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## **Paving the way toward an environmental National Spatial Data Infrastructure in Armenia**

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**Abstract:** Armenia is a small country geographically located in the South Caucasus region. Once the most industrialized republic of the Soviet Union, the country inherited a dramatic ecological situation from the Soviet era. After the mid-1990s, the economic policy of Armenia shifted towards a strong support for industrial development greatly ignoring ecological interests. As a result, mining-related industries such as dressing and metallurgical plants were permitted to operate without environmental regulations, and geo-exploration and exploitation works in deposits were conducted disregarding nature protection norms. As the key national environmental academic entity, the Center for Ecological-Noosphere Studies of the National Academy of Sciences of the Republic of Armenia (CENS) has a strong national role in delivering authoritative environmental information and data sets. Aware of the need for enhanced and more efficient delivery of information and data sharing, CENS engaged in recent years in several international capacity building projects directed to the setting up of an environmental Spatial Data Infrastructure (SDI). The goal of this SDI was both to provide enhanced capacities for intra muro maintenance and exchange of data among research groups and to allow various external stakeholders to access more efficiently geospatial data sets and services. This first step was successful in showing the potential of data sharing for internal institutional organization, to gain visibility towards key stakeholders in the country and the South Caucasus region, and to start engaging in international voluntary partnerships such as the Group on Earth Observations (GEO). CENS now envisions to scale up its SDI infrastructure to a national SDI (nSDI) in order to support a wider range of geospatial services towards the Armenian environmental community. This paper will discuss several aspects and challenges of the envisioned strategy for an Armenian nSDI. First, we present how the current components of the implemented SDI benefit the scientific and environmental communities in Armenia, with an emphasis on the promising link between high performance computing and geospatial services. Second, we examine how the EGIDA methodology – a GEO capacity building suites of activities developed in the FP7 project of the same name – can be applied to support the process of scaling up the infrastructure to become a nSDI, which has been selected as a pilot study in the FP7 EOPOWER project. Finally, we discuss the potential of future full-scale provision of geospatial services in Armenia and how these could benefit the various stakeholders involved in Armenia and in the South Caucasus region.



# Paving the way toward an environmental National Spatial Data Infrastructure in Armenia

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## INTRODUCTION

The term Spatial Data Infrastructure (SDI) refers to technologies, policies and people supporting the sharing of geospatial information throughout all levels of government, commercial and the non-profit sectors, academia and citizens. The goal of an SDI is to make geospatial information more accessible to the public, to improve quality of this information, to avoid duplication effort and to "establish key partnerships with states, counties, cities, tribal nations, academia and the private sector to increase data availability" (FGDC 2013).

SDI can be implemented at different geographical scales. Well-known examples of SDIs are the Global Earth Observation System of Systems (GEOSS) (GEO Secretariat 2005) and the United Nations Spatial Data Infrastructure (UNSDI) (Henricksen 2007) at the global level, and the Infrastructure for Spatial Information in the European Community (INSPIRE) (European Commission 2007) at the regional level. At the sub-national level the example of Spain is singular as most provinces have built up their own SDI, e.g. IDEAndalucia, GeoEuskadi, Cartomur, IDECanarias and the SDI of Catalonia.

One of the first countries that implemented a National Spatial Data Infrastructure (NSDI) was the United States of America in the 1990s, under the impetus of the Federal Geographic Data Committee (FGDC). This initiative was engaged after President Clinton signed in 1994 the Executive Order 12906 that defined the NSDI as "the technology, policies, standards, and human resources necessary to acquire, process, store, distribute, and improve utilization of geospatial data" (Office of the Federal Register 1994). Many national initiatives have followed since that time, like in Australia under the impulse of the Australian and New Zealand Land Information Council (ANZLIC), in Malaysia (Arshad et al., 2010) and in the Netherlands (Kos and Van Loenen, 2005). The setting up of a NSDI is logically influenced by national specificities such as the political background, the technological state of progress and the environmental policy. In Japan for example the building of the NSDI was mainly driven by the concern for handling earthquake-related emergencies (Masser 2005).



## Environmental status of Armenia and data sharing activities

Geographically, Armenia lays in the northern part of the South Caucasus and is a place of origin of two major water arteries: rivers Kura and Araks. All countries of the region sharing borders with Armenia use Kura-Araks catchments and share emerging environmental problems. Activities targeting environment research, awareness and conservation in Armenia are vital for the country's future and by extension for the South Caucasus region.

Among the few organizations dealing with environmental studies in Armenia, the Center for Ecological-Noosphere Studies (CENS) of the National Academy of Sciences of the Republic of Armenia is an active group with strong national leadership. CENS carries out environmental research activities on the complex assessments and modeling of ecological state of various environmental compartments (soil, water, plants) and develops scientific and methodical fundamentals of ecological expertise and optimization of natural resource management processes in the country. As a result of these activities, CENS has built and filled since early 1990 a large spatio-temporal registered environmental fieldwork database, together with a file-based multi-scale geodatabase for Armenia. However, no centralized way of managing these environmental data and the national inventory of environmental data (emission, land-use, etc.) existed. To overcome this shortcoming, CENS together with University of Geneva and the Institute for Informatics and Automation Problems (IIAP, leading ICT research and technology development institute) of the National Academy of Sciences of the Republic of Armenia initiated the creation of the national distributed processing capacities for environmental data sharing which was successfully implemented and deployed in the framework of the SNSF-SCOPES ARPEGEO ("Armenian distributed Processing capacities for Environmental GEOspatial data", <http://arpegeo.sci.am>) project.



This project (2011-2013) enabled the deployment of the first environmental data sharing and interoperability services in Armenia, which strengthened the national capacities of geospatial data sharing, increased the visibility and national position of CENS as an expert in environmental research, and expanded their regional and international networks in this field. The ARPEGEO project strongly benefited from the existing firm foundation of the Armenian e-infrastructure that integrates networks, distributed computational and storage resources, experimental workbenches, data repositories, tools, instruments, and other operational support enabling national and global virtual research collaborations. The e-infrastructure is operated by IIAP for more than a decade and offers research data services and repositories enabling scientists from many disciplines to upload and share data in Armenia and beyond.

## Potential and benefits of an Armenian nSDI

Being integrated to the Global initiatives like GEO or into the European Research Area (ERA) will allow Armenia to (1) further enable scientific exchange and partnering between the Armenian researchers and colleagues from ERA through long term strategic partnerships; (2) give Armenian researchers more opportunities for joint research or projects collaborations with EU funded projects, thus addressing the national scientific brain drain problem (i.e., Armenian scientists leaving the country to find a job elsewhere); (3) improve the competencies needed by Armenian researchers and staff members to participate to the EU funded projects calls.

Now is the appropriate time to consider scaling up this SDI with the aim of becoming the authoritative environmental platform in Armenia, allowing both the Armenian data providers to register their data sets and services, and all Armenian stakeholders to benefit from the infrastructure by easily accessing its content in standardized ways. This vision is what we are referring to with the term Armenian environmental nSDI. The benefits of the envisioned Armenian environmental nSDI would be numerous and could directly profit other spheres, for example:

- An effective Armenian environmental nSDI could positively influence similar initiatives initiated elsewhere in the South Caucasus region. For example the neighboring country Georgia, which was just accepted as the 90th GEO member country, is still lacking a roadmap toward an environmental SDI. The close collaboration between many Georgian and Armenian researchers (notably through collaboration in the FP7 enviroGRIDS project; Lehmann et al., 2014) is greatly facilitating exchange of good practices and experience, which could help Georgia to better frame the actions related to their nSDI.

- The actions associated with implementing the Armenian environmental nSDI will also facilitate the organizational and policy aspects of the stakeholders involved. This will be of great help to finalize the membership of Armenia in GEO and the related follow-up actions (e.g., establishment of a national GEO Committee).

- An Armenian environmental nSDI could facilitate the integration of other types of data and associated services. For example, integration of environmental data with geological and meteorological data sets could make it possible to implement early warning systems for geological disasters.

The main output of the ARPEGEO project was an environmental Spatial Data Infrastructure combining data resources, distributed computing platforms and computational services. A web portal of interoperable geoprocessing services was as developed to offer complex geoprocessing capabilities, and to hide low-level access mechanisms to computational resources by high-level graphical interfaces, making even non-GIS expert users capable of defining and executing distributed applications. The geospatial and environmental data sets and their associated metadata existing at CENS were integrated into the SDI by adopting the international standards from the Open Geospatial Consortium (WMS, WFS, WCS) and from the International Organization for Standardization (ISO 19139, 19115) [Atsatryan et al., 2012]. Innovative WPS Web Processing Service workflows were developed to connect to the Geographic Resources Analysis Support System (GRASS GIS, Neteler et al., 2011) in order to compute a set of vegetation indexes on user-defined satellite images (Atsatryan et al., submitted a,b). These WPS workflows can access both grid and cloud resources of the Armenian National Grid Initiative (ArmNGI). The ArmNGI environment is used in case of distributed processing of large amounts of spatial data with very complex calculations.



## Applying the EGIDA methodology to Armenia

The FP7 project EGIDA (Coordinating Earth and Environmental Cross-Disciplinary Project to Promote GEOSS; <http://www.egida-project.eu>) has produced a general methodological approach for implementing a (re-)engineering process of the existing Science and Technology infrastructures and systems, to be adopted at the national/regional level for a sustainable contribution to GEOSS and other relevant European initiatives. The EGIDA methodology has been adopted by the FP7 EOPOWER project (<http://www.eopower.eu>) by applied to four pilot studies in which this methodology will be further improved. One of these pilot studies is Armenia, with the goal of "contributing to institutional Capacity Building in order to make Earth Observation resources optimally used towards sustainable development in Armenia". The realization of this pilot using the EGIDA methodology is therefore directly aligned with the vision of an Armenian environmental SDI, and will pave the way towards its realization.

The EGIDA Methodology is based on a System of Systems approach, through the mobilization of resources made available from the participation in national, European and international initiatives and projects, hence it seemed applicable in the context of infrastructural and technological recommendations for Open Access to research data.

As shown in Figure 1, the EGIDA Methodology defines two sets of activities running in parallel:

- Networking Activities: to identify and address the relevant Science and Technology community and actors (Community Engagement);
- Technical Activities: to guide the infrastructure development and align it with the GEO/GEOSS interoperability principles (Capacity Building).

For each activity several actions and sub-actions are defined, with related practices and guidelines derived from the design phase.

EGIDA defines three typical scenarios, depending of the scope of the planned action. The Armenia nSDI can be mainly related to EGIDA scenario S1, which is defined as:

S1) Regional/National Initiative Scenario: a national project aimed to deploy a national/regional infrastructure for sharing information relevant for GEO/GEOSS. Project partners may adopt the EGIDA METHODOLOGY for an effective and efficient mobilization of resources, in order to design and develop the infrastructure making it a sustainable contribution to GEO/GEOSS.

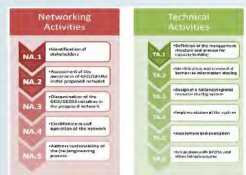


Figure - Overview of the main networking and technical activities in the EGIDA Methodology

## CONCLUSION

At the heart of the South Caucasus region, Armenia is currently suffering from several environmental problems. Some of them could be addressed and mitigated through improved environmental modeling, forecasting and analysis. Data availability and integration, and the connection to international data sharing initiatives such as GEO could greatly help in this regard. Paving the way to an environmental national SDI appears therefore as a priority for the key national players (CENS and IIAP) that deliver environmental data and associated services for already a long time. The recent involvement of CENS and IIAP in several major international European projects and initiatives targeting the improvement of data sharing is a very timely and ideal situation to envision a long leap forward for Armenia. The EGIDA methodology is also well suited to scale-up the existing SDI infrastructure and to improve the Armenian network of stakeholders. The experience that will be gained through this process will in turn help to improve the EGIDA methodology, which will benefit other countries in the region and beyond.

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EU FP7 EOPOWER project  
[www.eopower.eu](http://www.eopower.eu)

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[www.arpegeo.sci.am](http://www.arpegeo.sci.am)

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