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WEB-GIS DEVELOPMENT FOR GEOSPATIAL DATA DISSEMINATION IN EU OPERATIONAL PROGRAMMES

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Abstract

The ever increasing penetration of maps - the past decades in the classic web and today in any 'connected' smart device - and any type of potentially associated with them information, provides high capabilities of disseminating the outputs and results of a project especially when these are possessing spatial identity. This, combined with the increasingly strict dissemination requirements set by European Union for the beneficiaries of its funded Operational Programmes generates reasonable challenges to explore the capabilities of Web-GIS technologies for geospatial data dissemination purposes. Towards this direction, this paper attempts a review of the EU legislative framework established on top of INSPIRE directive and dealing with geospatial data and services critical issues such as: Metadata, Harmonization, Interoperability and Invocability. Through the experiences gained by the participation of authors in a Black Sea Basin Joint Operational Programme, a Web-GIS end user interface is presented along with the particularities and special requirements identified during project implementation. Furthermore, a demonstration of geospatial services invocability fulfilment is provided along with technical solutions.

Keywords: *Geospatial Dissemination, Geospatial Interoperability, Geospatial Services Invocability, Web-GIS, INSPIRE*

1. INTRODUCTION

Data dissemination was always a significant activity (Karatzas & Moussiopoulos, 2000) in all types of European Commission (EC) Operational Programmes (OP) and its legislative framework is continuously updated with new regulations and decisions (European Commission, 2016a). EC is paying special attention in data generated in its funding projects; for example, in the Horizon 2020 European Union (EU) Framework Programme calls, a special open data management activity, termed Open Research Data Pilot has been inserted in the proposal submission form, with the aim to make the research data generated accessible with as few restrictions as possible (European Commission, 2016b). In Black Sea Basin Joint Operational Programme (BSB JOP), as critical result indicator is considered the level of availability of monitoring data and information (ENI CBC, 2015). Special dissemination requirements arise for programmes where the spatial reference of the beneficiaries maters as for example happens in cross-border areas or interregional cooperation. In such cases, as most important particularity could be considered the need to apply the results and outputs of the projects in a boundary-specific area. Access to spatial data and various types of information is also required for assessment purposes by policy makers: for example environmental assessment at European level, is supported by data centers such as the European Soil Data Center (ESDAC) focusing on the state of soils in Europe (Panagos et al., 2012)

Extending the above rationale, one realizes the significance of the spatial identity of the data involved. The adjacency of the involved beneficiaries or their existence in a common area of the map justifies the employment of Geoinformation technologies for spatial data handling and management, with most representative tools, Geographic Information Systems (GIS). GIS today encompasses many critical aspects of geospatial data dissemination, including metadata information, geospatial web services, geospatial data sharing and interoperability, and all of the aforementioned terms are strongly related to the term Web-GIS (Evangelidis et al., 2014).

In this respect this paper exploits the experience gained by its authors through their involvement in a BSB project called SciNetNatHaz (A Scientific Network for Earthquake, Landslide and Flood Hazard Prevention, http://scinetnathaz.net/). One of the basic targets of the SciNetNatHaz project was the collection, harmonization, coding and free/open access of data related to Earthquakes-Landslides-Floods (ELF) hazards. At the final stage, all data and results produced had to be published through a Web-GIS platform. The particularities and special requirements raised in such a project lead to the design and development of an ergonomic end-user interface that is expected to serve the needs of representing not only the spatial information over the map, but also the related methodologies and descriptions. The whole Web-GIS development is thoroughly examined in the third section of the present work. Prior to this, the legislative EC framework with regard to spatial data requirements is reviewed. The fourth section, demonstrates the capability and the available options of reserving, the invocable geospatial web map services developed in the present work. Finally the paper enumerates the major difficulties met during the Web-GIS development and the potential challenges arising throughout such developments.

2. EU LEGISLATION FOR GEOSPATIAL

Requirements for both geospatial data and services involve, without being limited to, the following major topics: *Metadata, Interoperability, Harmonization and Invocability*. European legislation is built on INSPIRE Directive (European Commission, 2007; Bartha & Kocsis, 2011), upon which various regulations are being released, to meet the ever increasing geospatial technology progress. The following sections cover major activities related to the development of an EU funded project in conformance with the respective legislation for geospatial data and services.

2.1 Metadata creation

Metadata creation is an absolute necessity for data which are going to be distributed (open/freely accessed) because they provide valuable information necessary for their evaluation. Metadata records (descriptive data about the data) are files of information which describe the fundamental characteristics of a data file, an information resource or a geospatial service. It represents the “who”, “what”, “when”, “where”, “why” and “how” of the resource (FGDC, 2016).

EC has released the INSPIRE Directive (Infrastructure for Spatial Information in the European Community, Directive 2007/2/EC) which came into force on 15th May 2007 (European Commission, 2007). According to that, EU aims to create a Spatial Data Infrastructure (SDI) in order to facilitate the sharing of environmental spatial information among public sector organizations as well as the public access to spatial information across Europe, providing that way a better policy-making across boundaries (“European Commission,” n.d.). For the implementation of the aforementioned Directive regarding metadata, the European Commission (EC) released the Regulation (EC) No 1205/2008 of 3 December 2008 (European Commission, 2008) as well as supportive documents (European Commission, 2014)

2.2 Geospatial Data and Services Interoperability

The cooperative nature of the border dependant projects, raise the need to consistently combine spatial data from different sources, to share them among various end-users belonging to different authorities and to extensively exploit them through different applications. Furthermore, in a long term, the generated spatial data and project results will have to be discoverable, easy to be identified, the degree of their suitability will have to be evaluated and the terms of their usage to be explicitly defined. Thus, geospatial data involved throughout project activities will certainly have to conform to the EU INSPIRE directive, to ensure their compatibility and usability in a Community and transboundary context. In addition, interoperability of geospatial data from multiple sources will be achieved by defining the domain values to be used for attributes and the association roles of spatial object types and data types as specified by the EU regulation No 1089/2010 (European Commission, 2010), implementing INSPIRE directive.

2.3 Input from recognized EU projects

During a project design and implementation, valuable input from relevant projects dealing with identical or similar spatial entities, is expected to form the reference base for developing the data models on the lowest possible level and the accompanying metadata. The above are critical towards the development of an operational geographic database exploitable on future developments. Therefore, projects actions have to be aligned with the EU regulations implementing INSPIRE directive in order to achieve geospatial data services interoperability and harmonization (European Commission, 2010).

2.4 Geospatial Web Services Invocability

As "Invocable spatial data services" are defined (European Commission, 2014) those fulfilling EC metadata requirements (European Commission, 2008), having an accessible resource locator and also being publicly documented with technical information for their execution. According to the above recent EC regulation, geospatial data have to be served under invocable spatial data services. To conform with such a requirement geospatial web services should be implemented in accordance with the standards released by the Open Geospatial Consortium (OGC, http://www.opengeospatial.org/ogc) (Whiteside, 2007).

3. WEB-GIS DEVELOPMENT

3.1 The SciNetNatHaz BSB JOP project

The SciNetNatHaz (Scientific Network for Earthquake, Landslide and Flood Hazard Prevention) project's global objective is to achieve a strong regional partnership and cooperation by the development of a scientific network for the establishment of a scientific consensus, in order to setup common strategies and natural hazard prevention methods. Its members work together sharing competencies and resources to address earthquake, landslide and flood hazards which do have Trans - boundary consequences both on the economy and on the environment.

One of the specific objectives of the project was the development of a Web-GIS platform to support decision making and also provide data and information to the scientific community interested in Earthquake, Landslide and Flood Hazards (ELFH). Towards this direction, the Web-GIS development was based on open source software components, provided by the Open Source Geospatial Foundation (OSGeo, http://www.osgeo.org/), as regards both the final end-user web interface and the initial data preparation as well as the creation of the appropriate geospatial web services.

Figure 1 displays the development process workflow during initial project schedule, its discrete stages and the technical details during the transition between them. The following stages were identified:

1. Conceptual Design
2. Data Preparation
3. Metadata Creation

4. Desktop GIS - Spatial Data Presentation
5. Map Server - Web Map Services creation
6. Web-GIS - End user interface development

Figure 1. Web-GIS development Workflow

The following paragraphs describe in detail each stage and the intermediate processes.

3.2 Conceptual Design

The conceptual design of the system and the related data models, had taken into consideration relevant projects carried out in the past (synergies with previous research), as this, as already examined, is an EC spatial data requirement. Such a project was considered the InGeoClouds (Inspired GEOdata CLOUD Services) project (Sinigoj, 2014) which provided the data models dealing with earthquakes and landslides. These data models were further extended to fit SciNetNatHaz project requirements. An expansion was also necessary in order to incorporate and manage data related to floods.

Figure 2, illustrates the exploitation of existing data models from past projects, satisfying that way the related EU requirement described in section 2.3

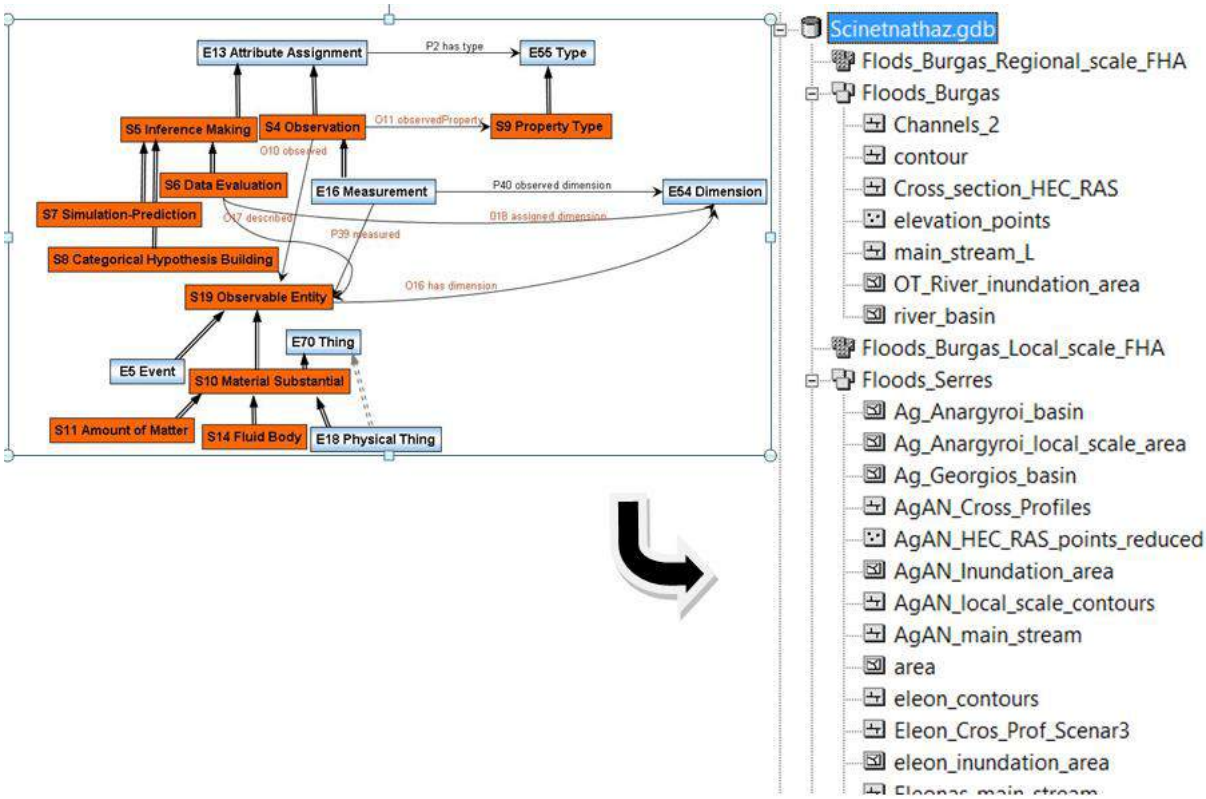

Figure 2. Exploiting existing data models from similar projects

3.3 Data Preparation

At this preliminary phase, basic data including topographic and geologic maps, hydrologic and meteorological data as well as additional information regarding past earthquake, landslide and flood events were collected from various sources from all the participating countries. Data were classified according to their thematic field, processed, harmonized, coded and prepared for further use.

Data were evaluated for their reliability in order to be used within the scopes of the project and those who failed the evaluation were rejected. Data which had a positive evaluation were forwarded for further processing which included all stages of the harmonization process: geo-referencing, spatial adjustments, reference system transformation, coding and metadata creation according to INSPIRE specifications.

Data preparation refers to the following data categories:

- General data (morphometric, geological, engineering etc.)
- Results after the application of selected methodologies

Depending on the hazard (flood, landslide or earthquake), the study area and the above mentioned categories, the following tree structure was adopted:

- Hierarchy Level 1: Hazard (Floods or Landslides or Earthquakes)
- Hierarchy Level 2: Pilot Implementation Area (e.g. Serres, Nymfaia etc.)
- Hierarchy Level 3: Data category (General Data or Results)

3.4 Metadata Creation

In this phase of the project implementation, the metadata files (records) for each collected dataset were produced according to the aforementioned INSPIRE Directive and its related regulations. The implementation of this procedure was based on the online tool "Metadata Editor" provided by the EC, INSPIRE Geo-portal (http://inspire-geoportal.ec.europa.eu/editor). The image below (Fig. 3) depicts the graphical user interface (GUI) of the metadata editor tool.

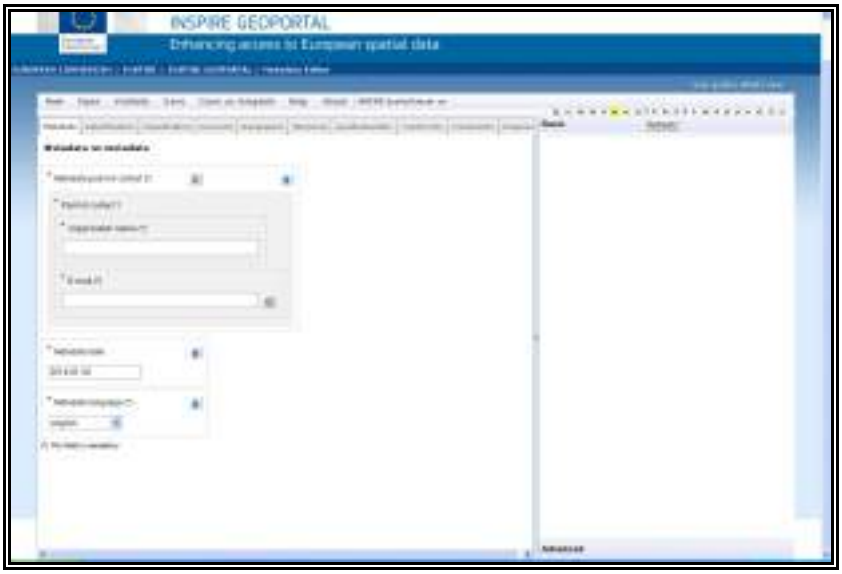

Figure 3. INSPIRE compatible Metadata Editor

After completion of the mandatory fields of information, the created records of metadata were saved in eXtensible Markup Language (XML) format, which is readable among various types of software including GIS related software. The metadata editor provides additionally a validation tool in order to examine the integrity of the generated metadata file.

3.5 Desktop GIS - Spatial Data Presentation

The QGIS (http://www.qgis.org/en/site/) , free and open source desktop GIS environment supported by OSGeo was selected for all spatial data processes. At this stage data prepared on stage 2 were imported in the selected desktop GIS environment and for every pilot implementation area a QGIS project was deployed containing the appropriate groups of data, spatial reference, symbology, description and metadata information.

The steps of the QGIS project deployment are briefly described, below:

- Step 1: Organizing data in the specified tree structure

In order to organize data the appropriate groups of data belonging to the same category had to be created. Grouping data is an area and hazard specific procedure. For example the groups created for presenting a hazard assessment contain morphometric and engineering geology data in the general data category, as shown in figure 4. In the same figure, the methodologies adopted are represented by different groups such as "Mora Vahrson" and "Hazus".

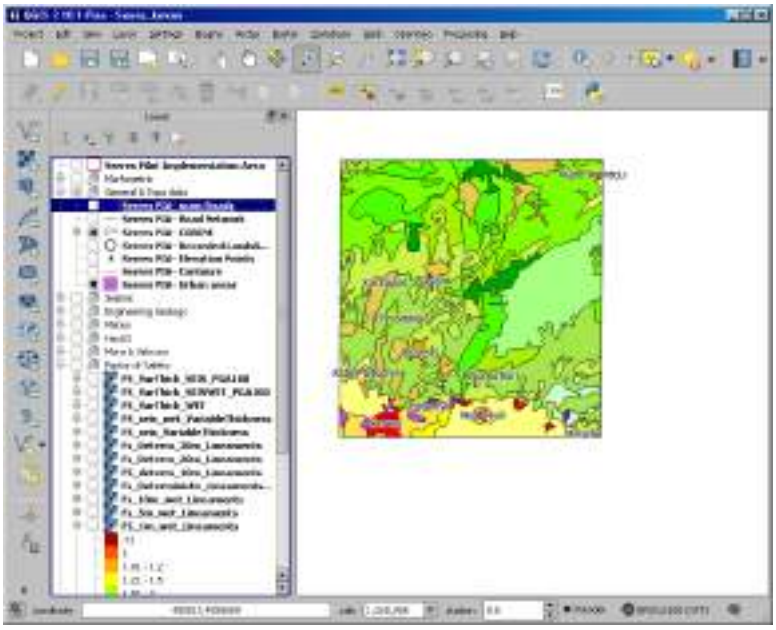

Figure 4. Organizing data for presenting a Hazard assessment

- Step 2: Symbolizing data

Data symbology is crucial for interpreting the results of an assessment. By specifying the range of values that correspond to a color, a legend was created for every layer and this symbology (Figure 5) was also transferred at the Web-GIS interface.

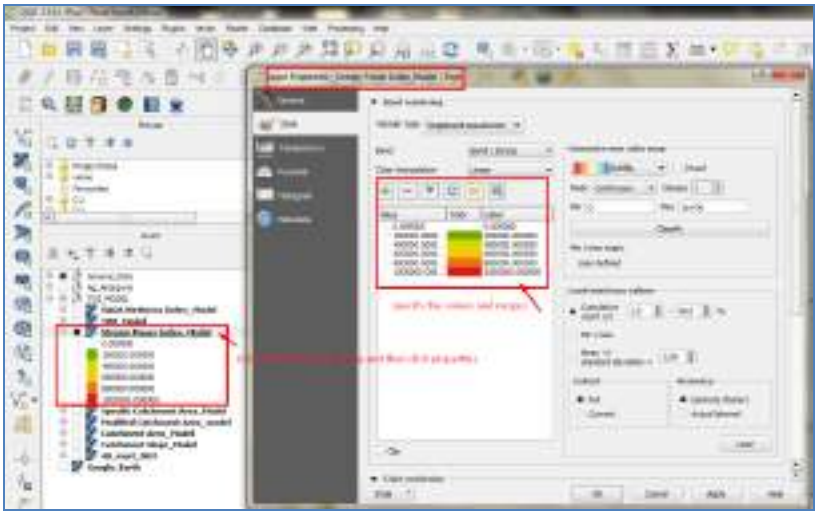

Figure 5. Data Symbology

- Step 3: Defining spatial reference

All data should belong to the same spatial reference system, which is WGS84 (EPSG: 4326)

3.6 Map Server - Web Map Services creation

Desktop GIS data had to be transformed in a way that will allow their web publishing. An open source map server was employed for this purpose, which also belongs to OSGeo foundation just as it happens with QGIS, the desktop GIS software selected. Geoserver (http://geoserver.org/), is a web mapping project, providing high level capabilities for sharing geospatial data. GeoServer supports OGC compliant standards such as Web Feature Service (WFS) (Vretanos, 2005), Web Map Service (WMS) (de la Beaujardiere, 2004), and Web Coverage Service (WCS) (Evans, 2003).

For every group layer a related workspace was created in order to store its layers. Every layer of the QGIS project was imported via the appropriate plug-in in the map server and a related Web Map Service was developed and parameterized as shown in Figure 6.

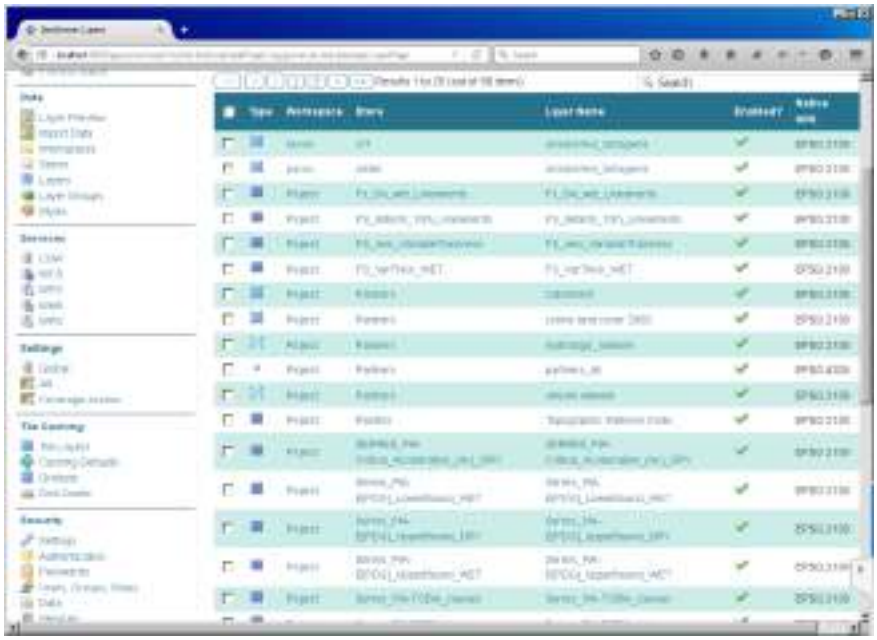

Figure 6. Creating geospatial web services

3.7 Web-GIS - End user interface development

The Web-GIS end-user interface was designed according to proven Web-GIS projects such as "Eyes on the forest" (http://maps.eyesontheforest.or.id/) (Uryu et al., 2010). The interface provides a high quality navigation experience by providing project thematic layers spatial representations and at the same time, metadata and comments on the respective related methodologies. In order to use technical information and data presentation simultaneously the end user interface design was based on three panes: a) the Layer pane, b) the Metadata/Information pane and c) the Map pane (Fig. 7).

All of the Web-GIS Interface functionality was developed with Javascript and HTML. The functional requirements as regards spatial data performance have been satisfied by employing OpenLayers (http://openlayers.org/) Javascript libraries. For the purposes of dividing the interface area in functional subareas, Jquery (https://jquery.com) Javascript libraries were employed.

A brief description of the interface panes is as follows:

- The left area (pane) contains the table of contents of the Web-GIS environment: the About section area, the base layers section area and a section area for every major category (Floods, Earthquakes and Landslides). Any of the above areas unwraps further content subareas when selected, which in most cases represent thematic areas with spatial vector and raster datasets. The structure of the various levels of layers follows the hierarchy described in section 3.2.
- The middle area reveals metadata information along with technical details for the selected topic of the left area. It is worth mentioning that the middle area provides the corresponding to the left pane content information even on mouse over the desired layer.
- The right pane contains the map of the selected pilot implementation area and the selected in the left pane spatial data layers.

The end user is allowed to customize the above areas with the desired width or to hide left and/or middle pane.

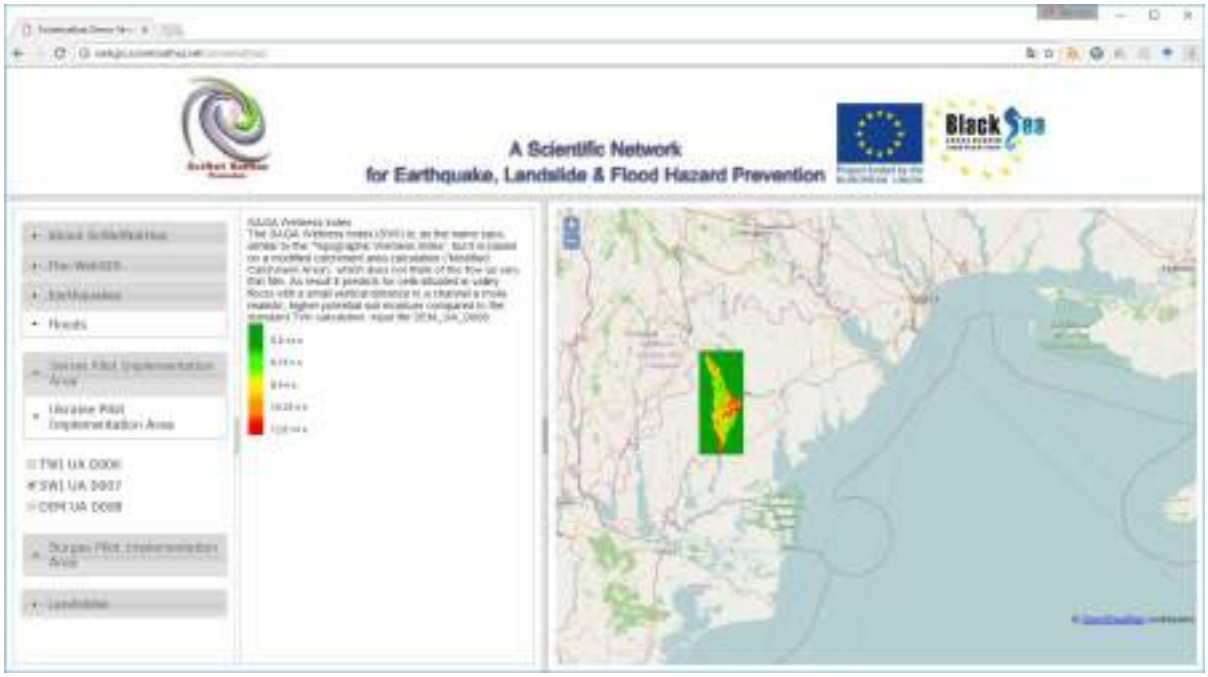

Figure 7. The three operational areas of SciNetNatHaz Web-GIS interface

4. DEMONSTRATING GEOSPATIAL DATA SERVICIES INVOCABILITY

Data services invocability is a quite recent requirement of the EU legislative framework and has been examined in section 2.4. At this section, the capability of re-serving, reusing, or even parameterizing a Web Map Service provided by SciNetNatHaz project Web-GIS environment, is demonstrated.

4.1 Data Services Reuse and Parameterization

The simplest way to retrieve a WMS service and apply simple modifications on its basic parameters is by using REST requests through the browser's URL address bar, as shown in the example below:

```
http://83.212.59.12:8080/geoserver/Project/wms?
service=WMS&
version=1.1.0&
request=GetMap&
layers=Project:Critical_Acceleration__Ac__DRY_clip&
styles=&
bbox=458124.32206279394,4547301.035222588,479785.5518268988,4570134.933970493&
width=728&
height=768&
srs=EPSG:2100&
format=image/png
```

The result of the above URL submitted request on SciNetNatHaz Web-GIS server is presented in figure 8:

Figure 8 shows the Ac/PGA Index (FEMA Methodology for landslide hazard assessment. The index is calculated as the ratio of Critical Acceleration (Ac) defined as the horizontal acceleration that produces a factor of safety Fs=1.0 on the slope, to the imposed PGA for a 475yrs earthquake).

By examining the parameters of the above WMS/GetMap request it is easy to apply some simple modifications such as for example on the Bounding Box (bbox parameter), or the pixel resolution of the image (width and height parameters) or the presentation format (format parameter).

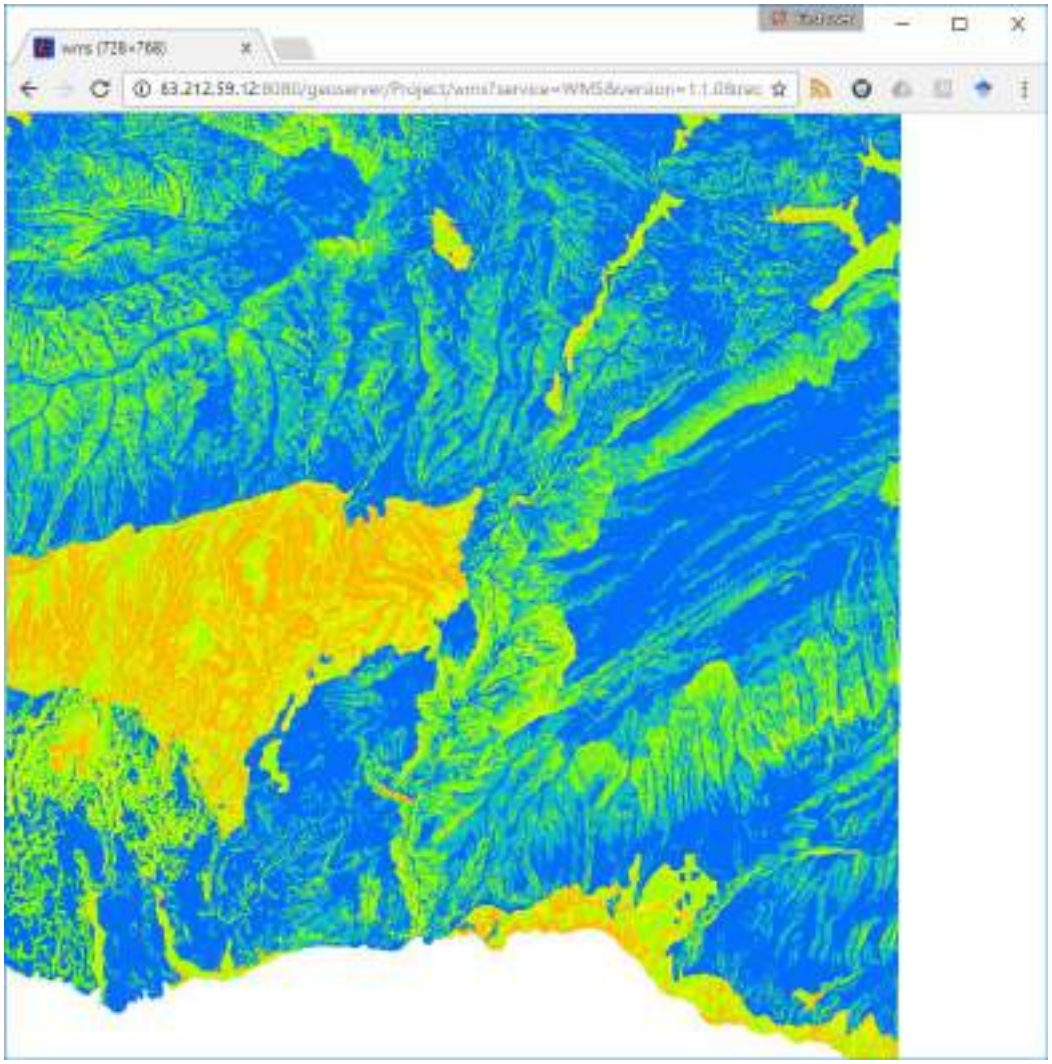

Figure 8. Submitting a REST request on SciNetNatHaz Web-GIS server

4.2 Data Services Re-serving

Data services re-serving, takes place in cases of incorporating open WMS services in another custom web interface. This is an ordinary need and is met in routine activities not necessarily involving geospatially referenced information, as for example, financial data, meteorological data etc. In such cases the primary server allows external requests and provides the requested information through appropriate web services. In the case of spatial information a communication between the two servers, the one initially serving a WMS service and the other which is going to re-serve the WMS service at a later stage, is required. A way to connect two servers is through a proxy connection. In a simple proxy connection the chained server acts like a gateway to the parent server hosting the data to be retrieved and passes unmodified the requests and the responses to the parent server and to the client accordingly.

A simple Javascript coding for submitting a request and getting the server response that may be later re-served is presented in the following lines. In order to submit a request of the previous section locally through a Javascript interface it is possible to utilize the Yahoo Query Language (YQL) Console API (https://developer.yahoo.com/yql/console/) as a proxy server. This way, it is possible to access data of different domains and therefore to overcome

the ‘Same Origin Policy’(https://en.wikipedia.org/wiki/Same-origin_policy) issue. A YQL link example (YQLURL) is as follows:

```
https://query.yahooapis.com/v1/public/yql?q=
select *
from xml
where
url='http://demo.boundlessgeo.com/geoserver/wms?service=wms%26request=getCapabilities
'
```

Through the above example a GetCapabilities request is formed, for getting the available maps offered by the server. This request can be further parameterized through an AJAX (Asynchronous JavaScript and XML) client request using the XMLHttpRequest function, as shown below:

```
var xmlReq = new XMLHttpRequest();
xmlReq.open("GET", YQLURL, true);
xmlReq.onreadystatechange = function(){
   if (xmlReq.readyState == 4 && xmlReq.status == 200) {
      //handle the response
      var xmlDoc = xmlReq.responseXML;
      // . . .
   };
xmlReq.onerror = function(){
   //handle the error (e.g. show at the message pane)
};
xmlReq.send(null);
```

In the above code snippet a new `XMLHttpRequest` object is created. It should be noted that older versions of internet explorer (IE5 and IE6) do not support the "XMLHttpRequest" object in which case new "ActiveXObject("Microsoft.XMLHTTP");" object can be used instead.

Then the "open() method" initializes a newly-created request, or re-initializes an existing one with parameters a GET method, the URL request, and in case the request is performed asynchronously is set to "true"

The "onreadystatechange" is a callback function. Whenever the "readyState" attribute of the "XMLHttpRequest" object changes an "EventHandler", calls this function in which case the response is handled only if the readyState is completed (case 4) and the response status is "200 OK" (https://developer.mozilla.org/en-US/docs/Web/API/XMLHttpRequest/readyState, https://developer.mozilla.org/en-US/docs/Web/HTTP/Status)

The "onerror" property is a callback function to be executed when the request fails. (https://developer.mozilla.org/en-US/docs/Web/API/XMLHttpRequestEventTarget/onerror). Then the "send()" method sends the request to the server and takes an optional parameter which is the body of the request that consists of any data to be send to the server. (https://developer.mozilla.org/en-US/docs/Web/API/XMLHttpRequest/send)

Finally, the server responds with XML data that may be parsed to a JSON object and be viewed on the end-user interface as paged table data.

```
<query xmlns:yahoo="http://www.yahooapis.com/v1/base.rng" yahoo:count="1"yahoo:created="2016-09-25T12:58:27Z" yahoo:lang="el-GR">
<results>
<WMS_Capabilities
xmlns="http://www.opengis.net/wms"xmlns:xlink="http://www.w3.org/1999/xlink"xmlns:xsi="http://www.w3.org/2001/XMLSchema-
instance"updateSequence="164" version="1.3.0"xsi:schemaLocation="http://www.opengis.net/wms
http://83.212.59.12:8080/geoserver/schemas/wms/1.3.0/capabilities_1_3_0.xsd">...</WMS_Capabilities>
</results>
</query>
```


5. CONCLUSIONS

Geospatial data dissemination may be nowadays adequately supported by open source software such as the popular OSGeo geospatial solutions. A combination of a) QGIS, open source desktop application for performing routine GIS tasks, b) Geoserver, web mapping software for developing geospatial services and c) custom Javascript applications on top of capable geospatial libraries such as OpenLayers and GeoExt, may support the typical development process workflow of the Web-GIS component of an EU research project. The aforementioned were employed for SciNetNatHaz, a BSB JOP project dealing with ELF issues, therefore involving pure spatial data or data with spatial identity. Throughout the whole development process of the SciNetNatHaz project the various involved experts, realized the significance of a proper Web-GIS interface as the key component for the success of the dissemination activities. However, the Web-GIS experts and developers faced the common difficulties met in cooperative projects involving partners from different countries with different groups of expertise and different priorities during project implementation. As expected, the most significant GIS aspect, strongly affected by such differentiations is that of Metadata. Lack of common standards, terminologies and low level data models, or lack of applicability of existing ones in partners' local conditions, generated divergences, gaps, opposed perceptions and understandings etc. The above obstacles affected the Web-GIS scheduled workflow and further corrective actions had to be taken with most significant ones: a) additional presentations of the Web-GIS progress in stakeholders meetings b) special training on the spatial data development activities and c) working groups between GIS experts and ELF software experts.

As soon as a project is completed a set of appropriate data services are officially launched presenting the outputs in various forms, such as texts, tables and maps. These data services have to be open for re-usage, parameterization and re-serving, according to recent EU legislation regarding access to the generated results of a funded project. The fulfillment of this requirement is demonstrated in the presented work by simply submitting REST requests through the browser's URL address bar. As long as the Web-GIS server of the project supports open geospatial services it is possible to explore the available geospatial data by submitting WMS-WFS/GetCapabilities requests. Then, it is possible to request specific data layers and parameterize critical parameters such as the coordinate reference system, the bounding box etc. Through the presented work the SciNetNatHAz Web-GIS server demonstrated the above mentioned interaction. Reserving geospatial data requires communication between the two involved servers: the one initially serving data and the other re-serving them. The Web-GIS server developed, again, satisfied this need by establishing

communication with a proxy server employed for this purpose. Finally, the demonstration process included advanced asynchronous requests for XML based data formats that may be further processed for presentation purposes.

Further actions concerning the Web-GIS environment include, enhancement with other publicly available geospatial web services in the area of ELF as well as sophisticated animations illustrating the progress of phenomena related to ELF based on spatiotemporal data.

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