Towards the Integration of Environmental Information in Europe

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Abstract

A vast variety of information sources exists for environmental information. Significant improvements result from sharing distributed data, information and information services resources. Attempts to focus such sources in a comprehensive manner led to the idea to build a Single Information Space in Europe for the Environment (SISE). A certain challenge lies in the contemplation of such a concentration of information and in providing access to an environmentally relevant information space.

In the coordination and support action ICT-ENSURE a multidisciplinary approach was chosen to pave the way to structure basic requirements for a SISE. Several structuring elements of an environmental information space are discussed from a content, legislative, administrative, organizational and especially technical perspective in sharing distributed data, information and information services. In addition, a conceptual system meta-model is used to formulate cause-effect relationships and the system dynamics of information flows between these different topics.

This paper presents the results of an information integration analysis, structured on the basis of a conceptual environmental meta-model. This amalgamating approach is used to build a framework for integrating environmental and sustainability-relevant information. The objective is to start to collect and assemble formerly incoherent pieces of a puzzle in a way that can form a coherent overall picture.

1. Introduction

A prerequisite for integration of environmental information is the study of environmental information sources, data sets and activities. A specific task consists of surveying these activities, keeping informed on the development of information generation and access in a multitude of organisations (EEA, EPA, public administration, industry, private sector, NGOs, voluntary initiatives etc.), in networks (EIONET, ERA-Net, ETC’s, EnviroInfo etc.) and research projects and programmes (FP6/7 etc.).

In the FP7 ICT-ENSURE project, a screening of information sources for an integrated environmental information space was scheduled (D7.1; see fig. 1). This topic is discussed on one hand under the idea of building a “Single Information Space in Europe for the Environment” (SISE), and on the other hand from the perspective of implementing a “Shared Environmental Information Space” (SEIS). The action line SEIS with its strong support from the Commission is fostered more by EEA, JRC and Eurostat, guided by DG Environment, whilst the origin of SISE can be identified more in DG Information Society and Media, with the objective to improve IT tools and infrastructures. A guiding principle in the ICT-ENSURE report “Conceptual Detailing SISE” (D7.2) was to analyse the state of the art in both action lines, SEIS and SISE, to watch their progress and to develop recommendations for further needs in realisation of an environmental segment of a Single European Information Space.
In 27 scientific surveys, a multitude of accesses to information sources are accomplished. Reports dealing with energy, climate, natural resources, agriculture, the eco-industrial complex, biodiversity, health, urban development etc. provide an overview about sustainability-relevant information sources.

Another means for structuring information flows is a conceptual meta-model which characterizes the structure of environmental information flows. Visualized as a System Dynamics Model, it highlights the potential role of ICT in environmental sustainability (D2.1). Based on integrated approaches for environmentally relevant issues, the applicability of the meta-model is tested in several areas (D2.3). This includes air quality control, water quality and quantity, application in industrial ecology and in modeling the impact of market dynamics on the environment. From a comparison between existing models of ecosystem services and biodiversity, e.g. the Ecosystems and Human Well-being (2005) assessment, the proposed Meta-model is found to adequately represent - on a rather high level of abstraction - the main characteristics of particular modelling exercises in this area.

1.1 SISE: Vision and Demand

The idea to integrate the immense pan-European diversity of environmental information is a vision. A first step to foster the free flow of environmental information is achieved by making distributed information sources available in the Web which meets the needs of administration, politics, research, business and the public. For origins of the idea of a SISE, see D7.1 and Schoupe (2008), and for further publications see Hřebíček, Legat, Nagy, Pillmann (2008) and Hřebíček, Pillmann (2009, 2011).

The objective of the implementation of a “Single Information Space in Europe for the Environment” (SISE) is only conceivable in the medium term for selected areas of environmental relevance. Requirements and demands for such areas can be found in multiple sources, e.g. in the EU’s 6th Environmental Action Plan, the Environmental Policy Reviews, the Digital Agenda for Europe and in DG-INFSO Expert Consultation Workshops. In the ICT-ENSURE project, emphasis was put on the focus areas: ICT in Energy Consumption and Energy Efficiency, ICT and Climate Change, ICT and Sustainable Use of Natural Resources, and ICT for Biodiversity as well as other key areas like ICT for Industrial Ecology and for Sustainable Urban Development. Ten further suggestions for implementation areas are included in the ICT-ENSURE deliverable D7.1 Chapter 5 “Sketches of possible areas prioritised for developing a SISE”. Furthermore, the authors conceptualized the integration of sustainability-relevant information to a SISE using five principal dimensions of a SISE: the content (semantic), legislation, policy, organisational, and technological dimensions.

According to the Digital Agenda, SISE might be a starting point for reviewed and modernised services for a “Public access to Environmental Information” in Europe, which are now fragmented along national borders. The SISE target groups in this project are primarily persons involved in research in the field of ICT for the environment, in administration, production, and technical services. As soon as SISE attains a reasonable maturity, this environmental information space should provide a European window of opportunity for the media and the interested public to gain access to proven environmental sustainability insights.

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1.2 ICT Aspects of SISE

The technical implementation of SISE depends on four levels of interoperability: (1) shared low level protocols such as HTTP, XML, or UTF-8; (2) common data exchange patterns such as Web Services, REST APIs, Feeds, or Linked Data; (3) domain data models which provide the structure and scope of the retrieved data; and (4) agreed reference vocabularies, making sure that multiple sources are talking about the same thing.

The global multi-faceted environmental knowledge expands continuously. A harmonization of fixed domain models may only work for a basic set of standard reporting obligations. In order to gather environmental information of relevance for science, politics, administration, the private sector, and the public, a SISE would therefore need valid input from a variety of information sources. Reference vocabularies, semantic web technology and specifically Linked Data patterns are the key to making yet-unharmonized peripheral knowledge domains accessible to a standard model.

An essential prerequisite of a dynamic infrastructure that will be able to keep up with the dynamics of environmental risks and evolving knowledge is the adequate funding of:

- Formalized and published domain models tied to their data using Semantic Web technology from leading-edge organisations and researchers;
- An expandable core reference vocabulary in the area of environment and sustainability as a kind of “docking station” for the more specific domain vocabularies; and
- Research on rapid discovery, harvesting and integration based on linkage between data sets and vocabularies.

Further technical and non-technical requirements were listed in D7.1 Chapter 4. Steps towards these requirements were conducted in ICT-ENSURE with the screening of information sources, the development of a conceptual Meta-Model, the Literature Information System, and the Research Programmes Information System. Examples of Web 2.0 technologies that are applied include the EEA “Eye on Earth” or the UK Office of Public Sector Initiative with the data transparency programmes*, where people submit information, applications and visualizations, and ideas. Moreover, places for developers are provided to discuss ideas, applications and the use of data and information.

2. Integration Approach for Environmentally Relevant Issues

Early developments of methodologies to organize environmental statistics were taking place in the 1970s at Statistics Canada. The *Stress Response Environmental Statistical System STRESS* was proposed by David Rapport and Anthony Friend (1979). This and essential further developments to a Pressure-State-Response Model (PSR) and to the extended Driving forces-Pressure-State-impact-Response model (DPSIR) is given e.g. in Stanners et al. (2008). In “Framework for Environmental Assessment on Indicators at the EEA” also a short history of the PSR model used at OECD and the further development and application of the DPSIR Model at EEA are given.

An interim insight of the development of the integrated approach in the DPSIR Model development is provided in the Environmental Pressure Indices Project, conducted by Eurostat in co-operation with the EEA and financed by the European Commission, Environment DG. In this project a comprehensive description of the most important human activities that have a negative impact on the environment is assembled. The first indicator publication “Towards Environmental Pressure Indicators” (Eurostat 1999) covers about 60 environmentally relevant indicators.

For a DPSIR application for integration of ecosystem services see Iannucci, Munafò and Sambucini (2011).

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* http://data.gov.uk/
2.1 Meta-model for Sustainability-Relevant Information Flows

A meta-model allows the complexity of information to be dealt with in a twofold manner: (i) it reduces complexity for the user in focusing on general structural characteristics of the varied information in the system, and (ii) it preserves complexity for the user in allowing information contents to be entered via the meta-model. Therefore, the meta-model approach is an efficient tool for information management in fields of application where large numbers of different information contents (entries and types) ought to be integrated.

The proposal responds to the diagnosis that, up to now, only rudimentary search and navigation helps are available, but it is not about the mere extension of information portals with additional metadata (like keywords etc.). The concept is to provide an additional mode of access to information, based on a systemic view on the area under investigation. A general structure of the meta-model is shown in Fig. 2.

![Fig. 2 Conceptual Meta-model for ICT for Environmental Sustainability Research (simplified)](Source: ICT-ENSURE Deliverable D2.2, Pillmann)

In the kernel of the model, the interaction between the natural environment and the anthroposphere is arranged. The kernel “Human activities” can be specified by including e.g. public and private households, industrial activities, agriculture and the transport sector. The natural environment with air, water and soil may also reflect problem areas like waste, land-use changes, energy balances, or climate change. Several “communication channels”, influencing primarily driving forces or conservation strategies, have their origin in information processing with ICT.

The main task of the meta-model is to visualize the interrelationship between separated areas and to organize the access to and the distribution of sustainability-relevant information. Therefore, in the concrete example, the determinants and influences of economy, social processes and dynamics on individual behaviour has to be specified. Thus, simplified, the following components are of particular relevance.

1. Analysis of data and knowledge about the environment
2. Systematisation of this information in ICT
3. Communication and distribution of information via media (publications, the Web, conferences, mass media etc.)
4. Inquiries about the effectiveness of information in decision processes
5. Design of influences on socio-political processes (legal measures, incentives, taxes).
The lines within the diagram are highlighting the origin, the transfer and/or the exchange of environmentally relevant information, which can be characterized by a set of basic dimensions. These dimensions are the (1) application area, (2) spatial dimension, (3) temporal dimension, (4) information representation (written material, Web sites; etc.), (5) sender and receiver of information (scientists, environmental agencies, governments, NGOs, companies, consumer protection agencies, concerned citizens etc.).

The input/output presentation should reveal that this is a highly dynamic system with a multitude of discrete and continuous-time elements, feedback/feed forward loops, disturbances, uncertainties, nonlinearities and unstable processes. This model representation is chosen as a basis for a tentative further computer-assisted integration of the environmental and sustainability-relevant information space.

The left hand side of the diagram indicates some addressees of environmental information in politics, administrations and organisations. Environmental goals (e.g. pollution reduction, national environmental action plans, Agenda 21, Eco Management and Auditing Scheme - EMAS) are influencing politics, administrations and enterprises. Legislation and other measures (taxes, fostering environmentally friendly technologies, information, research, international agreements etc.) should represent the indirect impact of environmental information on industry and the public at large.

During the preparation of the ICT-ENSURE project the idea arose to structure the work packages in such a systemic manner. Now a first set of results is available.

1. Scientific surveys in selected areas provide a survey in environmental topics.
2. A concept of a Single Information Space in Europe for the Environment. It includes an analysis of programmes, projects, networks and sources on environmental information, and ICT requirements and trends to access distributed environmental information sources.
3. Eight specialized workshops also in EnviroInfo conferences. The information loop is enhanced with an information system on national research programmes in the field as well as a literature information system with conference papers.

3. Sketches to Structure a European Environmental Information Space

To pursue the idea of an environmental information space, a multidimensional project strategy with further measures/investigations is needed. This strategy includes networking and dissemination activities and a structural meta-model approach for organizing the access to distributed information. A consistent continuation of the project approach would therefore stimulate the integration and use of environmental information in Europe. Recommendations for SISE are listed below.

3.1 Expert Opinions about SISE

70 experts have been asked for an assessment of the possibility to create a SISE. So far, from 28 replies to fundamental questions, a preliminary interpretation indicates that:

- SISE should offer search facilities linked to sites, which are predefined and known to be important and reliable.
- Environmental information should be included from government, public authorities and scientific information sources. To a limited extent, grey literature should be included.

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7 The idea for a Meta-model of Environmental Informatics dates back to 1990. In the proceedings of the conference “Informatik für den Umweltschutz” a forerunner of EnviroInfo conferences, a regulatory concept for assigning papers to subject areas was presented. In EnviroInfo 2002, a general framework structure for environmental topics was published (Pillmann, 2002).
• SISE should provide information for environmental administration and policy (85%), citizens (64%), research institutes, scientists, consultants, IT experts (64%) and Green interest Groups/NGOs (43%). (Percentages reflect multiple answers.)
• SISE should be implemented as a network of web portals (79%) or Web portal (21%).
• A SISE should be operated by a dedicated centre like the European Topic Centres (43%), by the European Environment Agency (36%) or distributed in national centres (21%).
• The focus of the further development of SISE is seen in the organisational domain (57%) and in the semantic domain (39%).

If isolated results from research programmes and good practice cases stay visible and operable beyond the individual project life-span, the chances for integrating the environmental information increase. Successful examples are the long lasting PortalU programme of the Environmental Information System Baden-Württemberg.

3.2 High-ranking Requirements
Much attention has to be paid to ongoing efforts in research programmes with challenging ICT aspects, combined with environmental sustainability applications and those on the Digital Agenda for Europe. This includes INSPIRE, SEIS, GMES, GEOSS, ENVIROFI - Future Internet, and selected national research programmes. From a broader perspective - eGovernment services combine to implement cross-border eEnvironment services, including advanced sensor networks. Based on experiences with efforts to integrate European environmental information:

• A SISE needs a legislative basis, similar to the INSPIRE directive. The initiation of this legislation could start immediately by reviewing the directive “Public Access to Environmental Information”.
• SISE needs key enablers in political and administrative positions.
• Based on the political agenda, an agreed vision for first subtopics in a SISE implementation has to be stipulated. Proposals were formulated in D 7.1 Chapter 5.
• For effective information integration, the co-operation of environmental and ICT experts has to be fostered continuously.

Other key principles formulated for INSPIRE may also be applied to the SISE development. These include: (1) a stepwise implementation; (2) starting with a minimum extent, with a plan to increase capabilities; (3) forward thinking cost/benefit considerations; (4) feasibility and adaptability to local diversities; and (5) an evolutionary design (Annoni/Craglia 2009).

3.3 Content Related Research Requirements
Based on a core reference vocabulary for environmental topics, a systemic approach for SD topics has to be developed that extends beyond the DPSIR classification. The ICT-ENSURE conceptual Meta-Model (D2.2 and D2.3) could serve as an organising principle for semantic access to existing Web-spaces. On the basis of the main topics of sustainable development (SD), the research space should be segmented. Resources of a European concept of segments can be UN Sustainable Development Issues, the organisation of EEA Web information and various SD indicator sets, e.g. from Member States or Eurostat.

Furthermore, main information resources in selected sustainability-relevant areas are prepared in D8.2b “Final Survey Report”. Here a meta-survey of accesses to European information resources was compiled

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8 see D7.2 Chapter 6
including topics like: Energy, Natural Resources, Climate Change, Industrial Ecology, Biodiversity, Quality of Life, Sustainable Urban Development, Health and Risk Management. In D7.1 Chapter 5, a set of sketches of possible prioritised areas was prepared.

3.4 Strategic Requirements and Network Building

The progress in e-government and the efforts in eEnvironment services can be used to foster information integration in an environmental information space. An analysis of the impacts originating from the research activities in the environmental domain similar to the WING study\(^\text{10}\) should be elaborated to identify the further demand for services.

Fostering pan-European communication between scientists and persons in the private sector helps to extend the knowledge base needed for SISE. Experienced experts from EU organisations (EEA, JRC, other agencies) and EU programmes (FP7, CIP, GMES, GEOSS etc.), especially from the dynamically developing SEIS “Towards a Shared Environmental Information System”\(^\text{11}\) are the first target groups. Others are experts from Member States, joint programmes and organisations e.g. from Interreg, LIFE+, CIP, ICT-PSP, COST, ERAwatch, ESF etc. Conferences and workshops are platforms for network building. Examples are Conferences like EnviroInfo, ISESS, and iEMSs.

As another means of fostering the evolution in ICT and environmental sustainability research simultaneously, a network of expert networks is recommended similar to EIONET or IMPEL\(^\text{12}\). Such an interlinked network could use the annual EnviroInfo conferences as a stable observation and communication platform.

In discussions with experts during the ICT-ENSURE project events, it was brought up that a link between different DGs (notably DG Environment and DG INFSO) would facilitate information exchange and the implementation of interdisciplinary programmes. As an example on a national scale, the set up of a steering committee with members of involved organisations has successfully supported the environmental information system in Baden-Württemberg (Germany) for more than two decades.

3.5 Requirements in ICT technology and -tools

The progress of Geospatial Functionalities via Web Services, applied in the field under consideration, is now mature. INSPIRE has established the European standard in this area, where the spatial data themes in the Annex III\(^\text{13}\) are predominantly of environmental relevance. In addition, GIS technologies and visualisation provide easy to understand information situating it in the frame of a spatial context, e.g. for integration of climate change scenarios in resource management planning.

Multilingual tools for information access like the European multilingual thesaurus GEMET and the UDK-Thesaurus (in German and English) can be used for navigation in the information space. In the future, a transition from poly-hierarchical thesauri to a systemic-centered design can pave the way to Semantic Web functionality.

Access to tools and services in the private sector helps to open up information sources; e.g. the European EMAS III (Eco Management and Audit Scheme) application and the Environmental Management System ISO 14001.

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11 SEIS will assist in the selection of cost-effective measures that optimize the economic, social, health and environmental impacts, with streamlining of reporting and monitoring obligations … (SEC/2008/0111 final)
12 EIONET - European Environment Information and Observation Network IMPEL - European Union Network for the Implementation and Enforcement of Environmental Law
Semantic information resources in the environmental domain allow interoperability across disciplinary boundaries and Service Oriented Architectures for web-based environmental services. Web 2.0 technologies provide access and help people to submit information, applications and visualizations, communicate ideas, and provide space for developers to discuss methods, applications and the use of data and information. Examples are given e.g. in the EEA “Eye on Earth” or in the UK Office of Public Sector Initiative with the data transparency programmes\(^{14}\), including SPARQL as query language which can be used to express queries across RDF (Resource Description Framework) data sources.

ICT services cover relevant sources in the environmental information space. Example are:

- Environmental information systems
- Literature information systems (e.g. \(\text{http://iai-uiserv1.iai.fzk.de/ictensure/site?mod=litdb}\))
- Project information systems. Here the dedicated service “Information System on Research Programmes in the Field of ICT for Environmental Sustainability” provides free access to European research activities (\(\text{http://iai-uiserv1.iai.fzk.de/ictensure/site?mod=progdb}\)).

Ideas for new services often emerge in EnvirolInfo conferences. An example is a Legal Map. Similar to usual maps, geospatial functionalities of GIS are used to establish a multi-domain legal atlas. In Europe this would be possible on the basis of e.g. \(\text{http://eur-lex.europa.eu}\) and more focused to the environment in \(\text{http://ec.europa.eu/environment/policy_en.htm}\). Another perspective is opened up by the ICT-ENSURE deliverable D2.1 which outlines the role of ICT in environmental sustainability research.

### 4. Conclusions

A Single Information Space in Europe for the Environment might today seem far from reality. Keeping in mind that cutting-edge technologies are embraced within a few decades, and considering the rapid emergence and expansion of Web technology, search engines, and spatial data infrastructure, in fact an undeniable window of opportunity exists for a SISE. During the FP7 project ICT-ENSURE, experiences were gathered in workshops and conferences, from reading reports and papers, and from studying the results of national and EU research programmes, as well as via discussions with experts. The evidence gained from these extensive inputs points to the conclusion that all heterogenic prerequisites to proceed towards a distributed environmental information space already exist, and a fully functional SISE could be a reality in a foreseeable future.

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\(^{14}\) \(\text{http://data.gov.uk/}\)

\(^{15}\) \(\text{http://www.ict-ensure.eu} \rightarrow \text{Downloads and Resources} \rightarrow \text{Deliverables}\)
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