The Framework for Environmental Software Systems of the European Environment Agency

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Abstract. The European Environment Agency (EEA) is the authoritative European environment node and hub, and a key initiator within networks of knowledge co-creation, sharing and use in European Union (EU). It ensures the quality, availability and accessibility of environmental data and information needed to support strategic area: informing policy implementation and assessing systemic challenges. It actively communicates data, information and knowledge to policymakers, the public, research communities and others (nongovernmental organizations, businesses) as well as to regional and international processes including those of the United Nation and its specialised agencies and promotes information governance as a driver of public empowerment and behavioural change. In the past few years the EEA's environmental information systems as well as environmental modelling with the support of environmental software systems have been supporting decision making processes within the EU Systems have undergone rapid development and grew up to support the knowledgebase of European Commission and EU member countries. Specifically, new infrastructure to support supply services (collection of data); networking (knowledge management); workflows (planning, automation, quality management); development of final products and public services (reports, web sites, public data and information services) were put in place. EEA strengthens the infrastructure for environmental data and information sharing both at the EEA and in the European Environment Information and Observation Network with Member Countries, taking into account the Shared Environmental Information System (SEIS) and the Infrastructure for Spatial Information in Europe (INSPIRE) developments. The paper presents the framework for the of development of EEA environmental software systems and information services accepted in Multiannual Working Plan of the EEA for 2014 – 2018 and its implication for ICT.

Keywords: EEA · environmental data · information system · environmental services · environmental monitoring · Eionet, SEIS · Copernicus · INSPIRE

adfa, p. 1, 2011.

1 Introduction

Environmental software systems in the European Union (EU) should support the current *Environment Action Programme* to 2020 (7th EAP) entitled *Living well, within the limits of our planet* entered into force in January 2014. This programme is based on a 2050 vision of EU centred on ecological limits, a circular economy and society's resilience. To move towards this vision, the 7th EAP sets out nine priority objectives, comprising three thematic objectives, four enabling objectives, one urban objective, and one global objective [1].

The 7th EAP aims at achieving existing objectives and targets in a mid-term perspective to 2020/2030, with EU policies [2, 3, 4]: the Climate and Energy Package 2020 and associated roadmaps; the EU Strategy for Adaptation to Climate Change; Europe 2020 and the Resource Efficiency Roadmap; the Biodiversity Strategy to 2020; and specific legislation for water, waste, air etc. In addition, the 7th EAP promotes new ways of thinking and innovation in order to realise the EU 2050 vision beyond existing policy targets. This gives a large framework of application Information and Communication Technologies (ICT) and updating and development of environmental software systems.

The overall aim of the 7th EAP is to step up the contribution of environment policy to the transition towards sustainability, understood as a resource-efficient, low-carbon economy in which natural capital is protected and enhanced, and the health and well-being of citizens is safeguarded. The 7th EAP is also the basis for EU involvement in global agendas such as Rio+20, the United Nations Framework Convention on Climate Change [5], the Montreal Protocol on Substances that Deplete the Ozone Layer [6], and the Convention on Biological Diversity [7], as well being the basis for wider European activities, which are increasingly framed in a 2050 perspective [8].

The *European Environment Agency* (EEA) [9] is one of the most important agencies of the EU with ICT support to environment protection. It is located in Copenhagen, Denmark. Its main task is to provide sound, independent environmental information. The EEA is a major information source for those involved in developing, adopting, implementing and evaluating environmental policy, and also the general public. Currently, the EEA has 33 member countries. The Regulation [10] establishing the EEA was adopted by the EU in 1990. It came into force in late 1993and its work started in earnest in 1994. This Regulation also established the *European Environment Information and Observation Network* (Eionet) [11]. EEA's mandate is to help the EU and member countries make informed decisions about improving the environment, integrating environmental considerations into economic policies and moving towards sustainability and coordinate the Eionet.

The EEA, according to the above 7th EAP visions [1], aims to support sustainable development and to help achieve significant and measurable improvements in information about Europe's environment, through the provision of timely, targeted, relevant and reliable information to policy making agents and the public.

The aim of the paper is an introduction of the recent independent evaluation of the EEA and discussion how EEA operates in a complex, multi-level and multi-actor governance setting at EU (e.g. Copernicus, Eurostat, INSPIRE, SEIS), national, and

global levels, which also includes research institutes (e.g. Joint Research Centre), businesses, and nongovernmental organizations (NGOs). We discuss the specific role of the EEA to build the capacity of for environmental software systems in member countries, using the Eionet as its unique partner to generate two-way flows of quality-assured environmental data and information.

The EEA's understanding of the nature of environmental challenges has evolved in recent decades, requiring corresponding changes to information flows and assessments with using ICT. The continuous flow of new information and updated scientific insights into environment and climate issues improves the knowledge base for environment and climate policies [2, 3, 4]. Fulfilling its role as an interface between science and policy, the EEA will work closely with the European Commission (EC), its DG Research and Innovation (RTD), DG Communications Networks, Content and Technology (CNECT), DG Environment (ENV), DG Health and Consumers (SANCO), Eurostat (ESTAT) and Joint Research Centre (JRC), and others in seeking to influence activities under the EU Framework Research Programmes (Horizon 2020 and earlier). The EEA also aims to exploit the insights that result from these programmes.

Furthermore, we introduce the key goals of environmental software systems and decision making processes of the EEA in the new Multiannual Work Programme 2014-2018 (MAWP) [12] and introduce important environmental software systems and ICT used in SEIS, Copernicus, INSPIRE activities.

2 Structure of the Multiannual Work Programme 2014-2018

To secure the knowledge and evidence base for a framework of the Priority objective 5 of the 7th EAP [1], the MAWP [12] is structured around four strategic areas:

- **Strategic area 1 (SA1): Informing policy implementation.** There is providing feedback and input to long-established and emerging policy frameworks, objectives, and targets through reporting on progress in recognised environmental themes, including links to those sectors that are the primary sources of environmental pressures, and through reporting on the state of and trends in natural environment systems (atmosphere, oceans, territories) using the DPSIR assessment framework (DriverForces, Pressures, State, Impacts, Responses).
- **Strategic area 2 (SA2): Assessing systemic challenges.** There is providing support to improving synergies and policy coherence across environmental, economic and social systems by applying established and experimental integrated assessment techniques and prospective analysis, with both a short-term and a long-term perspective. This work supports the long-term vision for 2050 set out in the 7th EAP.
- **Strategic area 3 (SA3): Knowledge co-creation, sharing and use.** There is providing support to the work in the above areas by building and maintaining networks of people and information systems as the basis for sharing and co-creating content, whether that be data, indicators, or assessments, in a transparent manner with other actors at national, European and global levels. Communications, in the broadest sense of the word, will also play a major role in ensuring that information

promotes a dialogue with a dialogue with stakeholders and reaches out to the society at large. Targeted information, communication and participation are important instruments for achieving significant and measurable improvement in Europe's environment, responding to emerging challenges and societal developments.

- **Strategic area 4 (SA4): EEA management.** EEA management, administration, and operational services make up a fourth area of work. The guiding principles of this work area are strict adherence to all the principles, rules, and regulations that apply to the EEA, as well as continuous improvement of the efficiency and effectiveness of EEA management.

These strategic areas cover complete EEA/Eionet information processes.

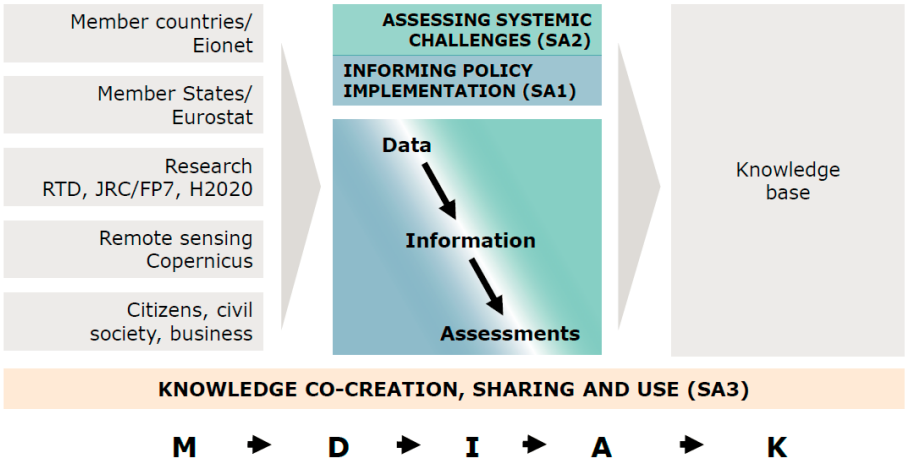

Fig. 1. Strategic areas SA1, SA2, SA 3 and EEA/Eionet core processes (Source [12])

We can see at the bottom of the Fig. 1 the overall EEA/Eionet core processes from **M**onitoring (in the broadest sense) through **D**ata, **I**nformation and **A**ssessments to **K**nowledge. This value-adding chain is at the heart of the work of the EEA and Eionet.

The development of the architecture of the environmental software systems of EEA has evolved in line with the principles of *Shared Environmental Information System* (SEIS) [13] and will contribute to the full implementation of the *Infrastructure for Spatial Information in Europe* (INSPIRE) [14] by 2019. The activities will support the European Open Data Portal [15], the Open Data Strategy of the EU 2020 Digital Agenda [16], and ensure compliance with the Århus Convention [17]. Highlights include the provision of:

- thematic data and expertise to support the involvement of EEA member and cooperating countries in international conventions and related activities, as described in many areas under SA1 and SA2;

- expertise, data, and assessments to ensure European contributions to global and United Nation (UN) activities, including to UN Environment Program (Global Environmental Outlook [18], UNEP-Live [19]) and the post Rio+20 activities [20];
- expertise and capacity-building in networking and information partnerships. This is based on Eionet and SEIS approaches, particularly towards cooperating countries and the European Neighbourhood and towards countries and regions following EU priorities. Involvement in the Global Earth Observation System of Systems (GEO/GEOSS) [21] and Copernicus [22] are included here.

Enhanced involvement of the Eionet network to decision making processes of the EEA is sought across the strategic areas in the fields of data flows, indicators, policy effectiveness analysis, integrated assessments, communications, and the use of new analytical methods and technologies.

Established European Topic Centres[1] (ETCs), key components of Eionet, play an important role in the chain from environmental data to assessments, supporting the development and maintenance of the knowledge base in all areas of work under SA1, and also parts of SA2.

3 Shared Environmental Information System

The project *Shared Environmental Information System* (SEIS) [13], [23] is a mixture of components: it is a vision that encourages the modernisation of data handling of environmental information systems; a set of principals which underpin the decisions making; and a set of concrete activities where developers are, for example, supporting the establishment of a European spatial data infrastructure [14] together with the JRC and the EC; analysing environmental indicators and distributed exchange between the EU countries and EEA; and also working on governance issues in Mediterranean and North African countries.

SEIS is based on seven principles [23]. Environmental information should be:

1. Managed as close as possible to its source.
2. Collected once, and shared with others for many purposes.
3. Readily available to easily fulfil environmental reporting obligations.
4. Easily accessible to all users.
5. Accessible to enable comparisons at the appropriate geographical scale, and citizen participation.
6. Fully available to the general public, and at the national level in the relevant national language(s).
7. Supported through common, free open software standards.

[1] European Topic Centres are currently eight consortia of institutions across EEA member countries dealing with a specific environmental topic and contracted by the EEA to perform specific activities as defined in the EEA Strategy and the MAWP and the Annual Management Plan.

Under SEIS, EEA has worked with numerous EU institutes (e.g. DG ENV, JRC, ESTAT, etc.) and initiatives (Copernicus, INSPIRE) in order to reach successful implementation of its principles. These include:

- Achieving effective streamlining of legislative environmental reporting requirements, through such actions as the thematic strategy on air pollution (CAFE) [24];
- Directive 2007/2/EC – Developing an infrastructure for spatial information in Europe (INSPIRE) [14];
- Fostering a contemporary approach to the production, exchange and use of environmental data and information through, for example, the Water Information System for Europe (WISE) [25], European Marine Observation and Data Network (EMODnet) [26], BISE on biodiversity [27];
- Directive 2003/4/EC – Public access to environmental information (the Aarhus Convention) [17];
- The Copernicus initiative [22];
- European Environment Agency (EEA) services [9, 10];
- Group on Earth Observation (GEO) [21], which aims at building a Global Earth Observation System of Systems (GEOSS) [28];
- Other the EC funded activities for the effective distribution of open environmental software systems for environmental management.

The data input side of SEIS is predominantly based on environmental monitoring, which happens at the EU country level – the monitoring happens based on environmental legislation that individual countries must adhere to.

SEIS is not only about making information available for public access, it is also about making the data available for network communication via standard APIs (application programming interfaces) and open data formats [15]. Implementing and supporting SEIS-friendly ICT tools is one of the core activities of the EEA.

Basically, everything you see on our EEA's website [9], [11] is harvestable via external systems and linked data spiders, so the environmental data and information can be easily re-used, integrated and re-distributed by to a wider network of users. As a practical example, organisations are now able to easily exchange their catalogues of datasets creating more complete federated dataset catalogues, also known as Open Data Catalogues. The ICT makes it almost effortless for the EEA to contribute to the EU Open Data Portal [15].

Through EU legislation and based on its's mandate, the EEA is in a position to promote free access to environmental data. Resource wise, the EEA cannot afford to keep paying for data, and there is a policy framework in EU which supports this issue. There are three things in particular: one is the Aarhus Convention [17], which addresses countries outside EU and focuses on free access to environmental information, but also ensures citizens having the opportunity to, for example, go to court if certain organisations are not sharing data. Secondly, the Publish Sector Information Directive (PSI) [29] pushes public access administrators to make data available. And thirdly, the EEA has an access to information directive at the EU level that underpins the Aarhus Convention.

Another component of SEIS is remote sensing – data are received from satellites (e.g. Copernicus [22], GEOSS [28]). As another source over the past five years, citizen science in Europe has grown massively, and citizens have become actively involved in the collection of environmental data. In addition, EEA and Eionet are cooperating with the research community to gather research and statistics data.

4 Copernicus

The Europe's earth observation programme, known as Copernicus (previously Global Monitoring for Environment and Security – GMES) [22], is an EU - led initiative in partnership with the European Space Agency (ESA) [30].

The origins of the Copernicus programme can be traced back to a series of meetings involving the EC and European space industry representatives in Baveno, Italy, in 1998. The result was the Baveno Manifesto, which called for a "*long-term commitment to the development of space-based environmental monitoring services*" in Europe [31].

Currently in the early stages of implementation, Copernicus will produce data to inform EU, national and local level environmental policymaking and to support environmental monitoring, policy evaluation, modelling, forecasting and reporting. It is intended that Copernicus will make key contributions to EU flagship initiatives, including Resource-Efficient Europe [3], which focuses on securing Europe's needs in terms of natural resources, such as food, soil, water, biomass, ecosystems, fuels and raw materials [32].

Copernicus can be considered as a building block together with other EU initiatives, such as SEIS and INSPIRE. As a member of the GEO, the EC is also collaborating with 88 participating governments to build a worldwide GEOSS [28]. The aim is to inform environmental decision-making in a world facing increasing environmental pressures and to realise societal benefits such as improved management of energy resources and sustainable agriculture.

4.1 Earth Observation of the Land Services of Copernicus

By definition, the land service addresses a broad range of environmental data including soil, forests, ecosystems, biodiversity, water and waste. The land monitoring component of Copernicus became operational under the GMES Initial Operation (GIO) Land services, building on precursor activities, in particular, the Geoland2 [33] 7th Framework Programme (FP7) project.

Based on user consultation, a stepwise approach was defined starting with common "*multi-purpose*" information at Global, Pan-European and local level. The Pan-European and local land services are coordinated by the EEA in cooperation with DG ENV. A global extension of the land service is coordinated by the JRC and will provide basic terrestrial parameters relating to bio-geophysical factors, radiation and water, at global scale in near real-time. These will be relevant for crop monitoring, carbon budget, biodiversity and climate change monitoring at a worldwide level.

4.2 Copernicus and INSPIRE

Many Copernicus projects contributed in different ways to the development of INSPIRE. For instance, experts from the Copernicus Marine Service (MyOcean [34] project) contributed to the relevant INSPIRE data specifications. The discussions with Atmospheric Service (MACC [35] project) and the down‐stream service PASODOBLE [36] were mainly related to metadata. The interaction with Land and Emergency Services and INSPIRE took place indirectly by the introduction and promotion of INSPIRE components within these services through the GIGAS [37] FP7 project.

The role of INSPIRE in Copernicus' in situ data component was addressed by the GMES In‐Situ Coordination (GISC [38]) project led by EEA. Its aim was to act between data providers and to develop an initial framework for in situ data that also takes into account how demand will change over time.

4.3 Copernicus Services Challenges

Prior to the Baveno Manifesto, it was recognised that real value would not emerge from satellite observations alone; space-based monitoring would need to be combined with data collected on the ground (*in situ data*). In the same way that meteorologists combine satellite and in situ observations to make predictions about the weather, Copernicus integrates satellite and in situ observations to yield useful analysis of a wide range of environmental data.

Public and private sector partners are involved in data processing and the conversion of raw data from space into useful maps and applications-focused information, provided as Copernicus "*services*". Access to data is a real challenge for Copernicus as it relies on a number of scientific networks funded by research projects, entailing risks for long-term sustainability. Another challenge is the consistency of in situ data, which are often collected at national and local level, closely linked to the work on the INSPIRE Directive and SEIS initiative, as well as with the development of sectoral knowledge bases (for example, the water related system WISE [25]; BISE on biodiversity [27], and others on soils [33]).

5 INSPIRE

The INSPIRE Directive [14] laid down the general rules establishing the spatial data infrastructure (SDI) in the EU countries in support of EU environmental policies and policies or activities that may have an impact on the environment since 2007. This was very important for development of environmental software systems of the EEA and the EU countries. INSPIRE should be based on the infrastructures for spatial information that are created by the EU countries. These infrastructures should ensure that [14]:

- spatial data are stored, made available and maintained at the most appropriate level;

- it is possible to combine spatial data from different sources across the EU in a consistent way and share them between several users and applications;
- it is possible for spatial data collected at one level of public authority to be shared between other public authorities;
- spatial data are made available under conditions that do not unduly restrict their extensive use;
- it is easy to discover available spatial data, to evaluate their suitability for the purpose and to know the conditions applicable to their use.

In particular, the spatial data sets and services provided by EU countries to EU institutions and bodies in order to fulfil their reporting obligations under EU legislation relating to the environment shall not be subject to any charging.

Article 17 of the INSPIRE Directive [14] defines the spatial data sharing requirements in more detail. It requires EU countries to adopt measures for the sharing of spatial data sets and services that enable its public authorities to gain access to these spatial data sets and services, and to exchange and use those spatial data sets and services for the purposes of public tasks that may have an impact on the environment. The measures should preclude any restrictions likely to create practical obstacles to the sharing that might occur at the point of use. Hence, procedures regarding, for example, property rights, licensing and charging must be fully compatible with the general aim of facilitating the sharing of spatial data sets and services between public authorities.

The state of implementation of INSPIRE [39] shows that INSPIRE is being implemented across the EU with some delay, and non-uniformity, but so far in line with expected costs and benefits. INSPIRE is starting to achieve its objectives, which according to 92 % of respondents in the 2014 public consultation are as pertinent as ever. Moreover, as indicated in [38], INSPIRE is increasingly recognised as a foundation framework for integrating on a spatial basis and making more effective and efficient a range of policies affecting the environment. The strong connection established between the flagship Copernicus programme and INSPIRE can be a very significant element in the implementation of the INSPIRE directive in coming years.

5.1 INSPIRE Enabled Interoperability of Spatial Data Sets and Services

The measures defined by INSPIRE to achieve the interoperability of spatial data sets and services are without a doubt the core of INSPIRE, and one that sets it apart from other similar SDIs in the world. The most of these measures have yet to be implemented. Evidence from the public consultation also indicates that this part of INSPIRE is technically complex, which is perceived by about 20 % of respondents as an obstacle to implementation and use [39].

There is little doubt that the measures put in place by INSPIRE are complex, but no alternative could be identified in order to achieve the interoperability objective. Whilst the actions related to interoperability are appropriate, further modifications might be taken into consideration in order to enable further benefits.

The INSPIRE roadmap for implementation spans until 2020 and it is therefore natural that there are still gaps in implementation, in particular for obligations for which deadlines have not yet passed. From the public consultation and the direct observations it is also evident that some aspects of the INSPIRE Directive — notably the coordination at national and cross‑border levels, and the removal of obstacles to data sharing at the point of use — would increase the EU added value if better addressed.

6 Conclusion

The adoption of the EEA and Eionet model of implementing environmental software systems and environmental modelling and information systems as well as SEIS and INSPIRE principles at regional/Pan-European and international/global level can ensure coherence at all levels and also helps streamlining efforts at national level. Consequently, and decision making processes of the EEA shall take this into account, the fast developments in environmental software systems and related ICT, their links and synergies will need to be strengthened and further explored with initiatives such as the EU Digital Agenda [16], the European Earth Observation Programme (Copernicus) [22], [31, 32], the Global Earth Observation System of Systems (GEO/GEOSS) [28], UNEP live [19], and other key initiatives related to data and information sharing [39].

The knowledge of the EEA of the development of environmental software systems is increasingly co-created, shared and used in the Eionet network (flexibility in terms of membership, roles assumed, goal orientation, type of knowledge created, shared or used, etc are important factors here). A flexible and strategic vision on the EEA role as initiator, node, hub or switch is important to continue knowledge co-creation, sharing and use between EEA, Eionet and beyond.

Strengthening the integration of EEA and Eionet activities, including capacity building, remain central to the MAWP 2014-2018. An integral part of this is a deepening of Eionet via an enhanced collaboration and integration between EU countries and EEA activities following the principles of SEIS, INSPIRE and Copernicus.

Key objectives of EEA environmental software systems therefore are:

- Ensure the quality, availability and accessibility (based on SEIS and INSPIRE principles) of data and information needed to support SA 1 and SA 2.
- Communicate actively data, information and knowledge to policymakers, the public, the academic world, to regional and international processes including those of the UN and its specialized agencies.
- Promote information governance as a driver of public empowerment and behavioural change.
- Provide support to the work in the above areas by building and maintaining networks of people and - where needed - environmental software systems as the basis for sharing and co-creating content,
- Communications will also play a major role in making sure that information is targeted and ensures a dialogue with stakeholders and the society at large. Targeted information, communication and participation remain important instruments.

EEA will further enhance and focus its outreach capacities responding to emerging challenges and societal developments. Societal trends such as the ways to access information, networking, and co-creation of knowledge are influencing the way the EEA is asked to work and communicate.

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