managed by human like agricultural land or urban areas and four sub-categories: provisioning services, regulating services, cultural services supporting services so-called as ecosystem functions (Ecosystems and human well-being, 2005; Holms et al., 2017).

Sustainable land development is an iterative process. The article highlights the possibility to link the data from INSPIRE data themes or similar SDI to ES Indicators. This can significantly facilitate ES Indicator's assessment. Comparison of ES indicators' assessments between land development iterations helps to make strategical decision about direction of development in the next iterations.

In the background of other author's works, which are related to application solutions of spatial data infrastructure, idea of linking environmental data models to ecosystem service's indicators, seemed perspective to the authors, including for strategic decision making.

2 MATERIALS, PROCESSES AND CLASSIFICATIONS

To express values of ecosystem functions, concept of ecosystem services is increasingly used (Bennett et al., 2015). According Braat and de Groot (Braat and de Groot, 2012) there are ecological and economics roots of ES concept.

Figure 1 shows how alternative development plans are used for each new iteration in decision-making. This correlates with Patton's '*The Classical Rational Problem-Solving Process*': 1) Define the Problem, 2) Determine Evaluation Criteria, 3) Identify Alternative Policies, 4) Evaluate Alternative Policies, 5) Select the Preferred Policy, 6) Implement the Preferred Policy (Patton et al., 2013).

Information for decision-making can be harvested in automated way using SDI as data source.

Another article states that – Decision-making processes in strategic planning are very complex and decisions can be made in many levels. The major problem is to create harmonized automated process where decisions can be made in any level (Pinson, Louçã and Moraitis, 1997).

Figure 2 shows the distributed Sustainable land management approach across different management levels, where feedback is implemented at every level of development. The process goes in a spiral.

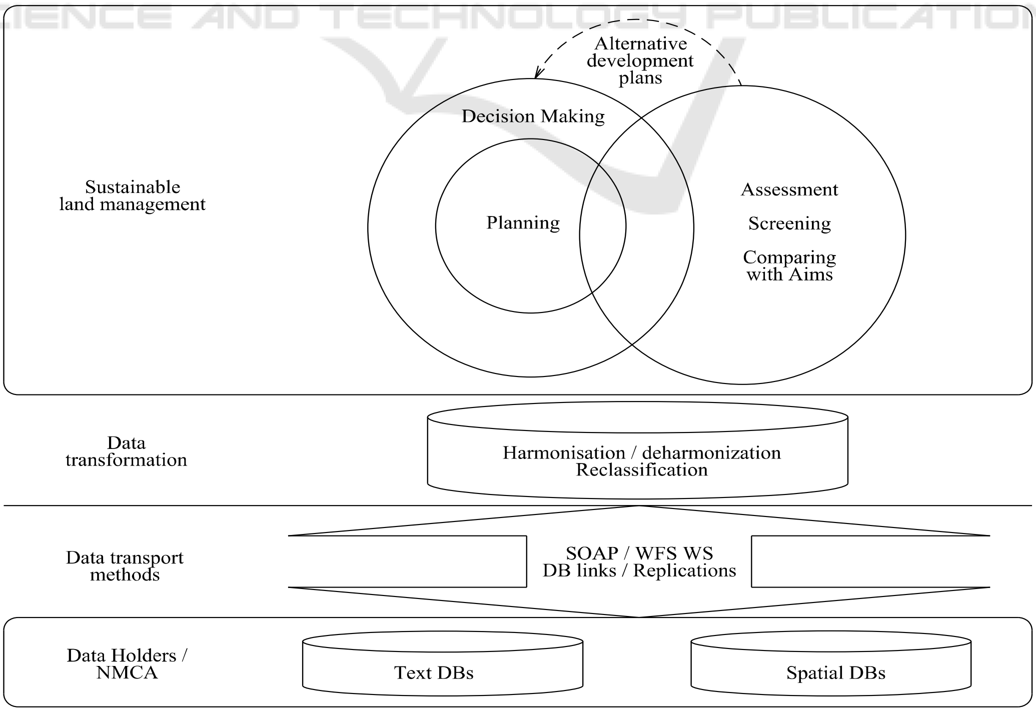

Figure 1: Information system's architecture for land development (Holms et al., 2017).

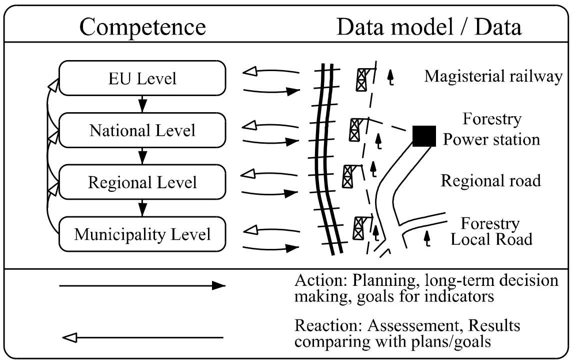

Figure 2: Distributed decision making in Sustainable land management.

A similar situation is with Ecological issues (Fig. 3) where companies, corporations, industries interact with environment in non-linear way and on different scales (Whiteman et al., 2013). Alyoubi points to the importance of Knowledge Management. Nowadays Decision Support Systems is an inalienable tool for Complex Decision Making in knowledge-based solutions (Alyoubi, 2015).

Knowledge can be treated as a combination of united data model and data. For example, filled with data INSPIRE (EU Directive, 2007) data themes are a good example of Knowledge.

Figure 4 (Cano et al., 2017) describes Stakeholders Dialogue. There is described classical minimalistic rational planning process scheme, where there is data collection (Model, Data), data processing/analyzing (Algorithms), next iteration's plan and results from previous iteration (Solution) and reaction as 'Stakeholders Dialog'. Big bullets from left and right shows, that this is a spiral/iterative process.

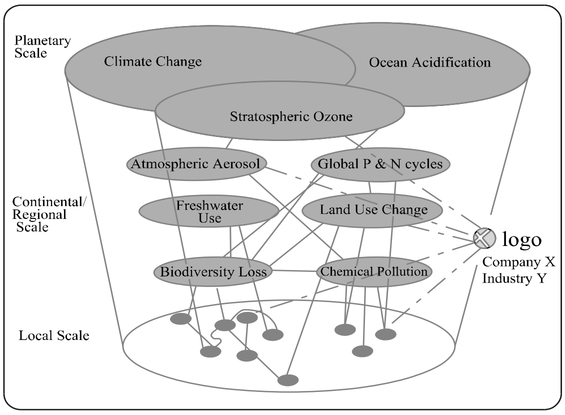

Figure 3: Levels of Ecological issues (Whiteman, Walker and Perego, 2013).

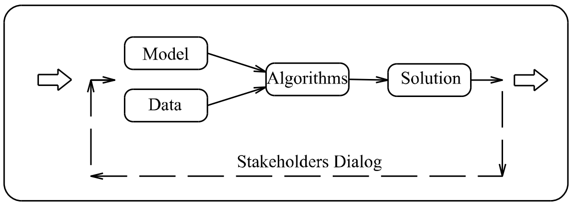

Figure 4: Decision support system framework diagram (Cano et al., 2017).

2.1 Classification

It is relatively easy to make links between two data models. But in our case no harmonized data model exists for ES. There are at least three major classifications for ES:

- Common International Classification of ES (CICES);
- Classification from Millennium Ecosystem Assessment (MEA2005);
- 'The Economics of Ecosystems & Biodiversity' (TEEB) classification.

In practice not all of the ES indicators can directly be aligned with INSPIRE data model. For example, indicator (from Table 1) 'Number of traps for the river lamprey' can not be linked with INSPIRE data model without additional information. This additional, mostly textual information, is available in other stakeholder's registers in unharmonized way. In long term it would be more beneficial if this additional information was identified, harmonized, standardized and available in machine readable format, for example, in XML or JSON formats.

In Europe, as in other places, SDI is in implementation process. In Europe this process is provided by INSPIRE directive (EU Directive, 2007), which describes advanced data model for environmental data. The list of land use categories to be used in INSPIRE Land use are specified by Hierarchical INSPIRE Land Use Classification System (HILUCS). The HILUCS is applicable for existing and planned land use, and is available in human and machine readable way. In the future this classifier may be supplemented to ensure harmonization with ES classification.

2.2 Ecosystem Services Assessment

Benjamin Burkhard tried to get spatial and statistical information on the capacities of different land cover types to provide ES. As a data source there was used spatial (CORINE Land Cover and Land Use) and

Table 1: Example of Indicators from Deliverables of LIFE Project realized in Latvia – "Assessment of ecosystems and their services for nature biodiversity conservation and management" (Mapping of ecosystems and their services in Saulkrasti and Jaunķemeri pilot areas, 2016).

Section	Division	Group	Class	Indicator
Provisioning	Nutrition	Biomass	Wild plants and their outputs	Yield of wild berries
			Wild animals and their outputs	Number of traps for the river lamprey
	Materials	Biomass	Fibres and other materials from plants for direct use or processing	Potentially harvestable timber volume
			Fibres and other materials from plants for direct use or processing	Herbs
	Energy	Biomass-based energy sources	Plant-based resources	Potentially harvestable timber volume for bioenergy

textual information. Spatial information was used to reference textual/statistical information. To make assessment, the spatial assessment matrices for every Land Use type were constructed (to reference textual data). After that 'Matrix for the assessment of the different land cover types' capacities to provide selected ecosystem goods and services' was built, where in X axis there are Land Cover types and in Y axis ES (Burkhard et al., 2009).

The authors of the article have similar idea, but as data source it would be more convient to use INSPIRE data and in Latvia adopted ES classification. This classification was introduced in LIFE project LIFE13 ENV/LV/000839 - "Assessment of ecosystems and their services for nature biodiversity conservation and management" which is being followed in Latvia (LIFE EcosystemServices, no date). Indicators were classified and published for two pilot areas for ES mapping purpose. An example of Provisioning ES indicators is available in Table 1.

3 PROPOSAL

There is still no harmonized classification of ES is available. Every stakeholder has their own classification of ES and assessment methods which makes it inconvenient to use this data to make some cross border research, planning or decision making. Cross boundary common understanding of classifications and assessment methodologies can significantly simplify the perception of the same problem by experts from different countries.

Already now it is possible to build Information Systems (IS) for strategic decision making in Land management to ensure Sustainable Land Development (Fig. 1), but there are obstacles in scalability. This is due to the fact that there are many ES classifiers and it is not always possible to harmonize data from different classifiers.

The same problems are with SDI. In Europe there is approved INSPIRE, but other world countries have their own standards and it is not always possible to harmonize spatial data between standards.

In addition, an issue arises with linking Ecosystem' Services indicators to SDI. In many cases it is possible to harmonize classifiers and to link indicators to data model from SDI, but on cross boundary scale there is a risk of partners using their own classifiers, that have not been harmonized.

Table 2: To ensure harmonization with Ecosystem Service, potentially extensible INSPIRE themes.

Potentially extensible INSPIRE theme	Ecosystem Services Indicator
Species distribution	Yield of wild berries
Agricultural and aquaculture facilities	Number of traps for the river lamprey
Land Use and Energy resources	Potentially harvestable timber volume
Species distribution	Herbs
Land Use and Energy resources	Potentially harvestable timber volume for bioenergy

At Pan-European level it is strongly advisable for strategic decision making in land management for spatial referencing to use INSPIRE themes (for example Land Use, but not only) with linked data from ES Indicators. In their turn Indicators should be harmonized in INSPIRE manner. And if Indicators concept gets enough maturity, INSPIRE themes should be supplemented with ES classification.

Table 2 shows an example of potential linkage between INSPIRE theme and Ecosystem Services Indicator.

The proposal is - at International Organization for Standardization (ISO) level to develop standardized and detailed (incl. Indicators) Ecosystem Services Classifier and to extend INSPIRE specification with standardized Ecosystem Services detailed classifier.

4 CONCLUSIONS

At the moment standardized Ecosystem Services Classifier do not exist, as well it is not harmonized with INSPIRE or another SDI data model.

In Europe at municipality, regional and national level it is possible to create distributed strategic decision making IS for land management and as data source using data from INSPIRE data model harmonized with Ecosystem Services' Indicators and if necessary appended it with standardized specific textual information from stakeholder's data stores.

For facilitating data exchange process in distributed strategic decision making IS for land management on Pan-European level it is recommended:

- to develop standardized and detailed (incl. ES Indicators) Ecosystem Services' Classifier and approve it at ISO level;
- to extend INSPIRE specification with standardized Ecosystem Services' detailed classifier.

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