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***The analysis of open source software and Data for  
establishment of GIS services throughout the network in  
a mapping organization at National or International  
level***

MEHRDAD JAFARI SALIM

Tutor:

Prof. Piero Boccardo

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## INTRODUCTION

Federal agencies and their partners collect and manage large amounts of geospatial data but it is often not easily found when needed, and sometimes data is collected or purchased multiple times. In short, the best government data is not always organized and managed efficiently to support decision making in a timely and cost effective manner.

National mapping agencies, various Departments responsible for collection of different types of Geospatial data and their authorities cannot, for very long, continue to operate, as they did a few years ago like people living in an island. Leaders need to look at what is now possible that was not possible before, considering capabilities such as cloud computing, crowd sourced data collection, available Open source remotely sensed data and multi source information vital in decision-making as well as new Web-accessible services that provide, sometimes at no cost. Many of these services previously could be obtained only from local GIS experts. These authorities need to consider the available solution and gather information about new capabilities, reconsider agency missions and goals, review and revise policies, make budget and human resource for decisions, and evaluate new products, cloud services, and cloud service providers.

To do so, we need, choosing the right tools to rich the above-mentioned goals. As we know, Data collection is the most cost effective part of the mapping and establishment of a Geographic Information system. However, it is not only because of the cost for the data collection task but also because of the damages caused by the delay and the time that takes to provide the user with proper information necessary for making decision from the field up to the user's hand. In fact, the time consumption of a project for data collection, processing, and presentation of geospatial information has more effect on the cost of a bigger project such as disaster management, construction, city planning, environment, etc. Of course, with such a pre-assumption that we provide all the necessary information from the existing sources directed to user's computer.

The best description for a good GIS project optimization or improvement is finding a methodology to reduce the time and cost, and increase data and service quality (meaning; Accuracy, updateness, completeness, consistency, suitability, information content, integrity, integration capability, and fitness for use as well as user's specific needs and conditions that must be addressed with a special attention).

Every one of the above-mentioned issues must be addressed individually and at the same time, the whole solution must be provided in a global manner considering all the criteria.

In this thesis at first, we will discuss about the problem we are facing and what is needed to be done as establishment of National Spatial Data Infra-Structure (NSDI), the definition and related components. Then after, we will be looking for available Open Source Software solutions to cover the whole process to manage; Data collection, Data base management system, data processing and finally data services and presentation. The first distinction among Software is whether they are, Open

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source and free or commercial and proprietary. It is important to note that in order to make distinction among softwares it is necessary to define a clear specification for this categorization. It is somehow very difficult to distinguish what software belongs to which class from legal point of view and therefore, makes it necessary to clarify what is meant by various terms. With reference to this concept there are 2 global distinctions then, inside each group, we distinguish another classification regarding their functionalities and applications they are made for in GIScience.

According to the outcome of the second chapter, which is the technical process for selection of suitable and reliable software according to the characteristics of the users need and required components, we will come to next chapter. In chapter 3, we elaborate in to the details of the GeoNode software as our best candidate tools to take responsibilities of those issues stated before.

In Chapter 4, we will discuss the existing Open Source Data globally available with the predefined data quality criteria (Such as theme, data content, scale, licensing, and coverage) according to the metadata statement inside the datasets by mean of bibliographic review, technical documentation and web search engines. We will discuss in chapter 5 further data quality concepts and consequently define sets of protocol for evaluation of all datasets according to the tasks that a mapping organization in general, needed to be responsible to the probable users in different disciplines such as; Reconnaissance, City Planning, Topographic mapping, Transportation, Environment control, disaster management and etc...

In Chapter 6, all the data quality assessment and protocols will be implemented into the pre-filtered, proposed datasets. In the final scores and ranking result, each datasets will have a value corresponding to their quality according to the sets of rules that are defined in previous chapter.

In last steps, there will be a vector of weight that is derived from the questions that has to be answered by user with reference to the project in hand in order to finalize the most appropriate selection of Free and Open Source Data. This Data quality preference has to be defined by identifying a set of weight vector, and then they have to be applied to the quality matrix in order to get a final quality scores and ranking. At the end of this chapter there will be a section presenting data sets utilization in various projects such as "Early Impact Analysis" as well as "Extreme Rainfall Detection System (ERDS)- version 2" performed by ITHACA.

Finally, in conclusion, the important criteria, as well as future trend in GIS software are discussed and at the end recommendations will be presented.

# 1. SPATIAL DATA INFRASTRUCTURE COMPONENTS AND CONSIDERATIONS

## 1.1 INTRODUCTION

Regardless to the governmental or nongovernmental, field of activities, size of the company and etc. in any mapping organization the goal is to provide access to geospatial information to be used by the users. Its effectiveness depends upon(TCO CEE Terrestrial Carbon workshop 2002):

- How easy the information is to access,
- The quality of the information available, and
- The tools you have available to create information “products” to support your decisions.

That information could be in document, geographic, spreadsheet, or multimedia format, however, it must be available in the *right place* at the *right time*.

Moreover, the access must be meaningful and user friendly. This means increased emphasis on making sure the information and data that are published are in a format that is useable and understandable.

*A Spatial Data Infrastructure is the technologies, policies, and people necessary to promote sharing of geospatial data throughout all levels of government, the private and non-profit sectors, and the academic community<sup>1</sup>.*

In other word, a Spatial Data Infrastructure (SDI) provides the structures, technology and rules to enable the publishing and access of integrated information – and thus get a meaningful and holistic picture of what is happening where.

## 1.2 DRIVING FACTORS TOWARD IMPLEMENTATION OF SDI

There are many factors “driving” the need for, interest in the development of a Spatial Data Infrastructure. In general, some common “drivers” for the development of a national or regional integrated response to information publishing and access include:

### 1.2.1 NEED TO BE MORE RESPONSIVE TO KEY PARTNERS AND CLIENTS

Decision-making today requires that the systems and information to be there to support it.

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<sup>1</sup> (US FGDC, <http://www.fgdc.gov/SDI/SDI.html>)

This often means streamlined approvals processes, access to the right information when it is needed, and information tools that enable staff to handle the additional loads and pressures.

Governments around the world are racing to streamline or eliminate perceived or real barriers to economic development. While the economic benefits of land related activities – such as agriculture, mining, environmental management – are large, there is often significant competition among many jurisdictions. Governments also face the challenge of development being done in a context of wise use and sustainability. Economic development and social development go hand in hand. The availability of data and information helps to ensure appropriate decisions and to eliminate barriers.

Over 80% of all government information has a spatial component or context. Geography therefore can serve as the common thread to weave together diverse databases. In fact, an effective “E-Gov” (the new service model) cannot be achieved without “G-Gov” (Geospatial data and GIS).

### 1.2.2 DEMAND FOR GREATER ACCOUNTABILITY

“Open government” policies at all government levels have created expectations in the public for increased access to information regarding government decision-making. Therefore, governments must ensure their business practices reflect the public demand for accountability. This means new approaches and tools need to be employed to enable staff to fully and properly record relevant data, to perform the necessary checks/audits, and to derive the necessary information on which to make sound decisions.

### 1.2.3 OPPORTUNITIES PROVIDED BY NEW TECHNOLOGIES

Current web and desktop technologies now mean that it can be relatively easy and cost effective to provide information publishing and access capabilities. Very low cost web browsers can be used to search for, access, and visualize geospatial information from any compliant server on the Internet. This presents a significant opportunity for *transitioning* nations to advance their SDI more rapidly.

### 1.2.4 ELECTRONIC EXCHANGE OF DATA AND INFORMATION

The Internet is increasingly becoming a viable vehicle for business applications and electronic commerce. Almost all governments and businesses and many individual computer users are adopting some Web-based computing technology as a means of interacting, researching, providing services, selling products. This trend presents new opportunities to change and enhance how all government business and communications takes place with clients and partners – in both directions.

## 1.3 SDI BENEFITS

In general, SDI benefits are reflected through:

- **Maximizing use:** Ready access to government data will encourage more extensive use of a valuable public resource for the benefit of the community;
- **Avoiding duplication:** By sharing data, the need for separate bodies to collect the same data will be avoided resulting in significant cost savings in data collection and maintenance;
- **Maximized integration:** By adopting common standards for the collection and transfer of data, more integration of individual and often disparate databases is possible.

- **Custodianship:** The identification of custodians for the principal data sets enable users to identify those responsible for implementing prioritized data collection programs and for developing data standards.
- **Better decision-making:** Ready access to existing spatial data is essential for many decision-making tasks such as protecting the environment, development planning, managing assets, improving living conditions, and national security, Improving ability for local, national, regional, and global decision making on issues of environmental, economic, and social importance.
- **Equity of access:** A more open data transfer policy ensures better access by the whole community.
- **Communications:** Communications on many levels – even program goals, objectives, and results are enhanced.
- **Partnership** and new business process opportunities.

#### 1.4 COMPONENTS OF A SPATIAL DATA INFRASTRUCTURE

A spatial data infrastructure successfully combines leadership, people, computer networking, publishing and access software, data, policies, and metadata into a framework that helps put the appropriate tools and rules in place to maintain data and turn them into useful information products to support operations and decision-making. The following diagram illustrates the components of a spatial data infrastructure solution.

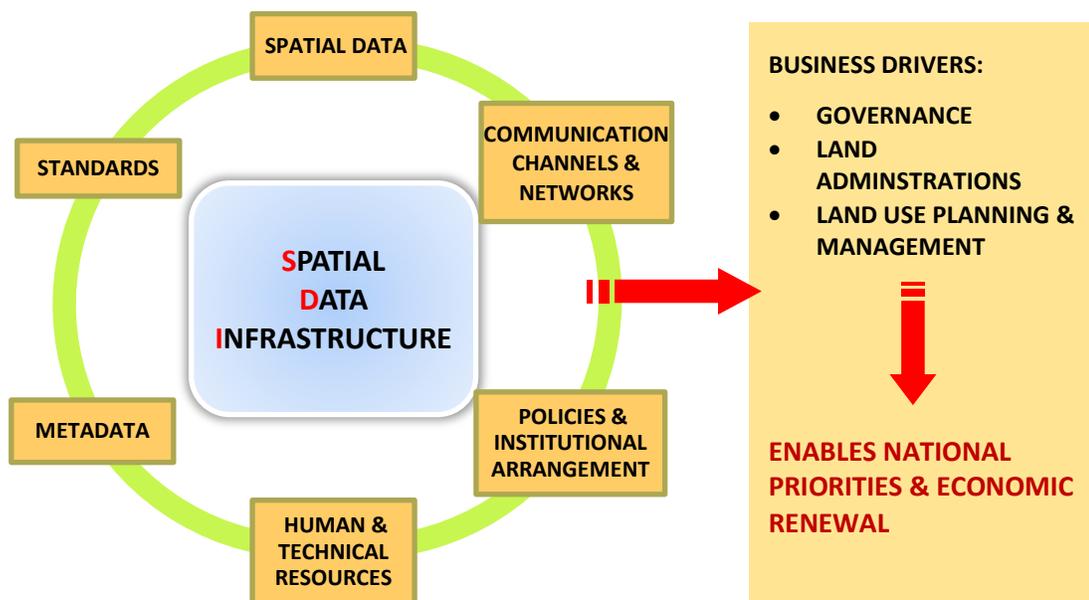


Figure 1: Components Of A Spatial Data Infrastructure

In order a SDI to be used, people need to know that the data exist, and how they can obtain it, therefore:

- They need to be authorized to look and access the data.
- They need to know the history of the data capture, in order to interpret it correctly, trust it and be able to integrate it meaningfully with data coming from other sources.

## Spatial Data Infrastructure Components and Considerations

- They need to know if the data relates and depend on the other data sets, in order to make sense of data.

Consequently, to leverage the full potential of geospatial data, an SDI must be made of different components to allow users to find, discover, evaluate, access and use these data, namely: (see Figure 1)

- A clearly defined core of spatial data;
- The adherence to known and accepted standards and procedures;
- Databases to store data and accessible documentation about the data, the so-called metadata;
- Policies and practices that promote the exchange and reuse of information;
- Adequate human and technical resources to collect, maintain, manipulate, and distribute geospatial data.
- Good communication channels between people/organizations concerned with Geodata, allowing the establishments of partnerships and shared knowledge;
- The technology for acquiring and disseminating data through networks;
- Institutional arrangements to collaborate co-operate and coordinate actions;

Besides the technical components that connect data 'islands' via the Internet, other aspects such as licensing agreements, data transfer standards, and data access policies must also be put in place to ensure consistent and reliable access. Consequently, a spatial data infrastructure is not only a technical facility, but also a complete framework that includes political, technical, business and social aspects (Shamei, B, et. al. 2004).

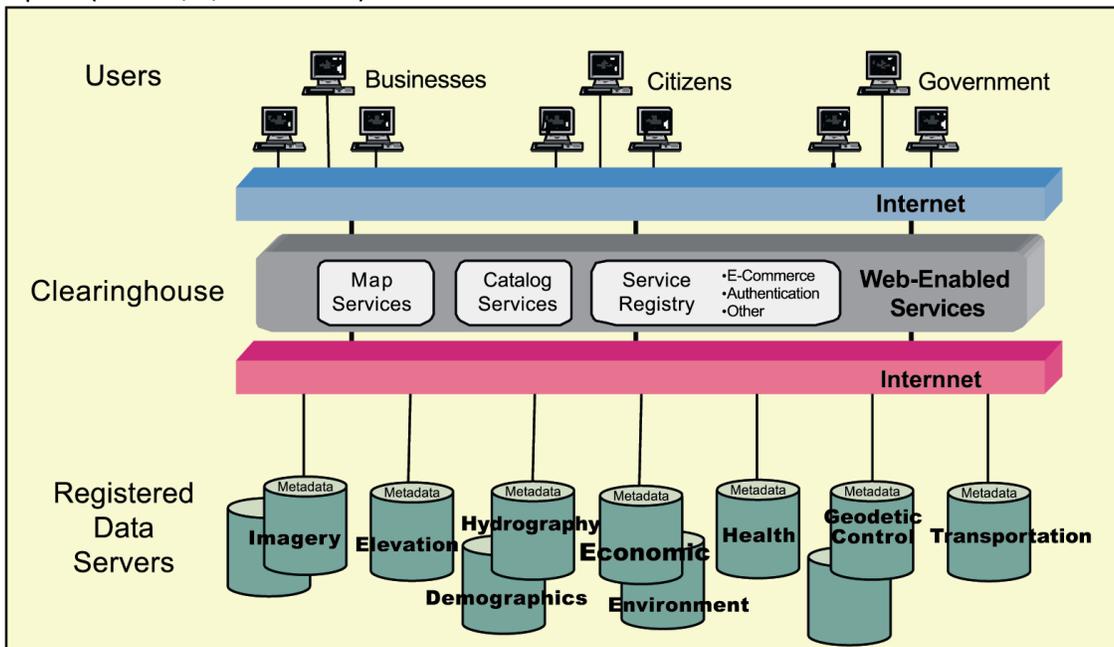


Figure 2: Functioning SDI

### 1.5 GIS SOFTWARE NEEDS IN SDIS

A Spatial Data Infrastructure should enable the discovery and delivery of spatial data from a data repository, ideally via one or more web services. Additionally, it is often desirable that the data provider is able to (remotely) create and update spatial data stored in a repository. Hence, the basic software components of an SDI consists of

1. a software client that can display, query, and analyze spatial data;
2. a catalogue service for the discovery, browsing, and querying of metadata or spatial services, spatial datasets and other resources;
3. a spatial data service that enables the delivery of the data via the Internet, and/or processing services such as datum and projection transformations;
4. a (spatial) data repository;
5. GIS software (client or desktop) that permits the creation and maintenance of data (Fig.1);

The catalogue service (item no: 2. above) functions in a similar manner to analogue directories such as the Yellow Pages. The extent of processing services (no: 3 above) is somewhat unlimited, but transformation services are generally fundamental to a distributed system.

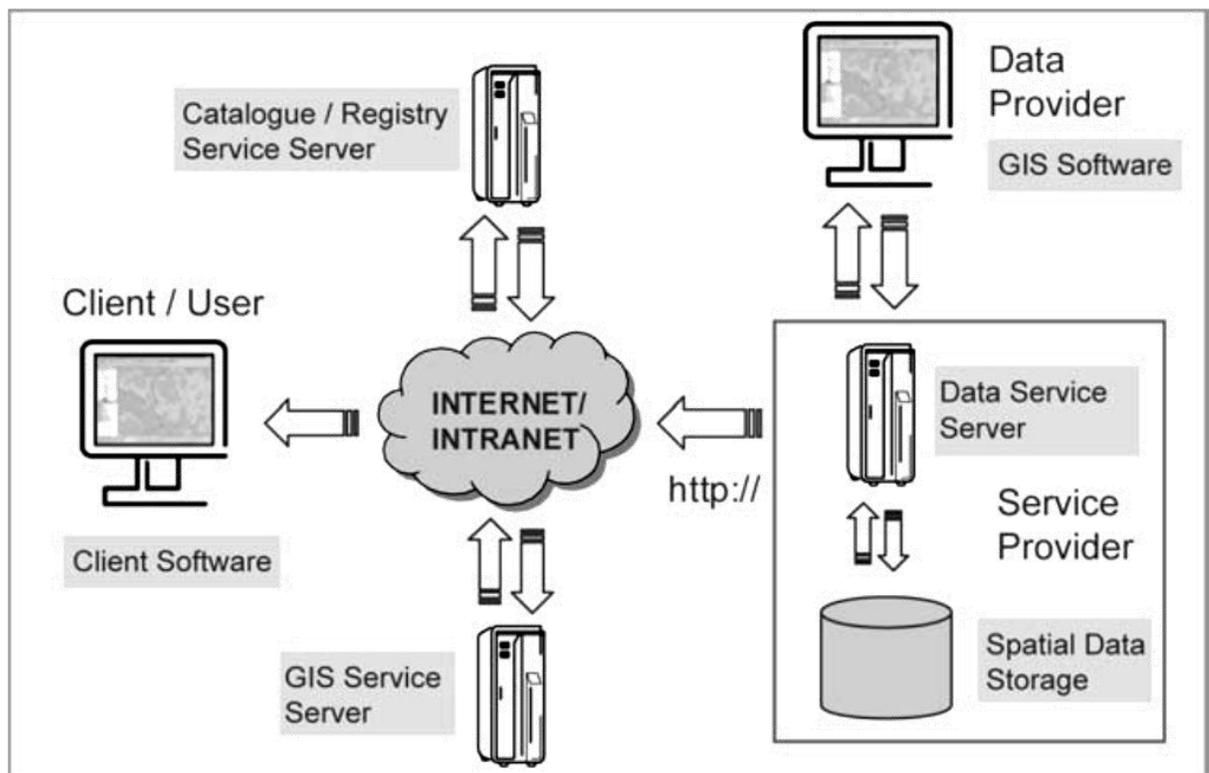


Figure 3: GIS SOFTWARE NEEDS IN SDI

## 1.6 CONCLUDING REMARKS

Our software review shows that for all categories of GIS software required for the implementation of an SDI, a free and open software product is available. A more detailed examination also reveals that several free products are able to compete with proprietary software, in particular the WebMap server projects, the spatial DBMS PostGIS, and the data viewer OpenLayers. Indicators for competitiveness in these instances are the number of “real-world installations” and their use in high-demand environments. However, if an organization chooses to implement an SDI using FOSS (2.4), then the appropriateness of FOSS projects and software need to be assessed. Key criteria for such an assessment are:

1. Functionality;
2. Support of common data distribution standards (e.g. OGC, ISO, CEN standards);

## Spatial Data Infrastructure Components and Considerations

3. Supported platforms (Windows vs. Linux, etc.);
4. Software reliability;
5. Options for customization;
6. Distribution costs,
7. Installation and maintenance effort (incl. costs),
8. Training and support options including pricing;

For a first evaluation of the software it is recommended that adopters make use of GIS distribution packages (for Linux), or Virtual Machine.

The licenses used by free and open source products ensure a low acquisition cost (typically no cost) for the software itself, and ensure that the software is customizable and adaptable to the SDI context. Hence, and with respect to the latter point, free and open source software often implement a wide set of (OGC) standards (See 2.1), and if not, at least permit the implementation/addition of components that are OGC/ISO standard compliant. The use of open source licenses allows an adopter to deploy SDI components to other locations at no additional cost, e.g., for horizontal scaling of a system. Finally, we note that helpful user and developer communities exist, and that support and maintenance options are offered by various companies, which are similar to those currently offered by proprietary software vendors. In summary, we see that FOSS4GIS software can provide a viable alternative to proprietary products - and we hope that our review helps to assess the utility of FOSS4GIS for SDIs. In Next Chapter, there will be a detailed review over the existing software to cover all the tasks that has been defined in this chapter for implementation of SDI.

## 2. THE STATE OF THE ART AVAILABLE SOFTWARE & SOLUTION

Choosing the right tools to perform a task is one of the key issues in any technical project. The right and the wrong is somehow a rational subject that may vary in time and places and mostly dependent upon the individual's point of view and corresponding constraints. From the other hand, there is no definite answer or 100% certainty for any decision taken to address quality-oriented phenomena.

In This chapter there will be sections regarding some definition of standards, Free, and open Source, as well as proprietary software leading to classification and listing of different types of GIS software according to their functionalities. There will be finally a part about the question that has to be answered by user with reference to the project in hand in order to finalize the most appropriate selection of FOSS<sup>1</sup>. In that section the important criteria that must be considered as well as future trend in GIS software are discussed and finally the recommendations and conclusion will be presented.

### 2.1 OPEN GEOSPATIAL CONSORTIUM (OGC) STANDARD

The Open Geospatial Consortium (OGC 2013) is an international industry consortium of 473 companies, government agencies, and universities participating in a consensus process to develop publicly available interface standards. OGC® Standards support interoperable solutions that "geo-enable" the Web, wireless and location-based services, and mainstream IT. The standards empower technology developers to make complex spatial information and services accessible and useful with all kinds of applications. In fact, OGC encourages development and implementation of open standards for geospatial content, processing, services, and data sharing.

OGC® and OpenGIS® are registered trademarks of the Open Geospatial Consortium. OGC is the brand name associated with the standards and documents produced by the OGC. The OGC Standard is "A document, approved by the OGC Membership that provides rules and guidelines, aimed at the achievement of the optimum degree of order (interoperability) in a given context.

When OGC standards are implemented in products or online services and two different software engineers working independently, the resulting components plug and play, and they work together without further debugging.

Therefore, it is important to find the OGC trademark associated with products that implement standards and have obtained the Certified OGC Compliant brand.



Figure 4: OGC Compliance

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<sup>1</sup> FOSS; Free and Open Source Software, FOSS4G; Free and Open Source Software for Geospatial information

Most of the OGC standards depend on a generalized architecture captured in a set of documents collectively called the Abstract Specification, which describes a basic data model for representing geographic features.

OGC(R) standards are technical documents that detail interfaces or encodings. Software developers use these documents to build open interfaces and encodings into their products and services. These standards are the main "products" of the Open Geospatial Consortium and have been developed by the membership to address specific interoperability challenges.

In developing a Web services application using OGC standards it helps to think of publish, find and bind as the key functions for applications in a Web services environment. See Figure 5

**Publish:** Resource providers advertise their resources.

**Find:** End users and their applications can discover resources that they need at run-time.

**Bind:** End users and their applications can access and exercise resources at run-time. Most of the OGC standards developed in recent years are standards for the Web services environment, and these

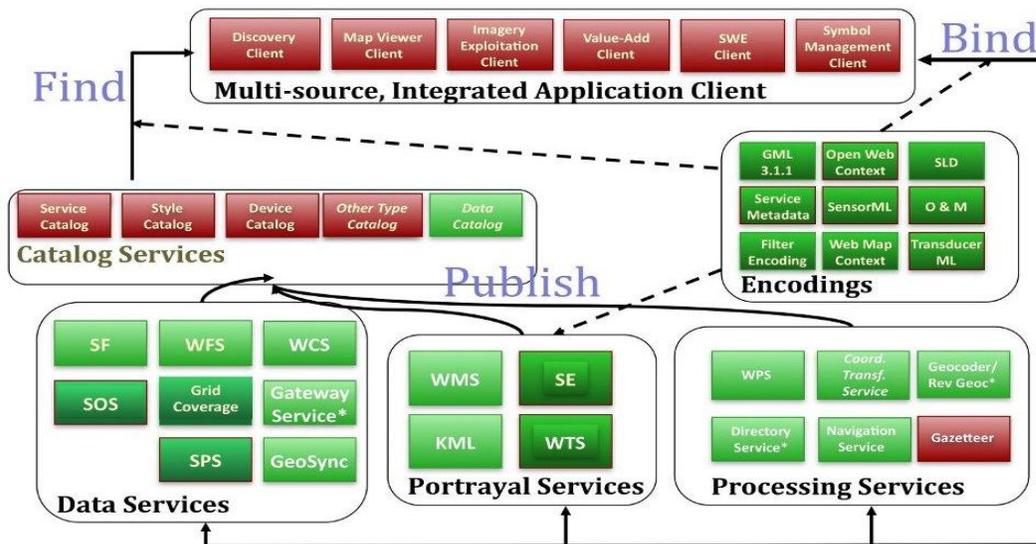


FIGURE 5 WEB SERVICE FRAMEWORK OF OGC GEOPROCESSING STANDARD

standards are collectively referred to as OGC Web Services (OWS). The figure below provides a general architectural schema for OGC Web Services. This schema identifies the generic classes of services that participate in various geoprocessing and location activities.

The OGC standards (See Figure 6) baseline comprises more than 30 standards, including<sup>1</sup>:

**CSW** - Catalog Service for the Web: access to catalog information; it is a standard for exposing a catalogue of geospatial records on the Internet. The format of each metadata record is defined in the standard only as XML. Whatever format is used, each record must contain a set of core fields, such as Title, Format, Type (e.g. Dataset, Dataset Collection, or Service), Bounding Box (a rectangle of interest, expressed in latitude and longitude), Coordinate Reference System, and Association (a link to

<sup>1</sup> [http://en.wikipedia.org/wiki/Open\\_Geospatial\\_Consortium#cite\\_note-3](http://en.wikipedia.org/wiki/Open_Geospatial_Consortium#cite_note-3)

another metadata record). It defines common interfaces to discover, browse, and query metadata about data, services, and other potential resources as well.

**GML** - Geography Markup Language: XML-format for geographical information; It is the XML grammar defined by OGC to express geographical features. GML serves as a modeling language for geographic systems as well as an open interchange format for geographic transactions on the Internet. GML contains a rich set of primitives, which are used to build application specific schemas or application languages. These primitives include, Feature, Geometry, Coordinate, reference system, Topology, Time, Dynamic feature, Coverage (including geographic images), Unit of measure, Directions, Observations, Map presentation styling rules.

**GeoXACML** - Geospatial eXtensible Access Control Markup Language (as of 2009 in the process of standardization)

**KML** - Keyhole Markup Language: XML-based language schema for expressing geographic annotation and visualization on existing (or future) Web-based, two-dimensional maps and three-dimensional Earth browsers. KML was developed for use with Google Earth, which was originally named Keyhole Earth Viewer.

**OGC Reference Model** - a complete set of reference models; The OGC Reference Model (ORM) describes the OGC standards and their relationships with ISO standards. The ORM provides an overview of OGC standards and serves as a useful resource for defining architectures for specific applications.

**OWS** - OGC Web Service Common

**SOS** - Sensor Observation Service; It is a web service to query real-time sensor data and sensor data time series and is part of the Sensor Web. The offered sensor data comprises descriptions of sensors themselves, which are encoded in the Sensor Model Language (SensorML), and the measured values in the Observations and Measurements (O & M) encoding format.

**SPS** - Sensor Planning Service; The OpenGIS® Sensor Planning Service Interface Standard (SPS) defines interfaces for queries that provide information about the capabilities of a sensor and how to task the sensor. The standard is designed to support queries that have the following purposes:

To determine the feasibility of a sensor planning request; to submit and reserve/commit such a request; to inquire about the status of such a request; to update or cancel such a request; and to request information about other OGC Web services that provide access to the data collected by the requested task.

**SensorML** - Sensor Model Language; SensorML can be used to describe a wide range of sensors, including both dynamic and stationary platforms and both in-situ and remote sensors

**SFS** - Simple Features – SQL; **Simple Features** (officially **Simple Feature Access**) is both an Open Geospatial Consortium (OGC) and International Organization for Standardization (ISO) standard **ISO 19125** that specifies a common storage model of mostly two-dimensional geographical data (point, line, polygon, multi-point, multi-line, etc.)

**Styled Layer Descriptor (SLD)**; A **Styled Layer Descriptor (SLD)** is an XML schema specified by the OGC for describing the appearance of map layers. It is capable of describing the rendering of vector and raster data. A typical use of SLDs is to instruct a Web Map Service (WMS) of how to render a specific layer.

**WCS** - Web Coverage Service: provides access, sub setting, and processing on coverage objects; The Open Geospatial Consortium **Web Coverage Service** Interface Standard (**WCS**) defines Web-based

retrieval of coverage's – that is, digital geospatial information representing space/time-varying phenomena. A WCS provides access to coverage data in forms that are useful for client-side rendering, as input into scientific models, and for other clients.

**WCPS** - Web Coverage Processing Service: provides a raster query language for ad-hoc processing and filtering on raster coverage. It defines a language for filtering and processing of multi-dimensional raster coverage's, such as sensor, simulation, image, and statistics data.

**WFS** - Web Feature Service: For retrieving or altering feature descriptions, It provides an interface allowing requests for geographical features across the web using platform-independent calls. One can think of geographical features as the "source code" behind a map.

**WMS** - Web Map Service (WMS): provides map images;

It is a standard protocol for serving georeferenced map images over the Internet that are generated by a map server using data from a GIS database. The WMS interface or online mapping portals like Google Maps return only an image, which end-users cannot edit or spatially analyze.

**WMTS** - Web Map Tile Service: provides map image tiles; It is a standard protocol for serving pre-rendered georeferenced map tiles over the Internet.

**WPS** - Web Processing Service: remote processing service; The **WPS** Interface Standard provides rules for standardizing how inputs and outputs (requests and responses) for invoking geospatial processing services, such as polygon overlay, as a Web service. The WPS standard defines how a client can request the execution of a process, and how the output from the process is handled. It defines an interface that facilitates the publishing of geospatial processes and clients' discovery of and binding to those processes. The data required by the WPS can be delivered across a network or they can be available at the server.

**GeoSPARQL** - Geographic SPARQL Protocol and RDF Query Language: representation and querying of geospatial data for the Semantic Web;

**WTS** - Web Terrain Service (WTS);

In this Thesis, it has been assured that utilization of geoprocessing and location services procurement and technology development programs and software are fully compliant with OGC standards!

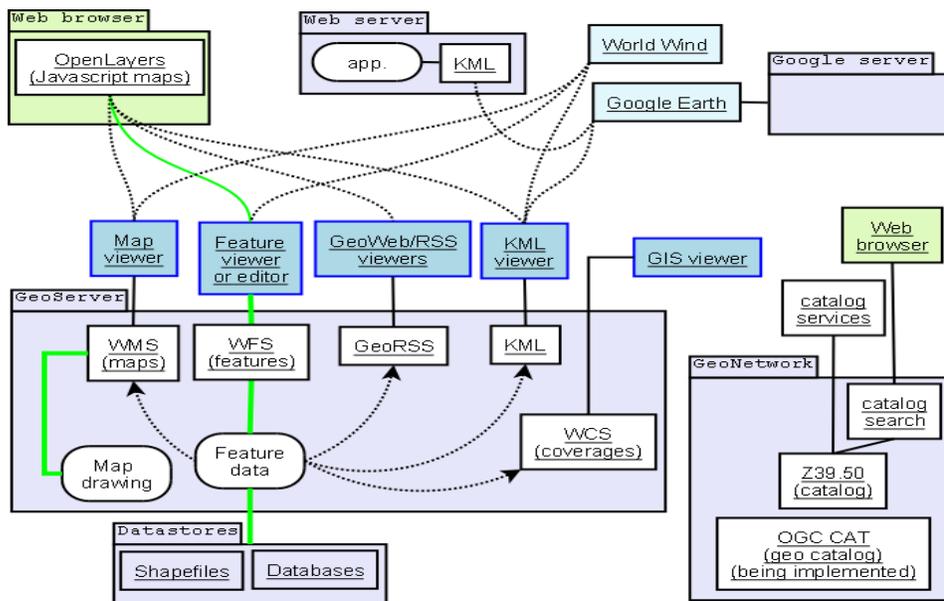


FIGURE 6 RELATIONSHIP BETWEEN CLIENTS/SERVERS AND OGC PROTOCOLS

## 2.2 OPEN SOURCE SOFTWARE

Open-source software (Open Source Software foundation 2013) is computer software with its source code made available and licensed with a license in which the copyright holder provides the rights to study change and distribute the software to anyone and for any purpose. Open-source software is very often developed in a public, collaborative manner. Programmers who have access to a computer program's source code can improve that program by adding features to it or fixing parts that do not always work correctly.<sup>1</sup>

Open source software licenses promote collaboration and sharing because they allow others to make modifications to source code and incorporate that code into their own projects. Some open source licenses ensure that anyone who alters and then shares a program with others must also share that program's source code without charging a licensing fee for it. In other words, computer programmers can access, view, and modify open source software whenever they like—as long as they let, others do the same when they share their work. In fact, they could be violating the terms of some open source licenses if they do not do this.

This is a common misconception about what "open source" implies. Programmers can charge money for the open source software they create or to which they contribute. However, since most open source licenses require them to release their source code when they sell software to others, many open source software programmers find it more lucrative to charge users for *software services and support* rather than for the software itself. This way, their software remains free of charge and they make money helping others install, use, and troubleshoot it.<sup>2</sup>

## 2.3 GNU GPL (GENERAL PUBLIC LICENSE)

GNU (Stallman 2013) was launched by Richard Stallman (rms) in 1983, as an operating system, which would be put together by people working together for the freedom of all software users to control their computing. rms remains the Chief GNUisance today<sup>3</sup>.

The primary and continuing goal of GNU is to offer a Unix-compatible system that would be 100% free software. Not 95% free, not 99.5%, but 100%. The name of the system, GNU, is a recursive acronym meaning GNU's Not Unix—a way of paying tribute to the technical ideas of Unix, while at the same time saying that GNU is something different. Technically, GNU is like UNIX. However, unlike UNIX, GNU gives its users freedom.

The ultimate goal is to provide free software to do the entire computer jobs, users want to do, and thus make proprietary software a thing of the past.

As a matter of the fact, published software should be free software. To make it free software, you need to release it under a free software license. We normally use the GNU General Public License (GNU GPL), but occasionally we use other free software licenses. Documentation for free software should be free documentation, so that people can redistribute it and improve it along with the software it describes. To make it free documentation, you need to release it under a free

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<sup>1</sup> [http://en.wikipedia.org/wiki/Open-source\\_software](http://en.wikipedia.org/wiki/Open-source_software)

<sup>2</sup> <http://opensource.com>

<sup>3</sup> <http://www.gnu.org/licenses/#GPL>

documentation license. It normally uses the GNU Free Documentation License (GNU FDL). It is important to note that due to the availability and popularity of commercial software that are always advertised by those companies these type of licensing are neglected.

### 2.4 THE FREE SOFTWARE DEFINITION

The free software definition presents the criteria for whether a particular software program qualifies as free software. (The Free Software Foundation 2013) "Free software" means software that respects users' freedom and community. Roughly, the users have the freedom to run, copy, distribute, study, change, and improve the software.

Thus, "free software" is a matter of liberty, not price. To understand the concept, you should think of "free" as in "free speech," not as in "free drink". With these freedoms, the users (both individually and collectively) control the program and whatever it does. When users do not control the program, the program controls the users. The developer controls the program, and through it exercises power over the users. Therefore, a "non-free" or "proprietary" program is an instrument of unjust power.

A program is free software if the program's users have the four essential freedoms:

- The freedom to run the program, for any purpose (freedom 0);
- The freedom to study how the program works and change it so it does your computing as you wish (freedom 1); and Access to the source code is a precondition for this;
- The freedom to redistribute copies so you can help your neighbor (freedom 2);
- The freedom to distribute copies of your modified versions to others (freedom 3); by doing this you can give the whole community a chance to benefit from your changes. Access to the source code is a precondition for this.

A program is free software if it gives users adequately all of these freedoms. Otherwise, it is non-free. While we can distinguish various non-free distribution schemes in terms of how far they fall short of being free, we consider them all equally unethical.

Freedom to distribute (freedoms 2 and 3) means you are free to redistribute copies, either with or without modifications, either gratis or charging a fee for distribution, to anyone anywhere. Being free to do these things means (among other things) that you do not have to ask or pay for permission to do so.

You should also have the freedom to make modifications and use them privately in your own work or play, without even mentioning that they exist. If you do publish your changes, you should not be required to notify anyone in particular, or in any particular way.

The freedom to run the program means the freedom for any kind of person or organization to use it on any kind of computer system, for any kind of overall job and purpose, without being required to communicate about it with the developer or any other specific entity. In this freedom, it is the *user's* purpose that matters, not the *developer's* purpose; you as a user are free to run the program for your purposes, and if you distribute it to someone else, she is then free to run it for her purposes, but you are not entitled to impose your purposes on her.

### 2.5 THE LIST OF AVAILABLE GIS SOFTWARE

GIS software encompasses a broad range of applications, which involve the use of a combination of digital maps and georeferenced data. Software that is used to create, manage, analyze, and visualize geographic data is usually incorporated under the umbrella term 'GIS software'(Steiniger, S.& Weibel,

R 2009). It can be sorted into different categories with respect to the tool sets that offer according to the tasks that can be accomplished. Such tasks involve basic activities that are common to daily computer usage such as (1) data visualization and exploration, (2) data creation, (3) data editing and (4) data storage. Other common GIS tasks include, (5) Integration of data from different sources (Blasby D. et al. 2002). (6) Data queries to select a subset of the data. (7) Data analysis, which we consider the creation of new information (output) from existing data (input). (8) Data transformation, as some analysis tasks require the user to transform, or manipulate, the data beforehand (e.g. transform the data into a different coordinate system, or convert them from raster to vector format), and lastly; (9) The creation of maps - the most common method used to visualize, analysis and query results. In this thesis,

(Steiniger, S.& Weibel, R 2009) Identified seven major types of GIS software as follows:

**Desktop GIS (Viewer, Editor, and Analyst/pro):** “Mapping software that is installed and runs on a personal computer and allows users to display, query, update, and analyze data about geographic locations and the information linked to those locations.”(ESRI 2012).

**Remote Sensing Software:** Remote sensing software generally focuses on the modification and transformation (geometrical and spectral) of aerial and satellite image data as well as LiDAR data. Such software can include photogrammetric tools (i.e., geometric) and remote sensing (thematic) analysis tools for image correction and filtering, georeferencing and orthorectification, mosaicking, vectorization and image object extraction.(Jensen 2006)

**Explorative Analyst Tools:** “[...] to describe and visualize spatial distributions; identify a typical locations or spatial outliers; discover patterns of spatial association, clusters, or hot spots; and suggest spatial regimes or other forms of spatial heterogeneity [...](Anselin, L., et al. 2000)

**Spatial DBMS:** “Spatial Database Management Systems (DBMS) are mainly used to store the data, but often also provide (limited) analysis and data manipulation functionality.”(Steiniger, S.& Weibel, R 2009)

**Web Map Server:** WebMap Servers are used to distribute maps and data over the internet. In particular the software, that supports the Open Geospatial Consortiums (OGC) Web Mapping Service (WMS) and Web Feature Service (WFS) standards.

**Server GIS/ WPS Server:** Server GIS is software that (I) is used remotely, (II) provides access to functionality via web protocols such as the OGC Web Processing Service(Schut, P. 2007) and (III) allows for the provision of data and input parameters from other web-based services (i.e., allows service chaining). (Neun, M., et al. 2008) Describe various data types that a Server GIS should be able to return, e.g., geometries, attributes (i.e., single values), single features, and complex data structures such as graphs.

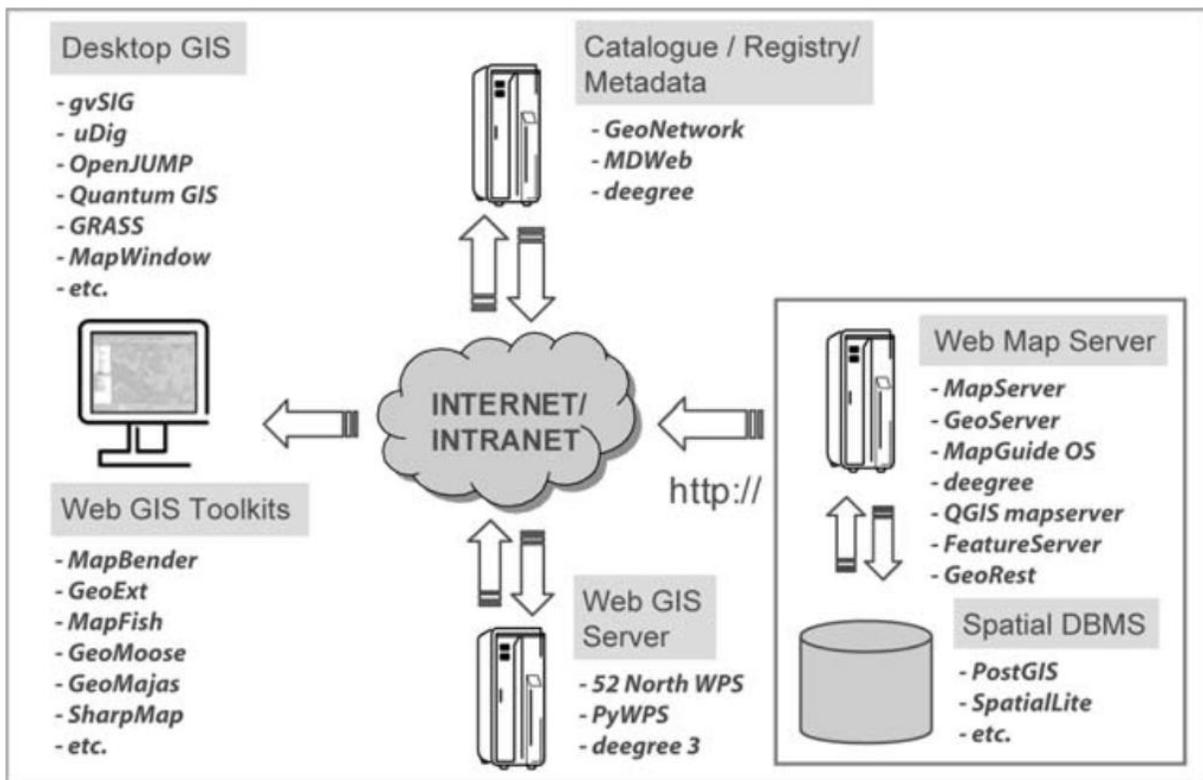
**WebGIS Client:** WebGIS Client software’s are used for data display and to access analysis and query functionality from Server GIS over the internet or intranet.

**Mobile GIS:** We consider Mobile GIS to be GIS software that (I) runs on a mobile platform, e.g., a tablet PC, a Personal Digital Assistant (PDA), or a mobile phone, and that (ii) provides special functions that support data acquisition and redlining (updating) in the field. As such, the functions provided by a mobile GIS platform are generally a subset of those offered by most desktop GIS augmented with direct positioning capability via either an internal or external GPS.(Steiniger, S.,Hunter, A. 2012)

**GIS Libraries:** Software libraries provide functionality that can be used by other applications, That is they do not offer a graphical or command-line user interface that allows direct use of the functions. Examples may include methods that; perform cartographic projections; enable reading and writing of different data formats; or provide geographical analysis algorithms, etc. Libraries can only be used by coupling them to a host application, i.e., a desktop GIS or a GIS server.(Steinige, S.,Hunter, A. 2012)

### 2.5.1 OPEN SOURCE GIS SOFTWARE

Our goal is to present an overview of (major) GIS software projects that develop free and open source software.



Websites with listings of free GIS software (projects)

<http://www.freegis.org>

<http://www.opensourcegis.org>

<http://www.osgeo.org>

The state of the art available Open Source Software in GIS, classified according to their functionality:

#### 2.5.1.1 DESKTOP GIS:

##### QUANTUM GIS (QGIS)

Quantum GIS (QGIS) is a user friendly, Open Source, client base where you can visualize, manage, edit, analyze data, and compose printable maps. It includes



powerful analytical functionality through integration with **GRASS**. It runs on Linux, UNIX, Mac OSX, and Windows and supports numerous vector, raster and database formats, and functionality. QGIS is OGC standards compliant (WMS, WF).

- Website: <http://www.qgis.org>
- License: GNU General Public License
- Software Version: 1.8.0
- Supported Platforms: Windows, Linux, Mac, Unix

## ILWIS

**ILWIS** (*Integrated Land and Water Information System*) is a GIS / Remote sensing software for both vector and raster processing. ILWIS delivers a wide range of features including import/export, digitizing, editing, analysis, and display of data, as well as production of quality maps. ILWIS was initially developed and distributed by "ITC", Enschede (International Institute for Geo-Information Science and Earth Observation) in the Netherlands for use by its researchers and students, but since first of July 2007, it has been distributed under the terms of the GNU General Public License and is thus free software. ILWIS has some very powerful raster analysis modules, a high-precision and flexible vector and point digitizing module, a variety of very practical tools, as well as a great variety of user guides and training modules all available for downloading. The current version is ILWIS 3.8.1. Similar to the GRASS GIS in many respects, ILWIS is currently available natively only on Microsoft Windows.



ILWIS supports, Orthophoto, image georeferencing, transformation, mosaicing, 3D visualization, production, and visualization of stereo image pairs as well as, Web Mapping Service (WMS) and Web Processing Service (WPS).

- Website: <http://52north.org/communities/ilwis>
- License: GNU General Public License
- Software Version: 3.8.1

## GRASS GIS (FULLY FEATURED GIS)

The Geographic Resources Analysis Support System, commonly referred to as GRASS, is a Geographic Information System (GIS) providing powerful raster, vector, and geospatial processing engines in a single integrated software suite. GRASS includes tools for spatial modeling, visualization of raster and vector data, management and analysis of geospatial data, and the processing of satellite and aerial imagery. It also provides the capability to produce sophisticated presentation graphics and hardcopy maps. GRASS is translated into twenty languages and it supports a huge array of data formats.



GRASS is used around the world in academic and commercial settings as well as by many governmental agencies and environmental consulting companies. It runs on a variety of popular hardware platforms and is free open-source software released under the terms of the GNU General Public License.

The GRASS software includes more than 400 built-in analysis modules. Additionally, over 100 community supplied modules and toolboxes are available freely, from the community wiki site. After nearly 30 years of continuous development, GRASS is both the oldest and largest Open Source GIS available. It is easily scriptable and versatile enough to be used both, for batch data processing on massively parallel supercomputers as well as a handy desktop GIS for handheld PDAs or notebooks.

## The State Of The Art Available Software & Solution

- Website: <http://grass.osgeo.org>
- License: GNU General Public License (GPL) version 2
- Software Version: 6.4.3
- Supported Platforms: GNU/Linux, Mac OSX, MS Windows

### GVSIG DESKTOP

GvSIG is a Geographic Information System (GIS) desktop application designed for capturing, storing, handling, analyzing and deploying any kind of referenced geographic information in order to solve complex management and planning problems. GvSIG is known for its user-friendly interface and being able to access all common vector and raster formats. It features a wide range of tools for working with geographic information (query, layout creation, geoprocessing, networks, etc.), which turns gvSIG into the ideal tool for users working in the land realm.



GvSIG is available in over 20 languages (Spanish, English, German, French, Italian...), as well as Windows and Linux (there are also non-official Mac OS X versions).

Provides common GIS tools like data loading, map navigation, query map information like alphanumeric information, distance measurement, thematic cartography, legend edition using common legend types, labeling, feature selection by many selection types, data tables with statistics, ordering, table relations, table linking, layout manager, geoprocessing tools, CAD, raster processing, etc.

It can work with raster format such as ecw, ENVI hdr, ERDAS img, (Geo)TIFF, GRASS, NetCDF,... as well as vector & CAD format such as, shapefile, NetCDF, GML, KML, DGN, DXF, DWG. The database file such as PostGIS, MySQL, Oracle, and ArcSDE can be imported into it.

It support numerous Open Geospatial Consortium (OGC) standards: WMS, WMTS, WFS and WCS layers, SLD legends, Web Map Context (WMC), Search on catalogues with CSW (ISO/19115 and ebRIM), Search on gazetteers using WFS-G recommendation.

- Website: <http://www.gvsig.org/>
- License: GNU General Public License (GPL) version 2
- Software Version: 2.0
- Supported Platforms: Windows, Linux

### USER-FRIENDLY DESKTOP INTERNET GIS (uDig)

User-friendly Desktop Internet GIS (uDig) is an open source spatial data viewer/editor, with special emphasis on the OpenGIS standards for internet GIS, the Web Map Server (WMS) and Web Feature Server (WFS) standards.



UDig is *User-friendly* (providing a familiar graphical environment for GIS users), *Desktop located* (running natively on Windows, Mac OS/X and Linux), *Internet oriented* (consuming standard and de facto geospatial web services) and, *GIS ready* (providing the framework on which complex analytical capabilities can be built, and gradually subsuming those capabilities into the main application).

For developers uDig provides a common Java platform for building spatial applications with open source components. The website provides series of clear tutorials covering making a simple tool through to releasing your own custom application.

It can be integrated with existing infrastructure: ArcSDE, Oracle, DB2 and more. It works

With vector format such as Shapefile, jpeg, png, tiff and more as well as advanced spatial raster formats ECW, MrSID, and JPEG 2000. It supports for compliant Web Map Servers (**GeoServer**, MapServer) and Java Application built using the **GeoTools**, JTS Topology Suite (JTS).

UDig has Implemented WMS, WFS, WFS-T, WMS-C, and SLD OGC standards.

- Website: <http://udig.refractions.net/>
- License: Dual BSD / EPL (Eclipse Foundation)
- Software Version: 1.4.0b
- Supported Platforms: Windows, Linux, Mac
- API Interfaces: GeoTools, Image IO-Ext, Java Advanced Imaging, Eclipse Rich Client Platform, Eclipse Modeling Framework

### KOSMO DESKTOP

Kosmo - Desktop is a user friendly, desktop GIS application, which allows you to explore, edit, and analyze spatial data from a variety of databases, vector, and raster formats. It follows WMS, WFS, and SLD OGC standards and provides excellent topology integrity. Its plugins architecture enables it to be easily customized for specific purposes.



Its Supported formats includes, Vector file formats such as Shapefiles, GML, DXF, DWG, DGN, CSV (by an extension), Raster file formats such as, ECW, MrSID, (Geo)Tiff, Erdas IMG, ENVI hdr, JPG, GIF, PNG, BMP. It also supports PostgreSQL, PostGIS, Oracle, and MySQL Databases.

- Website: <http://www.opengis.es/index.php?lang=en>
- License: GNU General Public License (GPL) version 2
- Software Version: 3.0 RC2
- Supported Platforms: Windows, Linux

### OPENJUMP GIS

OpenJUMP is an easy to use and powerful desktop GIS that enable users to display, edit, analyze, and conflate geographic data. It comes in a CORE and a PLUS edition, with the latter adding lots of useful plugins. OpenJUMP is excellent for data editing and rapid prototyping of GIS functions.



It can read vector file format such as GML, SHP, DXF+, MIF\*, CSV+, KML+ & TIFF, ASCII grid, JPG, PNG, JPEG2000+, MrSID, ECW+, and reads Database format such as PostGIS, ArcSDE\*, Oracle\*, MySQL\* and SpatiaLite\* as well as writing GML, SHP, WKT, DXF+, PostGIS & JPG, TIFF, ASCII grid\*, SVG+. It must be noted that the formats marked with a (\*) require an additional plugins, and with (+) are part of the PLUS edition. SEXTANTE raster analysis toolbox included in PLUS edition

- GML2, SFS, WMS, KML, and SLD OGC standards are supported.
- Website: <http://www.openjump.org>
- License: GNU GPL
- Software Version: 1.6.3
- Supported Platforms: Windows, Linux, Mac, Unix

## SAGA

SAGA (System for Automated Geo-scientific Analyses) is an open source geographic information system (GIS) used for editing and analyzing spatial data. It includes a large number of modules for the analysis of vector (point, line, and polygon), table, grid, and image data. Among others, the package includes modules for geostatistics, image classification, projections, simulation of dynamic processes (hydrology, landscape development), and terrain analysis. The functionality can be accessed through a GUI, the command line or by using the C++ API.



Digital Terrain Analysis and 3D visualization is one of the important capabilities of this software.

- Website: <http://www.saga-gis.org>
- License: LGPL v2.1 (api); GPLv2 (GUI and modules)
- Software Version: 2.1.0
- Supported Platforms: Windows, Linux, FreeBSD

## MAPWINDOW GIS AS DESKTOP GIS

MapWindow GIS is a Windows based, Open Source GIS client where you can visualize, manage, edit, analyze data, and compose printable maps. It includes powerful analytical functions through integration with GEOS and GDAL/OGR. MapWindow is easy to incorporate into MS-Office based products such as MS-Excel and MS-Access, as well as programs written in VB6, C++, C#, VB.NET, and Delphi, as MapWindow is based upon ActiveX controls.



MapWindow requires installation on a Microsoft Windows system before it can be run. MapWindow has a friendly graphical user interface, on the fly projection, print layout, feature labeling, vector and raster symbols library.

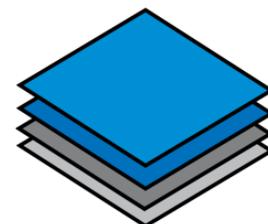
MapWindow supports Easy Viewing of many vector formats including ESRI shapefiles, MapInfo, SDTS and GML, and raster formats such as digital elevation models, aerial photography or landsat imagery. It supports, Tiles services, like OpenStreetMap, ArcGIS Online, digitizing tools for shapefile format, GPS tools to import and export GPX format, convert other GPS formats to GPX, or down/upload directly to a GPS unit and perform map algebra, terrain analysis, hydrologic modeling (TauDEM), and network analysis.

- MapWindow Comply with OGC Standards WMS, WFS, WMTS, and GML.
- Website: <http://www.mapwindow.org>
- License: MPLv1.1
- Software Version: 4.8.8
- Supported Platforms: Windows

## 2.5.1.2 GENERAL GIS VIEWING, EDITING AND ANALYSIS THROUGHOUT THE WEB

### OPENLAYERS AS BROWSER GIS CLIENT

OpenLayers makes it easy for web developers to embed dynamic maps, from a multitude of sources, in any web page. OpenLayers provides an extensive set of mapping tools and widgets, similar to the Google Maps API. All functionally runs inside the web browser, which makes OpenLayers easy to



install, without any server side dependencies.

It uses JavaScript API, Support for standard and customized protocols for interacting with servers, as well as Support for in-browser data rendering (using SVG, VML, or Canvas technologies), and mobile devices (with a focus on touch devices)

Commercial Layers such as Google and Bing can be integrated into it. It supports WMS, WMTS, WFS, WFS-T, GeoRS, Atom, ArcXML, GeoJSON, GeoRSS, KML, OSM, SLD, WMTS and GML OGC Standard, as well as OpenStreetMap (OSM), ArcGIS, Images, MapGuide, MapServer, TileCache.

- Website: <http://openlayers.org>
- License: 2-clause BSD License (aka FreeBSD License)
- Software Version: 2.13.1

### LEAFLET AS MOBILE FRIENDLY INTERACTIVE MAPS

Leaflet is a JavaScript library for browser based, mobile-friendly, interactive maps. It is lightweight, yet has all the features most developers ever need for online maps.



Leaflet is designed with simplicity, performance, and usability in mind. It works efficiently across all major desktop and mobile platforms out of the box, taking advantage of HTML5 and CSS3 on modern browsers while being accessible on older ones too. It can be extended with many plugins, has a beautiful, easy to use and well-documented API and a simple, readable source code that is a joy to contribute to.

It support Desktop Browser such as Chrome, Firefox, Safari 5+, Opera 11.11+, IE 7–10, IE 6 (not perfect but accessible)

It supports Mobile Browser such as Safari for iOS 3/4/5/6+, Android browser 2.2+, 3.1+, 4+, Chrome for Android 4+ and iOS, Firefox for Android, Other webkit-based browsers (webOS, Blackberry 7+, etc.), and IE10 for Win8-based devices.

It is extremely lightweight (around 31 KB of gzipped JS code) and needs no external dependencies

- Website: <http://leafletjs.com>
- License: BSD<sup>1</sup>
- Software Version: 0.6.2
- Supported Platforms: Windows, Mac, Linux, Android, iOS

### GEOMAJAS AS BROWSER GIS CLIENT

Geomajas is an extensible web-mapping framework, which seamlessly integrates powerful server side algorithms into the web browser.

The focus of Geomajas is to provide a platform for server-side integration of geospatial data (be it through GeoTools or Hibernate), allowing multiple users to control and manage the data from within their own browsers. In essence,




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<sup>1</sup> **BSD licenses** are a family of permissive free software licenses, imposing minimal restrictions on the redistribution of covered software.

Geomajas provides a set of powerful building blocks, from which the most advanced GIS application can easily be built.

What makes Geomajas unique is its strong server side focus. The processing, styling, filtering, caching, etc. of geospatial data always happens within a secured context. All this makes Geomajas applications incredibly scalable and performing, keeping the client a real thin client.

Geomajas integrates client-server architecture, enables geometry and attribute editing, and supports Cross browser, without the need for browser plug-ins.

It supports WMS, and WFS OGS.

- Website: <http://www.geomajas.org/>
- License: AGPL<sup>1</sup>
- Software Version: 1.8
- Supported Platforms: Windows, Linux, Mac

### MAPBENDER AS GEOPORTAL FRAMEWORK

Mapbender is a graduated OSGeo project. It is a web based geoportal framework to publish, register, view, navigate, monitor, and grant secure access to spatial data infrastructure services.



Mapbender is the tip of the iceberg, a meta-layer of software providing access to SDI components adhering to international standards. Mapbender allows users to easily create customized browser clients from a wide range of widgets (without any/with minimal) programming required. Widgets integrate with server functionality to provide advanced functionality like security proxying, digitizing, auto snapping and more.

Mapbender management applications are straightforward and easy to use providing highly focused functionality for the operation of large scale distributed SDI components. It is the tool of choice for SDI administrators who need to maintain, categorize, and monitor map and feature services. Mapbender grants access to individuals, groups and manages machine-to-machine access. Adherence to standardized services, such as OGC WMS allows taking advantage of interoperable services from a multitude of server platforms.

Mapbender is based on Symfony2, OpenLayers, Mapproxy, and jQuery. It can print high-quality maps using your own PDF templates. It implements WMS OGC Standards

- Website: <http://www.mapbender3.org/>
- License: Dual licensed under the GNU General Public License and Simplified BSD license.
- Software Version: 3.0.0.2
- Supported Platforms: Windows, Linux, Mac

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<sup>1</sup> The **Affero General Public License**, often abbreviated as **Affero** GPL and **AGPL** (and sometimes informally called the **Affero License**), refers to two distinct, though historically related, free software licenses: GNU General Public License, version 2 (GPLv2). And GNU General Public License, version 3 (GPLv3).

## MAPFISH AS WEB MAPPING FRAMEWORK

MapFish is a flexible and complete framework for building rich web-mapping applications. It emphasizes high productivity, and high-quality development.



MapFish is based on the Pylons Python web framework. MapFish extends Pylons with geospatial-specific functionality. For example, MapFish provides specific tools for creating web services that allows querying and editing geographic objects.

MapFish also provides a complete RIA-oriented JavaScript toolbox, a JavaScript testing environment, and tools for compressing JavaScript code. The JavaScript toolbox is composed of the ExtJS, *OpenLayers*, and GeoExt JavaScript toolkits.

MapFish is compliant with the Open Geospatial Consortium standards. This is achieved through OpenLayers or GeoExt supporting several OGC norms, like WMS, WFS, WMC, KML, GML etc.

- Website: <http://www.mapfish.org>
- License: BSD License
- Software Version: 2.2
- Supported Platforms: Windows, Linux, Mac

## GEOMOOSE AS WEB GIS PORTAL

GeoMOOSE is a browser based mapping framework for displaying distributed cartographic data. It is particularly useful for managing spatial and non-spatial data within county, city and municipal offices (from which GeoMOOSE originated). It extends the functionality of MapServer and OpenLayers to provide built in services, like drill-down identify operations for viewing and organizing many layers, selection operations, and dataset searches.



GeoMOOSE is fast, performing well with hundreds of layers and/or services at a time. Data from multiple custodians can be maintained with different tools and on different schedules as each map layer has its own set of configuration files for publishing, symbols, templates, as well as source data.

The user interface is easily configurable, and additional services can be added through a modular architecture.

It provides Distributed data maintenance amongst multiple owners as well as access maps from: MapServer, Google, VirtualEarth, YahooMaps, TileCache, ArcGIS REST, and other WMS. It supports configuration of multiple views of data sources.

GeoMOOSE is compliant with the Open Geospatial Consortium standards and supports WMS, WFS, and Transactional WFS.

- Website: <http://www.geomoose.org/>
- License: MIT based license<sup>1</sup>. <http://www.geomoose.org/info/license.html>

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<sup>1</sup> The **MIT License** is a free software license originating at the Massachusetts Institute of Technology (MIT). It is a permissive free software license, meaning that it permits reuse within proprietary software provided all copies of the licensed software include a copy of the MIT License terms.

## The State Of The Art Available Software & Solution

- Software Version: 2.6.1
- Supported Platforms: Windows, Linux, Mac

### CARTARO AS GEOSPATIAL CONTENT MANAGEMENT SYSTEM

Cartaro provides geospatial functionality and web services within the Drupal Content Management System<sup>1</sup> (CMS). With just a few clicks within Cartaro, you can set-up and run OGC standards based web services, as well as build maps into web pages. Cartaro builds upon robust Open Source components: the PostGIS database, GeoServer and GeoWebCache web services, OpenLayers maps in the browser, all managed from within the powerful Drupal CMS.



Cartaro is designed for CMS websites needing to handle geospatial data, and for organizations wanting a lightweight Spatial Data Infrastructure (SDI) with minimal configuration and programming.

Most SDI functionality comes right out of the box through the close integration of Drupal with PostGIS and GeoServer. The main features of Cartaro are:

Spatial data storage with true geometry data types;

Creation of data types from within the Drupal GUI;

Integrated online editing of geospatial data;

Data publishing with integrated maps;

Configuration of map layouts and behaviors;

Symbol styling;

Data publishing through OGC standards-compliant web services (OWS) like WMS and WFS;

High performance map output through GeoWebCache;

Transparent privilege handling and security for all spatial data;

Content publication workflow and revision moderation;

Basic metadata collection through access to GeoServer-GUI;

Full extensibility through thousands of Drupal modules or individual programming;

Compliant OGC Standard over WMS, WFS, WCS, FE, SLD, and GML;

- Website: <http://cartaro.org/>
- License: GNU General Public License (GPL) version 2
- Software Version: 1.0
- Supported Platforms: Windows, Linux, and Mac;

### GEONODE AS A GEOSPATIAL CONTENT MANAGEMENT SYSTEM

GeoNode is a Content Management System for geospatial data,



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<sup>1</sup> Drupal is an open source content management platform powering websites and applications.

which provides creation, sharing, and collaborative use of geospatial data. Datasets can be uploaded in various formats, maps can be edited, styled, and aggregated through browser-based tools, maps and metadata can be published and searched, and reviews, ratings, and comments can be captured from users.

GeoNode is built upon GeoServer, GeoExplorer, pycsw, Django, and GeoExt.

Spatial Data Discovery

Powerful spatial search engine

Federated OGC services

Metadata catalogue

Import and Manage Geospatial Data

Publish raster, vector, and tabular data

Manage metadata and associated documents

Securely or publicly, share data

Versioned geospatial data editor

Interactive Mapping

GeoExplorer GIS client

Graphical style editor

Create multi-layer interactive maps

Share and embed maps in web pages

Print maps as PDF

Support collaboration simultaneously

Provide possibility to review, rate, and comment on data

Support multi users

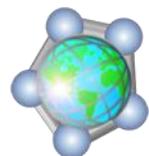
Supports announcements and notifications throughout the web

Compliant OGC Standard over WMS, WFS, WCS, FE, SLD, and GML

- Website: <http://geonode.org/>
- License: GNU General Public License (GPL) version 2.0
- Software Version: 2.0 RC1
- Supported Platforms: Windows, Linux, Mac
- API Interfaces: Python (Django)
- Support: <http://opengeo.org/technology/geonode/>

## GAIA GEOSPATIAL PLATFORM

Gaia is a platform designed for advanced geospatial network and SDI needs. Based on the CarbonTools PRO open-geospatial development toolkit, this viewer can access an array of geospatial sources with OGC's WMS, WMTS, WCS, WFS, and FE standards as well as, services such as Microsoft Bing Maps, Yahoo! Maps and OpenStreetMap



(OSM). It supports formats such as ESRI Shapefiles, Google Earth KML/KMZ, DXF, MIF, Geography Markup Language (GML), and GML Simple Features (GMLsf).

GAIA can use geospatial content from different sources and overlay them into a single map view, with each layer individually configured and styled. GAIA multi-layer view allows seamless use of multiple layers of different types. Panning, zooming, and other mapping tools provide a fast and convenient tool for browsing the map. GAIA uses dynamic caching of content to memory, providing enhanced mapping performance.

- Supported Platforms: Linux, Mac, Windows
- Commercial Support: <http://www.thecarbonproject.com>

## CHAMELEON

Chameleon is a distributed, highly configurable, environment for developing Web Mapping applications. It is built on MapServer as the core-mapping engine and works with all MapServer supported data formats through a regular MAP file. It also works well with OpenGIS Consortium standards for Web Mapping Services (WMS) and WMT Viewer Contexts through MapServer's support for these standards.

Chameleon incorporates the ability to set up quickly new applications from a common pool of widgets that can be placed in an HTML template file. These widgets provide a fixed piece of functionality, but the representation of the widget is usually highly configurable.

Chameleon is also extendable. Developers can create their own custom widgets and then use them in mapping applications.

Chameleon is Open Source, this means that you can use it freely for your own applications, and that you also have access to the source code. Just like with any Open Source project, we hope that users of Chameleon will contribute their improvements and report any problems or suggestions.

Chameleon technology was developed as the Configurable Web Mapping Client Component (CWC2) for Canada's GeoConnections Access Program. It is currently being used by the GeoConnections Discovery Portal and will be used by a number of CGDI based applications in the future.

- Website: <http://chameleon.maptools.org>
- Software Version: Chameleon version 2.6 rc1

### 2.5.1.3 WEB SERVICE PUBLISHING SPATIAL DATA TO THE INTERNET

#### GEOSEVER FOR WEB SERVICE

GeoServer is a web server that allows you to serve maps and data from a variety of formats to standard clients such as web browsers and desktop GIS programs. This means that you can store your spatial data in almost any format you prefer but that your users do not need to know anything about GIS data. At the simplest level, all they need is a web browser to see your maps exactly as you want.



GeoServer is the reference implementation of the Open Geospatial Consortium (OGC) WFS and WCS standards, as well as a high performance certified compliant WMS. GeoServer forms a core component of the Geospatial Web.

It supports data from a variety of data stores including, Vector, Shapefiles, External WFS, PostGIS, ArcSDE, DB2, Oracle Spatial, MySql, SQL Server, Raster, GeoTiff, JPG and PNG (with world file), image pyramid, GDAL formats, Image Mosaic, Oracle GeoRaster

Data is served as safe and quick images using WMS and WMTS protocols. As the data is served up as an image, your data is completely safe and secure. Unless they re-digitize your data, there is no way to steal your data. The appearance of each map layer can be controlled using the SLD standard, which allows features to be colored and labeled. By combining these rules with OGC Filters scale, dependent styling can be implemented allowing more detail to be added as a user zooms in. Label collision management, grouping, and priorities are also implemented.

Full vector data can be sent to a client using the WFS protocol. A WFS enabled client can download vector data and use it for mapping, spatial analysis, and other operations. Also, if authorized the user can modify the data and send it back to the server to update the stored data using the WFS-Transactional protocol. The data can be transmitted using GML (compressed) as well as other standard data formats like shapefile and json.

Raster data values can be sent to a client using the WCS protocol. A GIS client can request the actual raster data for use in spatial analysis. This allows a user to create applications, which can model the process described by your data.

On the fly reprojection, means that GeoServer supports the majority of the EPSG<sup>1</sup> database of projections and can re-project to any of them on demand to allow clients with limited reprojection support to pass the load to the server.

Tiling Cache is performed by GeoWebCache, which is integrated into GeoServer, tiles and caches map images from a variety of sources such as WMS. It implements various service interfaces (such as WMS-C, WMTS, TMS, Google Maps KML, Virtual Earth) in order to accelerate and optimize map image delivery. It can also recombine tiles to work with regular WMS clients.

Web Processing Service (WPS) by utilizing Geospatial algorithms, including those from JTS<sup>2</sup>, can be called through GeoServer WPS interface. This includes the chaining of processes, and using rendering transformations to create powerful visualizations through the WMS interface.

It supports numerous Open Geospatial Consortium (OGC) standards including; WMTS, WFS, WFS-T (transactional), WCS, WPS, FE, SLD, GML.

- Website: <http://geoserver.org/display/GEOS/Welcome>
- License: GNU General Public License (GPL) version 2
- Software Version: 2.3.4
- Supported Platforms: Cross Platform Java 6 - Windows, Linux, Mac
- API Interfaces: WMS, WFS, WCS, REST
- Support: <http://geoserver.org/display/GEOS/Commercial+Support>

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<sup>1</sup> The EPSG Geodetic Parameter Dataset is a structured dataset of Coordinate Reference Systems and Coordinate Transformations, accessible through this data registry.

<sup>2</sup> The **JTS Topology Suite** is an open source pure Java API of 2D spatial predicates and functions to conforms to the Simple Features Specification for SQL published by the Open GIS Consortium.

## MAPSERVER FOR WEB SERVICE

MapServer is an Open Source geographic data-rendering engine written in C. Beyond browsing GIS data, MapServer allows you create “geographic image maps”, that is, maps that can direct users to web content.



MapServer was originally developed by the University of Minnesota (UMN) ForNet project in cooperation with NASA, and the Minnesota Department of Natural Resources (MNDNR). Later it was hosted by the TerraSIP project, a NASA sponsored project between the UMN and a consortium of land management interests.

MapServer is now a project of OSGeo, and is maintained by a growing number of developers (nearing 20) from around the world. It is supported by a diverse group of organizations that fund enhancements and maintenance, and administered within OSGeo by the MapServer Project Steering Committee made up of developers and other contributors.

Advanced cartographic output including:

Scale dependent feature drawing and application execution;

Feature labeling including label collision mediation, Complex Multi Label/Symbol Symbology, Label Leader Offsetting, Precise Symbol Placement, and SVG Symbology;

TrueType font support for labeling and symbolization;

Map element automation (scale bar, reference map, and legend);

Thematic mapping using logical or regular expression-based classes;

Pluggable renderer support with drivers for AGG, Cairo, GD and OpenGL and others;

Special provisioning for tiled output generation;

Mask Layers;

Vector Fields;

Multiple Font Support;

Sophisticated spatial query support

Identify features by attributes, point, bounding box or geometry across one or more layers;

Support for raster queries;

Fully customizable, template driven output;

OGR-based query output generation;

Support for popular scripting and development environments

CGI/FastCGI;

PHP, Python, Perl, Ruby, Java, and .NET;

Cross-platform support

Linux, Windows, Mac OS X, Solaris, and more;

A multitude of raster and vector data formats

Native support for ESRI shapefiles, PostGIS, ESRI ArcSDE and Oracle Spatial;

Many other formats via GDAL and OGR;

Map projection support

On-the-fly map projection with 1000s of projections through the Proj.4 library;

Implemented Standards

Support of numerous Open Geospatial Consortium (OGC) standards, WMS (client/server), non-transactional WFS (client/server), WMC, WCS, Filter Encoding, SLD, GML, SOS, OM;

- Website: <http://www.mapserver.org/>
- License: MIT-style license
- Software Version: 6.2.1
- Supported Platforms: Windows, Linux, Mac
- API Interfaces: C, PHP, Python, Perl, Ruby, Java, and .NET
- Support: <http://mapserver.org/community;>

#### DEEGREE FOR WEB SERVICES

Deegree provides geospatial web services based upon Open Geospatial Consortium (OGC) and INSPIRE Network Services specifications<sup>1</sup>. Deegree supports WFS, WMS, WMTS, CSW, SLD, and WPS



It Supports KVP, XML and SOAP requests, GML output/input, On-the-fly coordinate transformation, as well as numerous back ends, such as PostGIS, Oracle Spatial, MS SQL Server, Shapefiles or GML instance documents

Deegree has capabilities for high quality rendering, and scale dependent styling and

Supports different backend, such as GeoTIFFs, and on-the-fly caching (using EHCACHE)

- Website: <http://deegree.org>
- License: GNU GPL
- Software Version: 3.3.1
- Supported Platforms: Windows, Linux

#### NCWMS FOR WEB MAP SERVICE

NcWMS publishes multi-dimensional data (such as environmental and weather data) as an OGC compliant Web Map Service (WMS). NcWMS quickly and




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<sup>1</sup> In Europe a major recent development has been the entering in force of the INSPIRE Directive in May 2007, establishing an infrastructure for spatial information in Europe to support Community environmental policies, and policies or activities which may have an impact on the environment. INSPIRE is based on the infrastructures for spatial information established and operated by the 27 Member States of the European Union. The Directive addresses 34 spatial data themes needed for environmental applications, with key components specified through technical implementing rules. This makes INSPIRE a unique example of a legislative “regional” approach.

efficiently extracts the map images from the very large data files typically associated with environmental data.

NcWMS is capable of Fast data extraction, Generation of time series and vertical profile plots, as well as Automatic recognition of vector-components and generation of vector arrows. It supports large range of projections (for both source data and target images) and creation of animations.

It supports NetCDF, GRIB, and OPeNDAP as Input formats and PNG, JPEG, animated GIF, KML

Implemented Standards in ncWMS is WMS and KML.

- Website: <http://www.resc.rdg.ac.uk/trac/ncWMS/>;
- License: Modified BSD License;
- Software Version: 1.1;
- Supported Platforms: All Java 1.5 platforms: Windows, Linux, Mac;

### EOXSERVER FOR WEB COVERAGE SERVICE



EOxServer is a server for presenting big Earth Observation (EO) data archives and metadata via Open Standards.

Earth Observation supported data currently includes 2D raster data generally acquired using sensors on satellites or aircrafts and including information about the time of acquisition and the footprint on planet Earth. It is typically used to monitor Earth's natural and built environment.

EOxServer builds upon an Open Source stack of software, which includes Python, *MapServer*, Django/GeoDjango, *GDAL*, PROJ.4, and a *Spatialite* or *PostGIS* database.

EOxServer supports WCS, WMS, OGC, GML, GMLCOV, EO-O&M, standards, as well as GeoTIFFs encoding for coverage's, GDAL library, predefined projections (CRSs), scaling, and interpolation.

- Website: <http://eoxserver.org/>
- License: MIT-style license
- Software Version: 0.3.0
- Supported Platforms: Linux, Windows, Mac

### GEONETWORK TO MANAGE METADATA CATALOGUE



GeoNetwork Open Source is a catalog application for managing spatially referenced resources. It provides powerful metadata editing and search functions, an embedded interactive web map viewer, and is based upon Open Standards. It allows immediate search and access to local and distributed geospatial catalogues as well as Up and down loading of data, graphics, documents, pdf files, and any other content type. It is an interactive Web Map Viewer to combine Web Map Services from distributed servers around the world. GeoNetwork allows online editing of metadata with a powerful template system. It is a native support for ISO19115/ISO19119/ISO19139/ISO19110, FGDC and Dublin Core formatted metadata.

GeoNetwork allows, group and user management, multi-lingual user interface and support CSW, according to OGC standards.

- Website: <http://geonetwork-opensource.org>
- License: GNU General Public License (GPL) version 2

- Software Version: 2.10.0
- Supported Platforms: Windows, Linux, Mac

### PYCSW FOR METADATA CATALOGUE MANAGEMENT

Pycsw enables users to publish a catalogue of dataset descriptions (metadata) to the web, using standards based interfaces and formats, such that it can be queried and updated by catalogue clients. pycsw is simple to setup within an Apache web server and can access metadata records stored as XML files within a database.



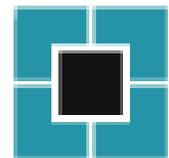
Pycsw is a Python implementation of the OGC Catalogue Services for the Web (CSW) standard. The project is certified OGC Compliant, and is an OGC Reference Implementation. The CSW standard defines common interfaces to discover, browse, and query metadata about spatial data, web services, and related resources.

Pycsw is Open Source, released under an MIT license, and runs on all major platforms (Windows, Linux, and Mac OS X). It supports for WMS, WFS, WCS, WPS, WAF, CSW, and SOS INSPIRE Discovery Services 3.0. It supports, GeoNode, and Open Data Catalog connectivity and is very lightweight (Python + CGI). It supports, GML, Dublin Core 1.1, SOAP 1.2, ISO 19115 2003, ISO 19139 2007, ISO 19119 2005, Metadata Standards.

- Website: <http://pycsw.org>;
- License: MIT;
- Software Version: 1.6.0;
- Supported Platforms: Windows, Linux, Mac;

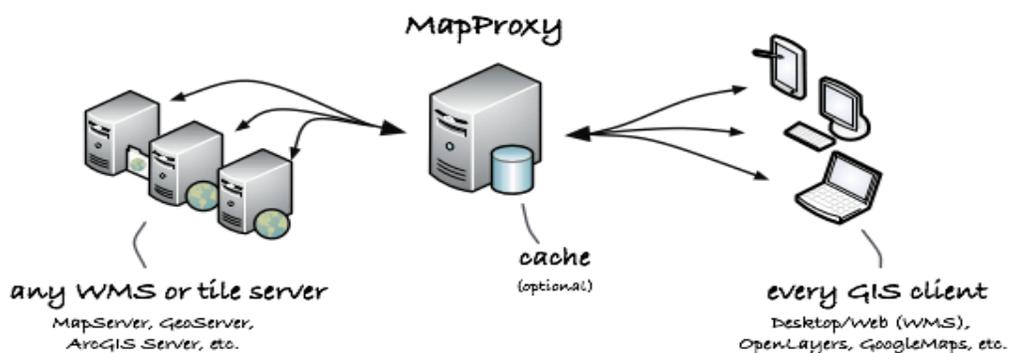
### MAPPROXY FOR PROXY WMS & TILE SERVICES

MapProxy speeds up mapping applications by pre-rendering and integrating maps from multiple sources and storing in a local cache. Layers can be made transparent, projections can be changed, multiple map layers can be transformed into one, watermarks can be added, and more...



MapProxy is flexible and scales from simple to complex use-cases: from a single tile cache for an **OpenLayers** web client to a central SDI node that combines, unifies, and accelerates dozens of distributed WMS services.

MapProxy is used for the German broadband atlas to deliver maps for thousands of users and the German Federal Agency for Cartography and Geodesy uses MapProxy to aggregate WMS services from all 16 states on the fly.



## The State Of The Art Available Software & Solution

MapProxy Input sources can be:

WMS from MapServer, GeoServer, etc;

WMTS from TileCache, GeoWebCache, etc;

MapServer and Mapnik directly, without WMS;

Any TileCache, Google Maps or Bing compatible source;

It is compliant with OGC standards in WMS, TMS, WMTS, KML, and allows tile cache e.g. stores identical images just once (e.g. ocean tiles), stores tiles in file system, MBTile files or CouchDB and add watermark to tiles.

It allows adding transparency to opaque layers, merging multiple sources, re-projecting to other SRS and building layer trees from different sources.

MapProxy accelerates existing WMS 10 to 100 times and allows on-the-fly reprojection.

- Website: <http://mapproxy.org/>;
- License: Apache Software License 2.0;
- Software Version: 1.5.0;
- Supported Platforms: Linux, Mac, Windows;

### QGIS SERVER FOR WEB MAP SERVICE

QGIS Server provides a web map service (WMS) using the same libraries as the Quantum GIS (QGIS) desktop application. Maps and print templates created in QGIS desktop can be published as web maps simply by copying the QGIS project file into the server directory. The resulting web maps look the same exactly as in the desktop. QGIS Server is usually run as CGI/FastCGI module within the Apache Web server.



It supports WMS, SLD implementation compliant with OGC standards, built-in PDF output, WYSIWYG map creation with QGIS, and advanced cartographic symbolization.

- Website: <http://www.qgis.org/>
- License: GPL
- Software Version: 1.8.0
- Supported Platforms: Windows, Linux

### TINYOWS FOR WFS TRANSACTIONAL SERVICE

TinyOWS is a high performance, Transactional Web Feature Service (WFS-T) which is lightweight and easy to deploy, using a CGI or FastCGI interface and using PostGIS for data storage.



TinyOWS is commonly used in conjunction with MapServer to provide WFS-T and fast WFS services for QGIS and/or OpenLayers clients. It is used in production in organizations around the world, including risk adverse government agencies. TinyOWS strictly implements the WFS 1.0, 1.1 standards, and it has passed all OGC CITE units tests. (~ 1000 unit tests)

It provides connection to PostGIS data, and is Configured using MapServer's configuration file, allowing a single configuration file for both applications. TinyOWS implements WFS, FE, and GML Standards, in compliance with OGC.

- Website: <http://tinyows.org>

- License: MIT
- Software Version: 1.1.0
- Supported Platforms: Linux, Unix, Mac, Windows

## ZOO-PROJECT AS A WPS SERVER

ZOO-Project provides a developer friendly Web Processing Service (WPS) framework for creating and chaining Web Processing Services.



A WPS provides web access to functions, which run spatial algorithms. ZOO-Project supports many programming languages.

ZOO is made of three parts:

*ZOO Kernel*: A powerful server-side C Kernel that makes it possible to manage and chain Web services coded in different programming languages.

*ZOO Services*: A growing suite of example Web services based on various Open Source libraries.

*ZOO API*: A server-side JavaScript API that is able to call and chain the ZOO Services, making the development and chaining processes easier.

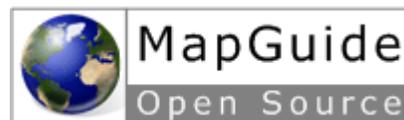
ZOO is based on a 'WPS Service Kernel', which constitutes the ZOO's core system (aka ZOO Kernel). The latter is able to load dynamic libraries and to handle them as on-demand Web services. The ZOO Kernel is written in C language, and it supports several common programming languages. It enables connection to numerous libraries and, above all simplifies the Web service end-developer's job.

A ZOO service is a link composed of a metadata file (.zcfg) and the code for the corresponding implementation. The metadata file describes all the available functions, which can be called using a WPS Exec Request, as well as the desired input/output. Services contain the algorithms, functions, and, it can be implemented in C/C++, FORTRAN, Java, Python, PHP, and JavaScript.

- Website: <http://zoo-project.org>
- License: MIT x/11
- Software Version: 1.2.0
- Supported Platforms: Windows, Linux, Mac

## MAPGUIDE OPEN SOURCE FOR WEB SERVICE

MapGuide Open Source is a web-based platform that enables users to develop and deploy web mapping applications and



geospatial web services. MapGuide features an interactive viewer that includes support for feature selection, property inspection, map tips, and operations such as buffer, select within, and measure.

MapGuide includes an XML database for managing content. Maestro allows users to edit the XML database and build a website without writing a single line of code. MapGuide also supports most popular geospatial file formats, databases, and standards.

MapGuide can be deployed on Linux or Windows, supports Apache and IIS web servers, and offers extensive PHP, .NET, Java, and JavaScript APIs for application development. MapGuide Open Source is licensed under the LGPL.

MapGuide supports, Interactive Map Viewing, Dynamic browser-based viewer, Feature selection and properties, Buffering, querying, and Printing and Plotting for Quality Cartographic Output, as well as Scale-dependent detail, Rule-driven thematic stylization, Anti-aliased image rendering, and True color

support. It can Perform coordinate reprojection, Create, manipulate, and analyze geometry and Implemented WMS, OGC Standards

- Website: <http://mapguide.osgeo.org/>
- License: GNU Lesser General Public License (LGPL)
- Software Version: 2.4.0 Pre-Release
- Supported Platforms: Linux, Windows

## 2.5.1.4 DATA STORES & STORING SPATIAL DATA

### POSTGIS AS SPATIAL DATABASE

PostGIS spatially enables the popular PostgreSQL object-relational database, allowing it to be used as a back-end database for geographic information systems (GIS) and web-mapping applications in the same manner as Oracle Spatial enables the Oracle database.



PostGIS is stable, fast, standards compliant, with hundreds of spatial functions and is currently the most widely used Open Source spatial database. PostGIS is used by diverse organizations from around the world, including risk-averse government agencies and organizations storing terabytes of data serving millions of web requests per day.

Database administration is available for desktop and the web via pgAdmin, php PgAdmin, and others. Data import/export can be done by command line tools (shp2pgsql, pgsq2shp, ogr2ogr, dxf2postgis) or from desktop and web GIS clients. These clients can also map and manipulate PostGIS spatial data tables. It allows hundreds of spatial functions including, Buffers, unions, overlays, distance and more as well as ACID<sup>1</sup> transactional integrity, R-Tree spatial index, Multi-user support, and...

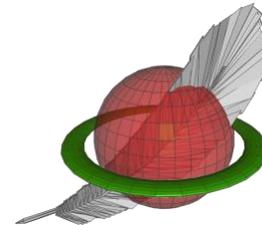
PostGIS implements SFQL OGC Standards.

- Website: <http://www.postgis.net>
- License: GNU General Public License (GPL) version 2
- Software Version: 2.0.3
- Supported Platforms: Windows, Linux, Mac
- API Interfaces: SQL

### SPATIALITE AS A LIGHTWEIGHT DATABASE

Spatialite is a SQLite<sup>2</sup> database engine with spatial functions added.

SQLite is a Database Management System (DBMS), which is simple, robust, easy to use and very lightweight. Each SQLite database is simply a file. You can freely copy it, compress it, and port it between Windows, Linux, and MacOs etc.



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<sup>1</sup> ACID stands for atomicity, consistency, isolation, and durability. These properties ensure predictable behavior, reinforcing the role of transactions as all-or-none propositions designed to reduce the management load when there are many variables.

<sup>2</sup> SQLite is a software library that implements a self-contained, server-less, zero-configuration, transactional SQL database engine. SQLite is the most widely deployed SQL database engine in the world. The source code for SQLite is in the public domain. (SQLite 2013)

The SpatiaLite extension enables SQLite to support spatial data conformity to OGC specifications.

It supports standard WKT<sup>1</sup> and WKB<sup>2</sup> formats, and implements SQL spatial functions, as well as the complete set of OpenGIS functions, which is supported via GEOS<sup>3</sup>.

The SpatiaLite supports full Spatial metadata along the OpenGIS specifications, alternative Geometry notations - EWKT, GML, KML, and GeoJSON, importing and exporting to shapefiles as well as coordinate reprojection via PROJ.4 and EPSG geodetic parameters dataset.

The VirtualShape extension enables SQLite to access shapefiles as VIRTUAL TABLEs and it can then perform standard SQL queries on external shapefiles, with no need for importing or converting them.

- Website: <http://www.gaia-gis.it/gaia-sins/>
- License: MPL v1.1 and GPL v3
- Software Version: spatialite 3.1.0 / librasterlite 1.1 / spatialite-gui 1.5.0 / spatialite-gis 1.0.0
- Supported Platforms: Linux, Mac, Windows

### RASDAMAN AS MULTI-DIMENSIONAL RASTER DATABASE



Rasdaman is an Array Database System, which provides flexible, fast, scalable geo services for multi-dimensional spatio-temporal sensor, image, simulation, and statistics data of unlimited volume. Ad-hoc access, extraction, aggregation, as well as remix and analytics is enabled through a NewSQL<sup>4</sup> raster query language with highly effective server-side optimization. Cloud/cluster parallelization is accomplished in a secure, administrator-controlled way. Data is stored in a PostgreSQL database, thereby achieving full information integration.

In addition to the raster query language, Rasdaman supports OGC's WMS, WCS, WCPS, and WPS web service standards, as well as C++ and Java APIs. A Rasdaman driver is part of GDAL and MapServer.

Rasdaman has received a series of international innovation awards, among them the prestigious European IT Prize and Geospatial Innovation Award. Technology is mature and stable, being in operational for more than ten years. Among the operators of Rasdaman, services are mapping agencies and climate data centers.

It is truly multi-dimensional - 1-D, 2-D, 3-D, 4-D, powerful, and has flexible query language for visualization, classification, convolution, aggregation, and many more geospatial functions. It allows full information integration of raster data with all geo data in the PostgreSQL database and support for the raster-relevant OGC standards, Reference Implementation for WCS, WCPS. Rasdaman implements WMS, WPS OGC Standards.

- Website: <http://www.rasdaman.org>
- License: GNU Lesser General Public License (LGPL) version 3

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<sup>1</sup> WKT stands for Well Known Text.

<sup>2</sup> WKB stands for Well Known Binary

<sup>3</sup> GEOS stands for Geometry Engine - Open Source

<sup>4</sup> NewSQL is a new database access language. NewSQL is a class of modern relational database management systems that seek to provide the same scalable performance of NoSQL systems for online transaction processing (read-write) workloads while still maintaining the ACID guarantees of a traditional database system.

## The State Of The Art Available Software & Solution

- Software Version: 8.5
- Supported Platforms: Linux, MacOS, Solaris

### PGROUTING AS ROUTING FOR POSTGIS

PgRouting extends the **PostGIS**/PostgreSQL geospatial database to provide geospatial routing and other network analysis functionality.

Advantages of the database routing approach are:

Data and attributes can be modified by many clients, like **Quantum GIS** and **uDig** through JDBC, ODBC, or directly using PI/pgSQL. The clients can use either PCs or mobile devices.

Data changes can be reflected instantaneously through the routing engine. There is no need for pre-calculation.

The “cost” parameter can be dynamically calculated through SQL and its value can come from multiple fields or tables.

PgRouting is available under the GPLv2 license and is supported by a growing community of individuals, businesses, and organizations.

PgRouting provides functions performed by various algorithms.

Website: <http://www.pgrouting.org>

License: GNU General Public License (GPL) version 2

- Software Version: 2.0
- Supported Platforms: Linux, Windows, Mac
- Navigation and Maps

### GPSDRIVE AS GPS NAVIGATION SOFTWARE

GpsDrive is a car (bike, ship, plane, foot) navigation system. GpsDrive displays your position provided from a GPS on a zoom able map. The map file is auto-selected depending on your position and preferred map scale. All GPS receivers which support the NMEA<sup>1</sup> protocol should be usable, as well as many USB GPSs using a binary protocol known to the Gpsd<sup>2</sup> GPS daemon and multiplexer.

GpsDrive downloads LANDSAT or OpenStreetMap data from the Web, or register your own images, and renders lively OpenStreetMap data stored in a PostGIS database using Mapnik as well as NASA’s Blue Marble high-resolution mosaic.

It allows verbal instructions using eSpeak; search for nearest POI waypoints within a given radius, route planning as well as server to keep track of your friends’ positions and Kismet Wi-Fi integration.



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<sup>1</sup> **NMEA** is a combined electrical and data specification for communication between marine electronics such as echo sounder, sonar, anemometer, gyrocompass, autopilot, GPS receivers and many other types of instruments. It has been defined by, and is controlled by, the National Marine Electronics Association.

<sup>2</sup>Gpsd is a software that receives data from a GPS receiver, and provides the data back to multiple applications such as Kismet or GPS navigation software.

- Website: <http://www.gpsdrive.de>
- License: GNU General Public License (GPL) version 2
- Software Version: 2.12
- Supported Platforms: GNU/Linux, Mac OSX

### GPS PRUNE TO VIEW, EDIT AND CONVERT GPS TRACKS

GpsPrune is a tool for viewing, editing, and converting coordinate data from GPS systems. It uses OpenStreetMap imagery to show recorded tracks and waypoints, and provides a variety of tools to let you edit, crop and prune the data points. It also has functions for correlating photos and audio files to the coordinates using the file timestamps.



GpsPrune uses Gpsbabel, if available, to read data directly from a GPS receiver, and can send the edited data back to the receiver too. GpsPrune runs on Mac OSX, Windows, and Linux, and is available in over ten different languages.

It allows Zoom able map imagery from OpenStreetMap, altitude or speed profile view, Interactive 3d view of the data, and automatic correlation of photographs and audio files with the loaded data using timestamps, as well as creation of charts such as altitude against distance, speed against time

- Website: <http://gpsprune.activityworkshop.net/>
- License: GNU General Public License (GPL) version 2
- Software Version: 13.1
- Supported Platforms: GNU/Linux, Mac OSX, Windows

### MARBLE AS A VIRTUAL GLOBE AND WORLD ATLAS

Marble is an open source KDE Education Project program similar to NASA World Wind or Google Earth. Besides choosing any number of maps to view on your globe (including OpenStreetMap), you are encouraged to include a KDE Marble widget in your application.



# MARBLE

Explore the neighborhood with Marble's rich set of city and street level maps. Search for addresses and places of interest. Marble takes care of querying various search back ends and presents their results in a unified view. Calculate pedestrian, bike and motorcar routes with ease - online and offline, with an arbitrary number of via points.

Start exploring the world. View clouds and sun shadow, follow satellites and space stations and display their orbits, all updated in real-time. Travel back in time and learn about historic views of our planet using maps from past centuries. Earth is not enough. Marble also offers maps of the moon and other planets.

Marble allows to search (Online address search, Online POI search), as well as routing & Navigation (Voice navigation, Online motorcar routing, Online bike routing, Online pedestrian routing, Offline routing optional download, Turn-by-turn navigation). It supports tools (Distance measurement, Bookmarks, Time Simulation, and Offline Mode) and OpenStreetMap integration.

- Website: <http://marble.kde.org>;
- License: GNU Lesser General Public License (LGPL) version 2.1;
- Software Version: 1.6.0;
- Supported Platforms: GNU/Linux, Mac OSX, MS Windows;

## OPENCNP AS MARINE GPS CHART PLOTTER NAVIGATION SOFTWARE

OpenCPN provides free navigation software for use at the helm of vessels of all types and sizes, as well as offline for route planning. It has been developed by a team of active sailors using real world conditions for program testing and refinement.



OpenCPN presents a user with the vessel's current position, speed, and course superimposed upon accurate navigational chart images, tide, and current predictions. Information received by standard radio links describing the position and intent of other vessels can also be shown.

As the host vessel moves, new charts are selected and displayed at user specified resolution and detail. Further, the user may enter routes and waypoints allowing interface to an external autopilot for precise course following.

OpenCPN supports, NMEA GPS or Gpsd daemon input, waypoint / autopilot navigation and unlimited route/mark creation.

- Website: <http://www.opencpn.org>
- License: GNU General Public License (GPL) version 2
- Software Version: 3.2.2
- Supported Platforms: GNU/Linux, Mac OSX, MS Windows;

## OPENSTREETMAP AS A TOOL FOR MAPPING THE WORLD

OpenStreetMap is a project aimed squarely at creating and providing free geographic data such as street maps to anyone who wants it. The project was started because most maps you think of as free actually have legal or technical restrictions on their use, holding back people from using them in creative, productive, or unexpected ways.



A number of programs have been included: JOSM<sup>1</sup>, Merkaartor<sup>2</sup>, Osmosis<sup>3</sup>, Osm2pgsql<sup>4</sup>, and a number of small command utilities. In addition, recent sample data for the host city and a number of JOSM plugins have been included.

OpenStreetMap is global massively crowd-sourced dataset, and widespread geo-application integration

- Website: <http://www.openstreetmap.org>
- license: OpenStreetMap data: [http://wiki.openstreetmap.org/index.php/OpenStreetMap\\_License](http://wiki.openstreetmap.org/index.php/OpenStreetMap_License)
- JOSM: GNU General Public License (GPL) version 2
- JOSM plugins collection: Ranging from Public Domain to GPLv3

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<sup>1</sup> JOSM is an extensible editor for OpenStreetMap (OSM) written in Java 6.

<sup>2</sup> Merkaartor is an OpenStreetMap editor for Unix, Windows and Mac OSX (prerelease, Intel only), distributed under the GNU General Public License.

<sup>3</sup> Osmosis is a command line Java application for processing OSM data. The tool consists of a series of pluggable components that can be chained together to perform a larger operation.

<sup>4</sup> osm2pgsql is a command-line based program that converts OpenStreetMap data to PostGIS-enabled PostgreSQL databases.

- Merkaartor: GNU General Public License (GPL) version 2
- Software Versions:
- JOSM: Latest stable snapshot (svn r6060)
- Merkaartor: 0.17.2
- Osmosis: 0.40.1
- osm2pgsql: SVN version 0.81.0
- Supported Platforms: GNU/Linux, Mac OSX, MS Windows

### VIKING TO MANAGE AND PLOT GPS DATA

Viking is a GPS data editor, analyzer, and viewer. Viking aims to be easy to use, yet powerful in accomplishing a wide variety of GPS related tasks. It uses a hierarchical layering system to organize GPS data, maps, and other layer types with spatial data, such as coordinate lines. It works with OpenStreetMap data and various online tile servers.



Viking allows Upload and downloads waypoints, tracks to and from your GPS with real time GPS tracking and track recording. It prepares tracks and waypoints for trips using maps from services such as OpenStreetMap and Bing Aerial. You only need to upload the data to your GPS before you leave. The maps together with your tracks and waypoints can also be printed and used during the trip as well as creating maps with coordinate lines. It enables speed analysis at different places.

- Website: <http://sourceforge.net/apps/mediawiki/viking/>
- License: GNU General Public License (GPL) version 2
- Software Version: 1.2.1
- Supported Platforms: GNU/Linux, MS Windows

### 2.5.1.5 SPATIAL ANALYSIS TOOLS

#### GEOKETTLE AS ETL (EXTRACT, TRANSFORM AND LOAD) TOOL

GeoKettle is a “spatially-enabled” version of Pentaho Data Integration (also known as Kettle). It is a powerful, metadata-driven spatial ETL (Extract, Transform, and Load) tool dedicated to the integration of different data sources for building and updating geospatial databases, data warehouses, and web services.



GeoKettle enables the Extraction of data from data sources, the transformation of data in order to correct errors, clean data, change data structure, make data compliant with standards, and Loading of transformed data into a target Database Management System (DBMS), GIS file, or geospatial web service. GeoKettle is particularly useful for automating complex and repetitive data processing without producing specific code, converting between data formats, migrating data between databases, feeding data into databases, etc.

## The State Of The Art Available Software & Solution

In the geospatial domain, GeoKettle compares to FME<sup>1</sup>, a proprietary spatial ETL tool. GeoKettle is stable, fast, standards compliant, with hundreds of functions and read/write support for many file formats, services, and DBMS. GeoKettle is used by diverse organizations from around the world, including governmental agencies, banks, and insurance and geospatial system integrators. It allows extracting data from 35+ database types such as MySQL, PostgreSQL/PostGIS, Oracle ... It supports OGC Web services such as SFS, WFS-T, WPS, CSW, SOS, GML, and KML.

- Website: <http://www.geokettle.org/>
- License: GNU Lesser General Public License (LGPL) version 2.1
- Software Version: 2.5
- Supported Platforms: Windows, Linux, Mac, Solaris

### GMT AS A THE GENERIC MAPPING TOOLS FOR CARTOGRAPHIC RENDERING

GMT is a collection of tools that allow users to manipulate (x, y) and (x, y, z) data sets (including filtering, trend fitting, gridding, projecting, etc.) and produce Encapsulated PostScript File (EPS). It allows illustrations ranging from simple x-y plots through contour maps to artificially illuminated surfaces and 3-D perspective views in black and white, gray tone, hachure patterns, and 24-bit color.



GMT supports many common map projections plus linear, log, and power scaling, and comes with support data such as coastlines, rivers, and political boundaries.

It supports gridding and contouring functions for quality cartography.

- Website: <http://gmt.soest.hawaii.edu>
- License: GNU General Public License (GPL) version 2
- Software Version: 4.5.6
- Supported Platforms: GNU/Linux, Mac OSX, MS Windows

### MAPNIK AS CARTOGRAPHIC RENDERING ENGINE

Mapnik is a toolkit for rendering beautiful maps, with clean, soft feature edges provided by quality anti-aliasing graphics, intelligent label placement, and scalable, SVG symbolization.



Most famously, Mapnik is used to render the OpenStreetMap main map layers.

It can comfortably be used for both desktop map design and web development. Mapnik has typically been embedded in Python applications which deliver their maps over the internet although scaling improvements have meant that Mapnik has recently been getting used to create high resolution paper maps too.

Essentially a collection of geographic objects (map, layer, data source, feature, geometry) exists, the library does not rely on “windowing systems” and can be deployed in any server environment. It is intended to play fair in a multi-threaded environment and is aimed primarily, but not exclusively, at

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<sup>1</sup> FME is software to transform and exchange Geospatial data into/from more than 300 formats to use and share.

web-based development. High-level Python bindings (boost. Python) facilitate rapid application development, targeting zope3, Django etc.

Mapnik is cross platform. Packages are available for most linux distributions and installers are commonly used on Mac OS X and windows.

- Website: <http://www.mapnik.org/>
- License: LGPL (GNU Lesser General Public License)
- Software Version: 2.0.0
- Supported Platforms: Windows, Linux, Mac

### TILEMILL AS A DESIGN STUDIO FOR WEB MAPS STYLING AND PUBLISHING

TileMill is a design studio for creating beautiful, web based, interactive maps from a wide range of existing spatial data sources.



Generated webmaps can use hover tooltips, clickable pop ups, interactive graphs and images, SVG markers, rich textures, and multiple layers. Customized maps can be exported to different formats like, .png, .pdf, .svg and MBTiles. The MBTiles spec defines how to store tiles as a single file, as a SQLite database.

Data can be sourced from vector data (CSV, shapefile, KML, GeoJSON), raster (GeoTIFF), as well as large data sources like OpenStreetMap, PostgreSQL, and SQLite.

TileMill makes use of the Mapnik map-rendering library (as used by OpenStreetMap) and uses the CartoCSS as a style sheet language.

TileMill is typically used in conjunction with a desktop GIS (like QuantumGIS) for preparing data, and a graphics editor (like GIMP) for creating icons, patterns, and textures.

TileMill can load data from a wide range of sources and formats such as, ESRI Shapefile, KML, GeoJSON, GeoTIFFs, CSV spreadsheet, OpenStreetMap, PostgreSQL, PostGIS, and SQLite.

TileMill publishes .png, .pdf, .svg, MBTiles, and maps as WebPages

TileMill does not support OGC standards, like WMS or WFS. Rather it adheres to the widespread practices of z/x/y tile schemes, used by Google and OSM and is based on the MBTiles and UTFGrid specifications.

- Website: <http://tilemill.com>
- License: BSD
- Software Version: 0.10.1
- Supported Platforms: Windows, Linux, Mac

### MAPTLER AS MAP PUBLISHING CREATE MAP TILES

MapTiler is a desktop application for the creation of map tiles for rapid raster map publishing. Geodata is transformed to tiles compatible with Google Maps and Earth - ready for publishing via direct upload to any web server or a cloud storage (such as Amazon S3).



No extensive configuration on the server side is necessary; any simple file

## The State Of The Art Available Software & Solution

hosting is fine. Dynamic interaction such as panning and zooming, overlay of markers and vector data is provided by powerful browser functionality. The application directly generates a ready to use simple viewer based on OpenLayers and Google Maps API and can be easily customized.

MapTiler is a multi-platform desktop application. Installers are available for Windows, Mac OS X and packages for Linux (Debian/Ubuntu).

MapTiler supports JavaScript APIs such as OpenLayers, Google Maps API, and follows OGC's standard for TMS as well as various file formats such as TIFF/GeoTIFF, MrSID, ECW, JPEG2000, Erdas HFA, NOAA BSB, JPEG and more...

- Website: <http://www.maptiler.org/>
- License: New BSD License
- Software Version: 1.0beta2
- Supported Platforms: Windows, Linux, Mac

### OSSIM FOR REMOTE SENSING

Open Source Software Image Map (OSSIM) is a high performance engine for remote sensing, image processing, geographical information system and photogrammetry.



OSSIM has been funded by several US government agencies in the intelligence and defense community and the technology is currently deployed in research and operational sites. It has been actively developing since 1996.

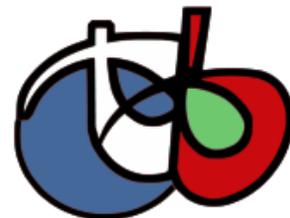
OSSIM is designed as a series of high performance software libraries, it is written in C++ employing the latest techniques in object-oriented software design. Many command line utilities, GUI applications, and integrated systems have been implemented - several of which are included with the software distribution.

It supports Universal Sensor Models (RPCs) and Wide range of Map Projections and Datums as well as precision terrain correction and ortho-rectification. It allows advanced mosaicing, compositing and fusions.

- Website: <http://www.ossim.org>
- License: GNU General Public License (GPL) version 3
- Software Version: 1.8.16
- Supported Platforms: Linux, Mac, Windows

### OTB FOR IMAGE PROCESSING

ORFEO Toolbox Library (OTB) is a high performance image-processing library. It is primarily used for processing remote sensing images such as those gathered by radars, satellites, and aerial photography. OTB provides tools for the future optic and radar images (tridimensional aspects, segmentation, classification, changes detection, texture analysis, pattern matching, optic/radar complementarities,).



OTB has been funded by the French Space Agency (CNES) in the frame of the Methodological Part of the ORFEO Accompaniment Program and has been actively developed since 2006. It is based on the established medical image-processing library ITK and is distributed as open source.

OTB supports ortho-rectification, map re-projection and sensor model refinement, and calibration as well as image fusion, filtering, blurring, de-noising, and enhancement.

Feature extraction, object detection, large-scale image segmentation, and classification using K-means, Markov random fields are supported by OTB. It is able to object-based image analysis, geospatial analysis, and stereoscopic reconstruction from optical images.

SAR data analysis is one of OTB's ability.

- Website: <http://www.orfeo-toolbox.org/>
- License: CeCILL (CeCILL is compatible with GPL and enhanced to address French law)
- Software Version: 3.18.1 (released in July 2013)
- Supported Platforms: Linux, Mac, Windows

## R PROJECT FOR STATISTICAL PROGRAMMING

R is a powerful, widely used software environment for statistical computing and graphics, which excels at analyzing and processing geographic data sets. Geospatial analysis capabilities within R are available in R packages (modules that extend the capabilities of R) that provide access to a large number of traditional and state of the art algorithms, often before they are available in other open source or proprietary software. R and its packages are able to process point, line, polygon and grid data. Users can accomplish a broad array of tasks such as image classification, statistical analysis to infer spatial relationships and patterns of features, and others. The functions available via R complement and advance capabilities found in GIS and image processing software.



The core R interface is a command line window, which provides excellent flexibility and control but tends to lengthen the time required to become a proficient user when compared to software with a graphical user interface (GUI). Fortunately, R is well documented on the web site, which eases the learning process. Scripts are often used to automate processing steps but there are GUIs, the leading one being RStudio<sup>1</sup>.

R is an implementation of the S programming language and there is significant compatibility between R and legacy S and S-Plus code as well as between R and the modern commercial version of S, TIBCO Spotfire S+. This makes it possible to convert different versions of S code to run on R without major code modifications.

R is a Complete Object Oriented Programming Language designed for Statistics and similar Mathematical intensive applications and hundreds of community contributed add-on packages for spatial statistics.

R supports handling of spatial data, point pattern analysis, Geo-statistics such as Spatial regression, ecological analysis.

- Website: <http://cran.r-project.org>
- License: GPL
- Software Version: 3.0.1
- Supported Platforms: Windows, Linux, Mac, Unix

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<sup>1</sup> <http://www.rstudio.com>

- Domain Specific GIS (Applications targeted at a specific domain)

#### SAHANA EDEN FOR DISASTER MANAGEMENT

Sahana Eden is a Family of Applications to Help You Help Others. It provides web based collaboration tools that address the common coordination problems faced during a disaster including finding missing people, managing aid, managing volunteers, and tracking camps effectively between Government groups, the civil society (NGOs) and the victims themselves.



Solutions are available for Disaster Management, Emergency Management, Development, Humanitarian, and Environmental sectors. Free and Open Source means that it is easily Customizable and Extensible. Sahana Eden is also able to integrate with other solutions and can provide a management/ticketing interface around crowd-sourced data - such as that collected in the Ushahidi incident mapping application.

The Sahana project was initiated by volunteers in the Sri Lankan FOSS development community to help their fellow citizens affected during the 2004 Asian Tsunami in December 2004. The system was officially used by the Government of Sri Lanka and the system was released as Free and Open Source software. Subsequently a re-write as a generic disaster management tools was incubated with the sponsorship of the Swedish International Development Agency, IBM, the US National Science Foundation and it has been used by dozens of Governments and NGOs since then.

The Sahana supports:

Mapping - Situation Awareness & Geospatial Analysis;

Requests Management - Tracks requests for aid and matches them against donors who have pledged aid;

Volunteer Management - Manage volunteers by capturing their skills, availability and allocation;

Missing Persons Registry - Report and Search for Missing Persons;

Disaster Victim Identification;

Shelter Registry - Tracks the location, distribution, capacity, and breakdown of victims in Shelters;

Hospital Management System - Hospitals can share information on resources & needs;

Organization Registry - "Who is doing What & Where". Allows relief agencies to coordinate their activities;

Ticketing - Master Message Log to process incoming reports & requests;

Messaging - Sends & Receives Alerts via Email & SMS;

Document Library - A library of digital resources, such as Photos & Office documents;

Ushahidi Integration - Able to integrate data from Ushahidi;

- Website: <http://eden.sahanafoundation.org/>
- License: MIT License
- Software Version: 1.0.1
- Supported Platforms: GNU/Linux, Mac OS X, Microsoft Windows

## USHAHIDI FOR INCIDENT TIMELINE & MAPPING

The Ushahidi Engine is a free and open source platform that allows anyone to gather distributed data via SMS, email or web and visualize it on a map or a timeline. Ushahidi goal is to create tools for democratizing information, increasing transparency and lowering the barriers for individuals to share their stories.



Ushahidi, which means “testimony” in Swahili, was initially developed to map reports of violence in Kenya after the post-election fallout at the beginning of 2008. Ushahidi roots are in the collaboration of Kenyan citizen journalists during a time of crisis. The website was used to map incidents of violence and peace efforts throughout the country based on reports submitted via the web and mobile phone. This initial deployment of Ushahidi had 45,000 users in Kenya, and was the catalyst for us realizing there was a need for a platform based on it, which could be use by others around the world.

Ushahidi supports Interactive map, timeline, ability to subscribe to report alerts based on proximity, CSS based themes, Scheduler, and Video upload.

- Website: <http://www.ushahidi.com>
- License: GNU Lesser General Public License (GPL) version 3
- Software Version: 2.7 (Bamako)
- API Interfaces: PHP
- Supported Platforms: Linux, Mac, Windows

## OSGEARTH AS TERRAIN RENDERING TOOLKIT

OsgEarth is a scalable terrain-rendering toolkit for OpenSceneGraph (OSG), an open source, high performance, 3D graphics toolkit. Just create a simple XML file, point it at your imagery, elevation, and vector data, load it into your favorite OSG application, and go! OsgEarth supports all kinds of data and comes with lots of examples to help you get up and running quickly and easily.



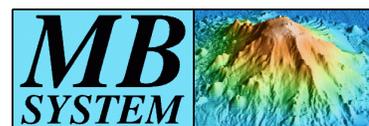
OsgEarth makes it easy to deploy scalable terrain models, create terrain models-either offline, or dynamically at run-time. It can also load whole-earth terrains without writing any code, and set up map tile caches to maximize performance. It can adjust layer opacity for multi-texturing effects and drape vector (GIS) data on the terrain.

OsgEarth supports GeoTIFFs imagery and Digital Elevation Model (DEM) files (plus lots of other formats) such as vector data like ESRI shapefiles. OsgEarth is OGC-compliant for WMS.

- Website: <http://osgearth.org/>
- License: GNU Lesser General Public License (LGPL)
- Software Version: 2.4.0
- Supported Platforms: Linux, Mac, Windows

## MB-SYSTEM FOR SEA FLOOR MAPPING

MB-System is an open source software package for the processing and display of bathymetry and backscatter imagery data derived from multi-beam, interferometry, and side scan sonar. It makes extensive use of the GMT software.



MB-System has been under development since 1993, with active support from a number of research and science organizations.

MB-System supports Interactive 3D visualization Read, gridding, statistical analysis, and extraction of cleaned bathymetric product, as well as side-scan and amplitude data processing and mosaicing. It supports Exporting data products to GIS and visualization packages and is able to process sub-bottom profiler data and tide modeling and correction.

- Website: <http://www.ideo.columbia.edu/res/pi/MB-System/>
- License: GNU General Public License (GPL) version 3
- Software Version: 5.4.2128
- Supported Platforms: GNU/Linux, Mac OSX, MS Windows (with Cygwin<sup>1</sup>)

#### ZYGRI B FOR WEATHER FORECASTING

ZyGrib is a program to download and visualize weather forecast data in the standard GRIB distribution format.



ZyGrib supports visualization of meteorological data from files in GRIB format, automatic download of weather and wave forecasts from IAC (fleet code) data, and playing animations of 8-day forecasts. ZyGrib can create regional weather maps (worldwide), or view a detailed quantitative forecast for a particular location as well as plotting wind, pressure, temperature, humidity, rain, snow, cloud cover, dew point, wave height, and high altitude data.

- Website: <http://www.zygrib.org>
- License: GNU General Public License (GPL) version 3
- Software Version: 6.1.4
- Supported Platforms: GNU/Linux, Mac OSX, MS Windows

### 2.5.1.6 GEOSPATIAL LIBRARIES

#### GDAL/OGR AS GEOSPATIAL DATA TRANSLATION TOOLS

Geospatial Data Abstraction Library (GDAL/OGR) provides command-line utilities to translate and process a wide range of raster and vector geospatial data formats.



The utilities are based upon a cross platform, C++ library, accessible via numerous programming languages. As a library, it presents a single abstract data model to the calling application for all supported formats.

GDAL/OGR is the most widely used geospatial, data access library. It provides the primary data access engine for many applications including MapServer, GRASS, QGIS, and OpenEV. It is also utilized by packages such as OSSIM, Cadcorp SIS, FME, Google Earth, VTP, Thuban, ILWIS, MapGuide, and ArcGIS.

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<sup>1</sup> From: <http://cygwin.com/>;Cygwin is:

- A collection of tools which provide a Linux look and feel environment for Windows;
- A DLL (cygwin1.dll) which acts as a Linux API layer providing substantial Linux API functionality;

GDAL supports large files - larger than 4GB, Library access from Python, Java, C#, Ruby, VB6 and Perl, as well as having a coordinate system engine built on PROJ.4 and OGC Well Known Text coordinate system descriptions.

GDAL supports over 50 raster formats, and OGR over 20 vector formats including:

Raster: GeoTIFFs, Erdas Imagine, SDTS, ESRI Grids, ECW, MrSID, JPEG2000, DTED, and more ...

Vector: MapInfo (tab and mid/mif), ESRI Shapefile, ESRI Coverage, ESRI Personal Geodatabase, DGN, GML, PostGIS, Oracle Spatial, and more ...

The OGR vector data model is compliant with the OGC Simple Features specification.

- Website: <http://www.gdal.org>
- License: X/MIT style Open Source license
- Software Version: 1.10.0
- Supported Platforms: Windows, Linux, Mac

### JTS TOPOLOGY SUITE (JTS, JAVA TOPOLOGY SUITE)

JTS is an open source library of spatial predicates and functions for processing geometries. It provides a complete, consistent, and robust implementation of fundamental algorithms for processing linear geometry on the 2-dimensional Cartesian plane.

## JTS Topology Suite

JTS includes the “JTS Test Builder” which allows users to run tests and experiment with geometry through an interactive desktop interface. JTS stability is ensured through an extensive test suite.

JTS is used by most java based Open Source geospatial applications, and GEOS, which is a C++ port of JTS, is used by most C based applications. Additional ports are available for C# and JavaScript.

JTS supports Well Known Text (WKT), Well Known Binary (WKB), GML 2, and Java Swing/AWT writing, as well as OGC Simple Features for SQL (SFSQL)

- Website: <http://tsusiatsoftware.net/jts/main.html>
- License: LGPL
- Supported Platforms: Windows, Linux, Mac

### GEOTOOLS A JAVA GIS TOOLKIT

GeoTools is an open source (LGPL) Java library, which provides standards compliant methods for manipulating geospatial data, and uses data structures based on Open Geospatial Consortium (OGC) specifications.



GeoTools is used by a number of projects including web services, command line tools, and desktop applications. GeoTools has, Integrated Geometry supports provided by JTS Topology Suite (JTS), capability to access GIS data in many file formats and spatial databases and work with an extensive range of map projections as well as filter and analyze data in terms of spatial and non-spatial attributes.

GeoTools can compose and display maps with complex styling and supports arcsde, arcgrid, GeoTIFFs, grass raster, gtopo30, image (JPEG, TIFF, GIF, and PNG), imageio-ext-gdal, image mosaic, image pyramid, and JP2K, matlab file formats.

## The State Of The Art Available Software & Solution

GeoTools supports db2, h2, MySQL, oracle, PostGIS, spatialite, sqlserver databases, app-schema, arcsde, csv, dxf, edigeo, excel, GeoJSON, org, property, shapefile, wfs vector formats, and Java data structures and bindings provided for the following: xsd-core (xml simple types), fes, filter, gml2, gml3, KML, OWS, SLD, WCS, WFS, WMS, WPS, vpf as Xml binding.

GeoTools is compliant with OGC standards in SLD, SF, CQL, WFS, WMS, and WPS.

- Website: <http://geotools.org/>
- License: LGPL
- Supported Platforms: Cross Platform Java 6

### GEOS A C/C++ SPATIAL LIBRARY

GEOS (Geometry Engine - Open Source) is a C++ port of the JTS Topology Suite (JTS). It includes the OpenGIS Simple Features for SQL spatial predicate functions and spatial operators, as well as specific JTS enhanced topology functions.



GEOS is the most widely used geospatial C++ geometry library, being used by open source projects such as PostGIS, QGIS, GDAL/OGR and MapServer, and by proprietary products including FME.

GEOS implemented OpenGIS Simple Features for SQL spatial predicate functions and spatial operators.

- Website: <http://geos.osgeo.org/>
- License: LGPL
- Supported Platforms: Windows, Linux, Mac
- API Interfaces: C, C++
- Support: <http://lists.osgeo.org/mailman/listinfo/geos-devel>, [http://www.osgeo.org/search\\_profile](http://www.osgeo.org/search_profile)

### LIBLAS A LIDAR DATA ACCESS MAPBENDER

LibLAS is a C/C++ library for reading and writing the very common LAS LiDAR format. The ASPRS LAS format is a sequential binary format used to store data from LiDAR sensors and by LiDAR processing software for data interchange and archival.



LiDAR (Light Detection and Ranging) is a form of high precision range detection much like a radar system that uses laser light as the electromagnetic emission. One of LiDAR systems' products is a "point cloud" data product that can be conceptualized as a series of point measurements representing distance from the sensor to a returned emission. A common storage format for these point cloud data is ASPRS LAS format. LibLAS makes coordinate reprojection via GDAL.

- Website: <http://liblas.org>
- License: BSD
- Software Version: 1.7.0

Supported Platforms: Cross Platform C++ – Mac OS X, Windows (via OSGeo4W), and Linux

### 2.5.1.7 COMMERCIAL OR PROPRIETARY GIS SOFTWARE

#### AUTOCAD MAP 3D

**Autodesk, Inc.** is an American multinational software corporation that focuses on acquiring 3D Computer Aided Design, 3D [http://en.wikipedia.org/wiki/Autodesk\\_-\\_cite\\_note-2](http://en.wikipedia.org/wiki/Autodesk_-_cite_note-2) design software for use in the architecture, engineering, construction, manufacturing, media, and entertainment industries, from independent developers and leveraging the maximum possible returns from those investments



Products that interface with its flagship AutoCAD software package include Map 3D, Topobase, and MapGuide.

AutoCAD® Map 3D software provides access to GIS and mapping data to support planning, design, and data management. Intelligent models and CAD tools help you to apply regional and discipline-specific standards. Integration of GIS data with your organization helps to improve quality, productivity, and asset management.

With AutoCAD Map 3D software, you can access and use CAD and GIS data from a range of sources. With comprehensive gas, water, wastewater, and electric industry data models, you can more easily organize disparate asset information and apply industry standards and business requirements.

AutoCAD® Map 3D supports, GIS analysis and planning tools, publishing and interoperability, Topographical data access and editing,

- Website: <http://www.autodesk.com/products/autodesk-autocad-map-3d/overview>
- Software Version: AutoCAD Map 3D 2014

#### BENTLEY MAP V8I

Bentley Map is a desktop geospatial information system that is 3D by nature and designed to meet the needs of infrastructure professionals. Bentley Map is offered in three editions aligned with user requirements: Bentley Map PowerView, Bentley Map, and Bentley Map Enterprise.



Bentley Map is a fully featured GIS that is 3D by nature. This mapping software is designed to address the unique and challenging needs of organizations that map, plan, design, build, and operate the world's infrastructure. It supports the creation, persistence, maintenance, analysis, and sharing of 2D/3D geospatial information. It is also ideal for developing custom GIS applications.

With Bentley Map, you can:

Leverage native Oracle Spatial or SQL Server Spatial to store and edit all types of spatial data

Utilize smart 3D Object Editing Tools

Publish i-models for use on Bentley Map Mobile

Analyze 2D and 3D spatial data

Access and share disparate data stored in non-Bentley formats

Define and administer feature models and rules-based symbology and annotation

Generate powerful 3D scenes and animations

## The State Of The Art Available Software & Solution

Manage the entire cadastral fabric

Publish high-quality maps for map books or large-scale plots

- Website: <http://www.bentley.com/en-US/Products/Bentley+Map/>
- Software Version: Bentley Map V8i

### GEOMEDIA® WEBMAP

GeoMedia® WebMap is Intergraph's web-based map visualization and analysis product that supports a broad range of customers needing to visualize and examine geographic data on the web. It enables users to publish industry-standard, programmable web services and build powerful geospatial interactive web sites. GeoMedia WebMap provides real-time access to geospatial data that your organization maintains or to geospatial data from any organization that has chosen to make it available through industry standard methods.



GeoMedia WebMap enables you to generate both raster and vector maps, and renders maps on the web using native browser functionality or one of several available plug-in technologies.

GeoMedia WebMap Advantage: a configurable and customizable browser-based web portal that can be used for finding, viewing, querying, and analyzing geospatial data published by Intergraph products and/or other standard web services. Using a modern services-oriented architecture, the Geospatial Portal enables the user to connect to many data sources at the same time.

GeoMedia WebMap Integrates multiple data sources into a single map view, supports 3D globe based on myVR technology<sup>1</sup>, supports WFS, WFS-T, coordinate transformation capability.

- Website: <http://geospatial.intergraph.com/products/GeoMedia/Details.aspx>
- Software Version: GeoMedia 2014

### GEOSPATIAL SDI

Geospatial SDI is an interoperable and scalable spatial data infrastructure for cataloging and delivering enterprise geospatial data over the web. It is designed for data providers that need to manage and serve secure or licensed information using standards based web services. The product adheres to Open Geospatial Consortium (OGC), INSPIRE, and International Standards Organization (ISO) standards for web services and metadata compliance, and can extend those offered in GeoMedia® WebMap and ERDAS APOLLO to the full set of services required of Spatial Data Infrastructure (SDI) implementations. In addition to publishing services, Geospatial SDI provides tools for managing, monitoring, and reporting service performance.



GEOSPATIAL SDI provides:

Secure access to OGC compliant web services;

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<sup>1</sup> myVR Software patented technology platform enables high-resolution real-time interactive network streaming of 3D geometry and graphics over networks with even limited bandwidth (+256kbps) on any 3D hardware supported (OpenGL) client platform including mobile (OpenGL ES)

Compatible with any standard INSPIRE and OGC clients, (CSW, WCS, WCTS, WFS, WMS, WPS, INSPIRE view service, INSPIRE discovery Service, INSPIRE direct download, and INSPIRE coordinate transformation service;

Facade and proxy architecture;

Performance and ease of integration;

Integration with the wider IT system environment;

Quality of administration, configuration, and service control;

- Website: <http://geospatial.intergraph.com/products/geospatial-SDI/Details.aspx>
- Software Version: GEOSPATIAL SDI 2014

## GEOMEDIA DESKTOP GIS

Intergraph's **GeoMedia** is a geographic information system (GIS) application for working with and conducting analysis on geographic information as well as producing maps from that analysis. GeoMedia is used for: creating geographic data; managing geospatial databases; joining business data, location intelligence and geographic data together; creating hard and soft-copy maps; conduct analysis in 'real-time'; base platform for multiple applications, geographic data validation, publishing geospatial information and analyzing mapped information.



The system does not rely on proprietary data, but rather accesses and uses data sources directly or data that adheres to open standards such as those defined by the Open Geospatial Consortium and others. It is an enterprise-based system, providing an organization the ability to access, conduct analysis, and distribute information through the organization or over the Web.

GeoMedia includes the following Windows desktop software:

GeoMedia Viewer, a free application that allows for map display, simple analysis and output of GeoMedia Geo-Workspace data. It is intended as a distribution mechanism for data created using GeoMedia products;

GeoMedia is licensed under three functional tiers:<sup>[1]</sup>

GeoMedia Essentials allows for dynamic, complex, and *ad hoc* query and perform basic spatial analysis of vector geospatial data across various data sources as well as create layered maps;

GeoMedia Advantage, adds to the functionality of Essentials by adding terrain and grid functions which will allow for additional analysis on digital elevation models, flow analysis and contour line generation; or

GeoMedia Professional includes added capability to collect features, linear referencing management, quality assurance and validation tools as well as database schema mapping and management.

Besides the desktop platform, there are also server-based GeoMedia products and well as GeoMedia products for various mobile devices to include smartphones and tablet computers. Optional extensions can be acquired separately to increase the functionality of GeoMedia.

- Website: <http://geospatial.intergraph.com/products/GeoMedia/Details.aspx>
- Software Version: GeoMedia 2014

## ERDAS IMAGINE

ERDAS IMAGINE is a remote sensing application with raster graphics editor, designed by ERDAS for geospatial applications. The latest version is 2013, version 13.0.2. ERDAS IMAGINE is aimed primarily at geospatial raster data processing, allowing the user to prepare, display, and enhance digital images for mapping use in GIS or in computer-aided design (CAD) software. It is a toolbox allowing the user to perform numerous operations on an image and generate an answer to specific geographical questions.



By manipulating imagery data values and positions, it is possible to see features that would not normally be visible and to locate geo-positions of features that would otherwise be graphical. The level of brightness or reflectance of light from the surfaces in the image can be helpful with vegetation analysis, prospecting for minerals etc. Other usage examples include linear feature extraction, generation of processing work flows ("spatial models" in ERDAS IMAGINE), import/export of data for a wide variety of formats, orthorectification, mosaicking of imagery, stereo and automatic feature extraction of map data from imagery.

- Website: <http://geospatial.intergraph.com/products/ERDAS-IMAGINE/ProductLiterature.aspx>
- Software Version: version 13.0.2

## ESRI

ESRI uses the name ArcGIS to refer to its suite of GIS software products, which operate on desktop, server, and mobile platforms. ArcGIS also includes developer products and web services. In a general sense, the term GIS describes any information system that integrates, stores, edits, analyzes, shares and displays geographic information for informing decision-making.



As of October 2013, the company's current desktop GIS suite is ArcGIS for Desktop version 10.2. The suite's components, ArcMap, ArcCatalog, and ArcToolbox, allow users to author, analyze, map, manage, share, and publish geographic information. The product suite is available in three levels of licensing: ArcView, ArcEditor, and ArcInfo. ArcView provides a basic set of GIS capabilities suitable for many GIS applications. ArcEditor, at added cost, allows more extensive data editing and manipulation, including server geodatabase editing. ArcInfo, at the high end, provides full, advanced analysis and data management capabilities, including geostatistical and topological analysis tools.

ArcGIS Explorer, ArcReader, and ArcExplorer are basic freeware applications for viewing GIS data.

ArcGIS for Desktop Extensions are available, including Spatial Analyst for raster analysis, and 3D Analyst for terrain mapping and analysis. Other more specialized extensions are available from ESRI and third parties.

Server GIS products provide GIS functionality and data deployed from a central environment. ArcGIS for Server is an internet application service, used to extend the functionality of ArcGIS for Desktop software to a browser-based environment. It is available on Solaris and Linux as well as Windows. ArcSDE (Spatial Database Engine) is used as an Relational database management system connector for other ESRI software to store and retrieve GIS data within a commercially available database: currently, it can be used with Oracle, PostgreSQL, DB2, Informix and Microsoft SQL Server databases. It supports its native SDE binary data format, Oracle Spatial, and ST-geometry. ArcIMS (Internet Mapping Server) provides browser-based access to GIS. As of ArcGIS 10.1, ArcIMS has been depreciated in favour of ArcGIS for Server, but there are still many instances of ArcIMS (10.0 and

older) in production environments. Other server-based products include Geoportal Extension, ArcGIS Image Server and Tracking Server as well as several others.

Mobile GIS conflates GIS, GPS, location-based services, handheld computing, and the growing availability of geographic data. ArcGIS technology can be deployed on a range of mobile systems from lightweight devices to PDAs, laptops, and Tablet PCs. The firm's products for this use are ArcPad, ArcGIS for Mobile, and ArcGIS for Server (Server-oriented APIs), ArcWeb Services (Web-oriented APIs), hosted geographic databases, ArcGIS mobile.

ArcGIS for mobile ADF is an Application Programming interface (API) for developing solutions on various Windows Mobile and Windows Embedded platforms (pocketpc, Smartphone, ultra-mobile devices, etc).

Developer GIS products enable building custom desktop or server GIS applications or embed GIS functionality in existing applications. These focused solutions can then be deployed throughout an organization. The firm's products for this are ESRI Developer Network or EDN, ArcEngine (Desktop-oriented APIs), ArcGIS for Server (Server-oriented APIs and a web development ADF which is part of ArcGIS for Server), ArcWeb Services (Web-oriented APIs).

ArcGIS includes internet capabilities in all ESRI software products. The services, provided through ArcGIS Online at [www.arcgis.com](http://www.arcgis.com), include web APIs, hosted map and geoprocessing services, and a user-sharing program. A variety of basemaps is a signature feature of ArcGIS Online. The ESRI Community Maps program compiles detailed user basemap information into a common cartographic format called Topographic Basemap.

- Website: <http://www.esri.com/products>
- Software Version: ArcGIS for Desktop 10.2

## MAPINFO

MapInfo Corporation initially incorporated as Navigational Technologies Incorporated, developed leading edge Location Intelligence solutions. The company was headquartered in North Greenbush, New York. It was acquired on April 19, 2007 by Pitney Bowes, and on January 28, 2009, the name of the Pitney Bowes division it had become was changed to Pitney Bowes Business Insight. From inception, MapInfo had grown quickly, appearing at number 23 in Inc. Magazine's annual list of the 500 fastest-growing private companies in the U.S. in 1992. MapInfo's product in Geoinformation includes:



**MapInfo GIS** Suite lets you create, access and manage geospatial assets, visualize business intelligence and customer data, and share high-quality interactive maps – quickly and easily.

**MapInfo Professional** is a powerful mapping and geographic analysis application. By visualizing the relationships between data and geography, MapInfo Professional makes it fast and easy to create, share and use maps by turning data into information.

**MapInfo Engage3D**, from streamlined map production to powerful 2D and 3D analytical tools, the Engage-suite turbo-charges the MapInfo Professional GIS environment with an extensive range of capabilities.

**MapInfo Vertical Mapper** is a spatial data analysis tool that lets you display, manage, and interpret grid-based continuous spatial information. Gain an upper hand by turning geospatial data into compelling information and actionable insight.

**MapInfo MapBasic**, Customize the geographic functionality of MapInfo Professional, automate repetitive operations, and integrate MapInfo Professional with other applications quickly and easily.

**MapInfo WEB** Instantly share location data via powerful interactive maps online. Publish spatial information in an easy way for organizations to enhance collaboration and boost efficiencies and cost savings.

**MapInfo Stratus** provides an efficient way to publish and share location data and geospatial assets through interactive, robust maps online, so you can enhance information sharing and collaboration across the enterprise internally or externally.

**MapInfo Exponare** is an information portal that makes corporate data more meaningful to facilitate better analysis and improved decision-making.

- Website: <http://www.mapinfo.com>

## REMOTEVIEW



Overwatch is an industry leader in geospatial analysis and exploitation solutions and services. Our flagship products, RemoteView and ELT/Series, provide a comprehensive range of capabilities, from high-powered exploitation and mapping for geospatial analysts to image analysis tools for tactical users. Overwatch's flexible solution architecture includes modules such as **Feature Analyst** and **LIDAR Analyst**, which include sophisticated visualization tools for geospatial intelligence professionals. Our integrated solutions division provides integration, customization and collaboration services to address a wide range of unique client needs. Overwatch helps imagery and geospatial analysts integrate multi-source data to deliver advanced exploitation capabilities, with greater accuracy, and in shorter response times than available alternatives.

RemoteView's main function is an imagery and geospatial analysis tool. It can display a wide array of imagery formats, elevation data sets, and vector data sets. Capabilities include image enhancements, photogrammetry, orthorectification, multispectral classification, pan sharpening, change detection, assisted search, location positioning, and 3D terrain visualization. These features allow an intelligence analyst to review large-scale imagery and generate annotated reports on any findings.

RemoteView for Windows comes in two versions, **RemoteView Desktop** and **RemoteView Pro**. RemoteView Desktop is an entry-level imagery exploitation and analysis solution, for focusing on a single image at a time or reviewing the results of another analyst's work. RemoteView Pro is the flagship product offering a greater number of tools, extensions, and capabilities.

Overwatch offers a series of extensions that add specialized capabilities to RemoteView<sup>1</sup>. These include:

Virtual Mosaic – a tool for quickly joining more than four adjacent or overlapping images;

3D Pro – a module that expands visualization tools to allow creating 3D virtual worlds for simulating real world conditions and planning missions;

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<sup>1</sup> [http://en.wikipedia.org/wiki/RemoteView#cite\\_note-RemoteView\\_Exsentions-4](http://en.wikipedia.org/wiki/RemoteView#cite_note-RemoteView_Exsentions-4)

RVConnect – a tool that enables automatic data sharing between RemoteView and ESRI’s ArcMap software;

V-TRAC Basic – a complementary video player that allows analysis of full motion video recorded by UAVs;

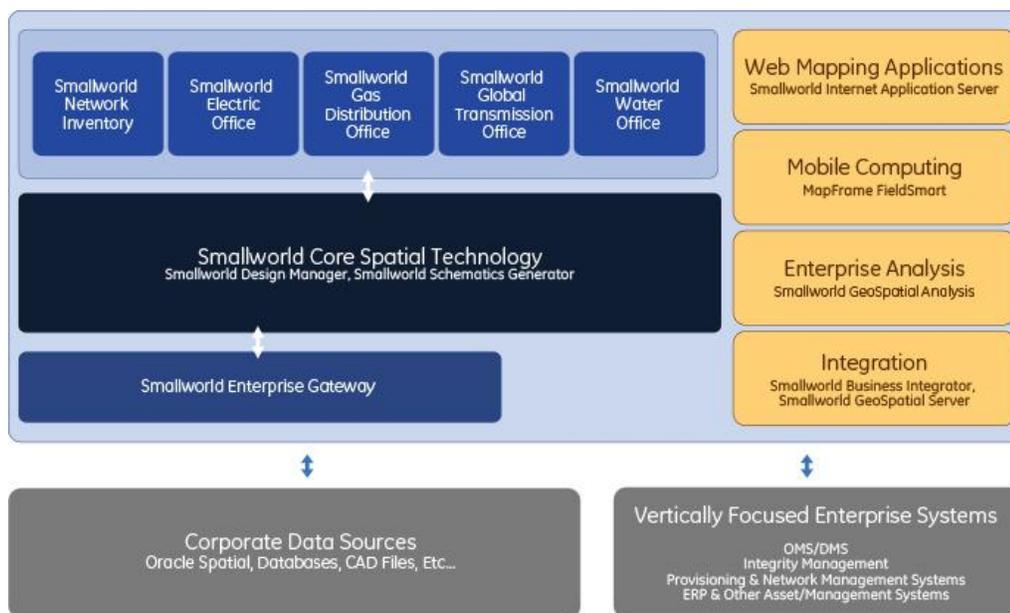
V-TRAC Pro – expands the abilities of V-TRAC Basic to include mark-up and reporting tools;

GeoCatalog for Desktop – a complementary database that makes it easier to organize and retrieve geospatial data;

### SMALLWORLD™ CORE



This revolutionary, object-oriented, database-driven product provides a powerful, consistent architecture at the heart of many applications, such as those used for planning electric, gas and water distribution systems, designing telecommunications networks and evaluating strategic market opportunities. The software integrates with other products that require spatial information, including systems for customer relationship management, market analysis, and network and work management.



Smallworld Core Spatial Technology is designed for deployment throughout distributed organizations, reaching all users who need to access and maintain the network asset inventory. Its database is highly scalable to handle very large networks while also modeling the detailed connectivity necessary for its advanced applications.

Smallworld Core Spatial Technology is designed around industry technology standards, allowing direct access enterprise data from Oracle® and other sources.

Smallworld Enterprise Gateway allows access to all network asset data throughout the organization. It synchronizes the data held in the Smallworld database with an enterprise Oracle® database to leverage the value of the Smallworld data for other business processes.

Smallworld Geospatial Server provides access to geospatial data and functions as web-services to support service-oriented integration with operational systems such as a Distribution Management System and provides OGC® certified services.

## The State Of The Art Available Software & Solution

Smallworld Web Solutions provide easy access to network data and applications for anybody in the enterprise through the web to support business processes without specific GIS expertise.

Smallworld Geospatial Analysis is the spatial business intelligence application, which leverages geospatial and all other data sources for operational and strategic asset management processes. It allows a wide range of users to generate visualization-based analysis on combined enterprise and spatial data to meet a range of business needs, including meeting regulatory reporting requirements, monitoring key performance indicators and optimizing network investment strategies using network data.

GE Energy's Smallworld GIS platform is based on three technologies:

An object-oriented programming language called Magik that supports multiple inheritance, polymorphism. It is also dynamically typed.

A database technology called Version Managed Data Store (VMDS) that has been designed and optimized for storing and analyzing complex spatial and topological data. The native Smallworld data-store can be stored in an Oracle Database. This allows the use of Oracle facilities for backups and recovery

Java Enterprise Edition architecture for web services and web mapping

### SUPERMAP GIS

SuperMap Software Co., Ltd. was founded by scientists from The Chinese Academy of Science (CAS) in 1997. SuperMap GIS is a complete integration of a series of GIS platform software, including Desktop GIS, Service GIS, Component GIS and Mobile GIS, which delivers GIS capabilities to all types of computers, including Desktop PCs, Servers and Mobile devices. It fulfills the needs for managing, visualizing, and analyzing spatial data, serving them out via the Web, and customizing all kinds of GIS applications that best fit the customers' business needs. This Chinese Software

SuperMap GIS includes the following products:

Service GIS-Development platform for customizing Web GIS Applications

SuperMap iServer JAVA; Java based Enterprise Service GIS

SuperMap IS .NET; .NET Based Enterprise Service GIS

SuperMap iClient; Web SDK for customizing Rich Internet GIS Applications

Component GIS- Platform for Customizing Desktop GIS Applications

SuperMap Objects; COM-based Components GIS

SuperMap Objects.net; Pure .NET Components GIS

SuperMap Object Java; Pure Java Components GIS

Desktop GIS - Professional and Ready-to-Use GIS Clients

SuperMap Deskpro; Professional and All-in-One Desktop GIS

SuperMap Express; Professional GIS Data Authoring Desktop GIS

SuperMap Viewer; Free GIS Data Viewing Desktop GIS

SuperMap Desktop .NET; New Generation .NET based Desktop GIS

Mobile GIS – GIS Especially Designed for Mobile Devices

eSuperMap; General Mobile GIS Development Platform

SNE; Navigation Application Development Platform

SuperMap FieldMapper; Desktop GIS Special for Mobile Devices

Website: <http://www.supermap.com/>

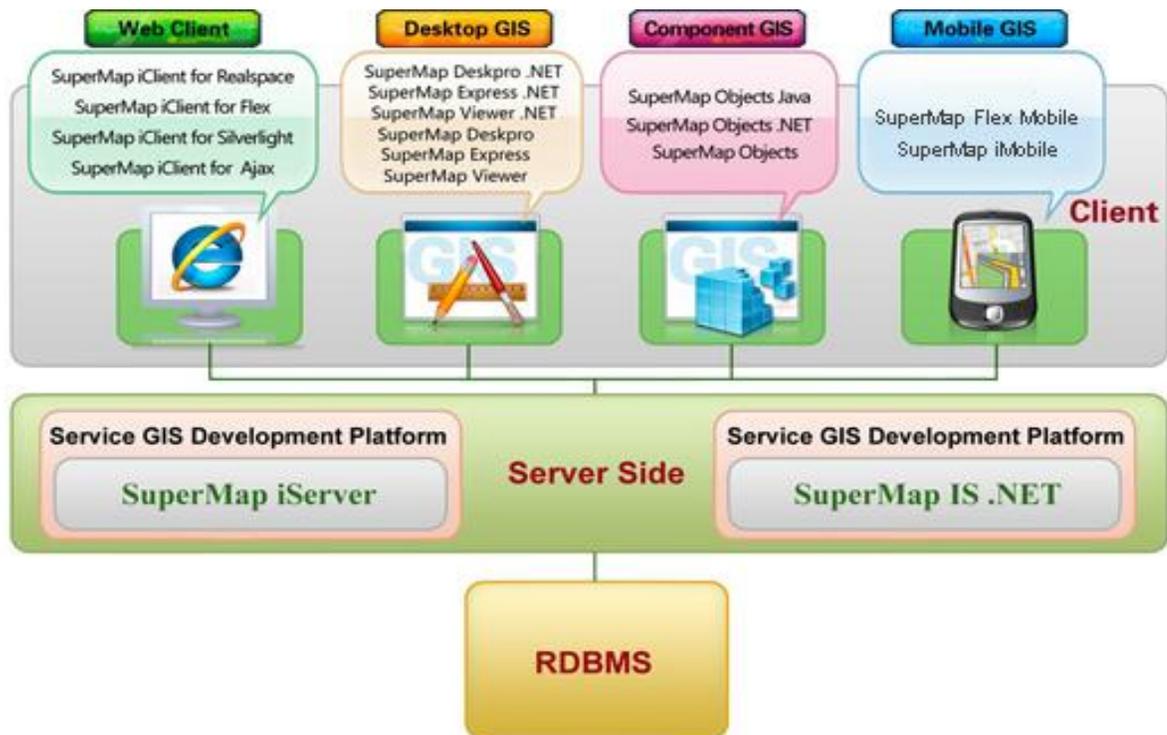


FIGURE 7 SUPERMAP GIS 6R PRODUCTS

## 2.5.2 SOFTWARE MANUFACTURERS AND PROJECTS

GIS software is not only provided by companies but increasingly also by free and open source software projects. While commercial vendors usually offer products for all of software categories, open Source Software projects often concentrate on a single category, e.g. desktop GIS or WebMap server.

The key players in the GIS software market today are Autodesk, Bentley, ESRI Inc., GE (Smallworld), Pitney Bowes (MapInfo), and Intergraph. GIS software companies tend to target specific application domains. For instance, ESRI's ArcGIS product tends to be mainly used for business analysis, planning, and environmental applications, while Autodesk, GE and Bentley products are rather used in utility and facility management. Competitive GIS software that is developed by free software projects exists as well - especially with respect to server applications (MapServer, GeoServer) and spatial DBMS (PostGIS). Free desktop GIS projects, such as Quantum GIS and gvSIG, currently experience growing user communities. Such free GIS software rather complements the set of proprietary software instead of competing with it.

### 2.5.3 SELECTING FREE AND OPEN SOURCE GIS SOFTWARE

There are well-known benefits of open source software, such as cost savings, vendor independence, and open standards. However, there are also a number of barriers, such as knowledge barriers, legacy integration, forking, sunk costs, and technology immaturity (Nagy, D., Yassin, A. M., & Bhattacharjee, A. et. al 2010). (Nagy, D., Yassin, A. M., & Bhattacharjee, A. 2010)

Knowledge barriers often exist because potential users are not aware of the availability or relevance of FOSS4G<sup>1</sup>, nor of the technical requirements necessary to make effective use of FOSS4G.

Legacy integration has been problematic when using FOSS4G, but in recent years there have been numerous middleware solutions developed that have minimized this barrier.

Forking of a project occurs when different groups develop software, and the resulting components no longer interoperate with each other because the original project failed to impose adequate standards. This can result in the failure of smaller open source projects that fail to maintain a large enough developer base. This particular barrier can be addressed through the development of self-managed standard groups within a project.

Sunk costs arise due to prior investment in proprietary software. The simplest way to address this barrier is to compare future cost streams of maintaining proprietary software versus open source software.

With regard to technical maturity, it is essential that software be evaluated independently against case studies derived from an organization's core functionality. As an organization, it would be folly to adopt FOSS4G just because other organizations do, or based solely on claims in the literature.

Instead, the decision to adopt FOSS4G should be based upon careful considered rationale (Ven, K., Verelst, J., & Mannaert, H. 2008). The selection process, if it is for business, research, or teaching, should be based on a rigorous software evaluation process.

Among the criteria that should be applied during the evaluation process are for instance: software functionality, software stability, platform support, market share, credibility (and branding) of the software manufacturer, as well as the size of the support and distribution network. While these criteria are common to the selection of proprietary software - with respect to free and open source software other criteria are also important. In particular, consideration should also be given to the software project that created the FOSS4G software, since the status of the project will influence software support, software evolution (in terms of functionality and domain of use), and prolonged existence see also (Cruz, D., et al. 2006).

A formal software selection process should consist of five steps (Figure 8):

- (i) Develop software use cases for own context (or "user stories")
- (ii) Establish a set of evaluation criteria based on the use cases,
- (iii) Perform the software evaluation with respect to the established criteria,
- (iv) Develop a weighting criteria according to application context (note, weighting is intended to be flexible so as to allow for different contexts),
- (v) Select the software based on results of the evaluation and weighting scheme.

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<sup>1</sup> FOSS4G stands for Free and Open Source Software for Geospatial.

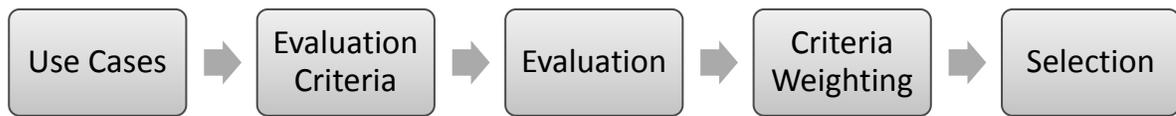


Figure 8 Possible Software Selection Process

Sets of evaluation criteria for free (GIS) software have been proposed by several authors, e.g., (Reid, J., & Martin, F. 2001),(Ramsey 2007),(Wagner 2006),(Cruz, D. et al. 2006, 11), (Sveen 2008), (Steiniger, S., & Bocher, E. 2009). Out of those publications a list of criteria has been compiled by(Steinige, S.,Hunter, A. 2012), presented in Table 2. In the Table 1 the criteria has been sorted out according to their relevance if the software is to be used for business only.

Table 1: Project and Software evaluation criteria

GIS use objectives	<ul style="list-style-type: none"> <li>✓ Accomplish different tasks in an efficient way; Data sharing within various department with different tasks; OGC's Standards: WFS, WMS, WCS are necessary to be compliant with</li> </ul>
<b>Evaluation Criteria</b>	
Functional	<ul style="list-style-type: none"> <li>✓ Required Functionality</li> <li>✓ Usability</li> <li>✓ Customization options</li> <li>✓ User level (viewer vs. analyst)</li> <li>✓ Project road map/ focus</li> <li>✓ Nice to have functionality</li> </ul>
Technical	<ul style="list-style-type: none"> <li>✓ Supported Operating Systems</li> <li>✓ Programming Language</li> <li>✓ Reliability (Maturity, Robustness)</li> <li>✓ Maintainability</li> </ul>
Organizational	<ul style="list-style-type: none"> <li>✓ Size/ Existence of user and developer community</li> <li>✓ Project drivers &amp; lead</li> <li>✓ Adoption by companies and administration</li> </ul>
Support	<ul style="list-style-type: none"> <li>✓ Company/hotline support</li> <li>✓ Documentation</li> <li>✓ Email lists</li> <li>✓ Forum</li> <li>✓ Wiki</li> </ul>
Economical	<ul style="list-style-type: none"> <li>✓ Migration costs</li> <li>✓ Training Costs</li> <li>✓ Maintenance Costs</li> </ul>
Legal	<ul style="list-style-type: none"> <li>✓ License type (GPL, LPGL, BSD)</li> </ul>

In Table 1 all evaluation criteria needed to be checked with the target software project. The organizational and legal criteria are those confusing and interpretable subjects. These two shows how good support from the community will be. The more users and developers a software project has, the higher the chance that users experiencing similar issues will help each other. The probable receiving

necessary needed support will increase by strong leadership. License type (GPL, LPGL, BSD)<sup>1</sup> which a free software is distributed with, can cause legal issues in future. So from legal point of view it's important to clarify these criteria (GNU GPL (General Public License)).

To narrow down the subject of software evaluation it is beneficial to start it with basic set of questions that are linked to above criteria. These questions are listed In Table 2

Table 2 Complementary Questions

<b>Guiding Questions</b>
<b>Functionality:</b>
Can you deliver detailed case studies / uses cases that show what the user should be able to do with the software and what they should not be able to do? (Note: what the user should <i>not</i> be able to do adds requirements.)
<b>For desktop GIS or web-based service infrastructures:</b>
Do you want to create maps, or do you need analysis functionality as well? I.e., do you need a simple data viewer, or do you need a data editor and analysis functions too? See for instance the GIS tasks listed in Error! Reference source not found.
Are your data in raster or in vector format?
Are your data stored in a database or files? Do you want to write your data to a database or files?
<b>Platform:</b>
Will your users work with Microsoft Windows, MacOS, or Linux only? Do you prefer a cross platform product that runs on MacOS and Linux as well? (Note: this may become important when adding custom functionality)
<b>Support:</b>
What programming languages are your users and developers comfortable with? (Note: this is important for user support on email lists and forums)
Is hotline and emergency support needed?
Do your functional requirements need custom developments? (Notes: If others are contracted for customized development, then these external developers need to be available. Also, if community developers or contractors should help, then the software should support easy implementation, e.g. by offering a plug-in mechanism and an API.)
<b>Other:</b>
Is using free-of-cost but proprietary GIS an option, or even low-cost but proprietary solutions? (Note: if yes, the set of software to be considered may be much larger.)

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<sup>1</sup> The GNU GPL, Basically, you are allowed to use, redistribute, and change the software, but any changes you make must also be licensed under the GPL.

The LGPL is similar to the GPL, but is more designed for software libraries where you want to allow non-GPL applications to link to your library and utilize it. If you modify the software, you still have to give back the source code, but you are allowed to link it with proprietary stuff without giving the source code to all of that back. The BSD says, "Here's the source code, do whatever you want with it, but if you have problems, it's your problem". That means you can take "BSDed" code and turn it into a proprietary application if you so wish - there's nothing saying you have to give the code back (although it is nice to do so).!!!

## 2.6 CONCLUSION

However, in each case in particular there could be different questions to be asked and answered. These questions can be originated from national or international as well as business and commercial points of view. Some of them are concerned by Managers that has to take care of politics, hi level long-term economic trend and some of them are technical issues that deals with technological nature of GIS software. Nevertheless, it is getting clear that the future belongs to Open Source Software for Geospatial FOSS4G, and the lack of maturity in this field is being vanished during the ages. The more experiences that GIS community gains throughout the development of FOSS4G push them closer into the core design of the software which in past was a black box controlled and dominated by giant GIS software companies. The increasing number of papers, reports as well as the sheer number of downloaded FOSS4G, prove the fact that the future belongs to those who establish it through the breaking all the barriers and bridge towards solving GIS related subjects.

According to (Steinige, S.,Hunter, A. 2012) we see three characteristics features for future FOSS4G development, besides a growth in users:

Emergence of new projects;

Consolidation, due to projects that stop their developments (e.g. MapBender and MonoGIS);

Collaboration among projects;

Apart from the necessity for transition showed by GIS community toward Free and Open Source Software that caused considerable multi Software exchange and collaborations; establishment of OSGeo foundation can play an important role as a focal point in this way and has been useful and very efficient.

## 3. GEONODE A WEB APPLICATION FOR DATA SHARING

### 3.1 INTRODUCTION

Federal agencies and their partners collect and manage large amounts of geospatial data but it is often not easily found when needed, and sometimes data is collected or purchased multiple times. In short, the best government data is not always organized and managed efficiently to support decision making in a timely and cost effective manner.

National mapping agencies, various Departments responsible for collection of different types of Geospatial data and their authorities cannot, for very long, continue to operate, as they did a few years ago like an island. Leaders need to look at what is now possible that was not possible before, considering capabilities such as cloud computing, crowd sourced data collection, building information models (BIM), available remotely sensed data and multi source information vital in decision-making as well as new Web-accessible services that provide, sometimes at no cost. Many of these services previously could be obtained only from local GIS experts. These authorities need to consider the available solution and gather information about new capabilities, reconsider agency missions and goals, review and revise policies, make budget and human resource for decisions, and evaluate new products, cloud services, and cloud service providers.

In order to reach that target it is necessary to have a Geospatial Platform to provide that service and capability. An Internet or intranet-based platform with capability to provide shared and trusted geospatial data, services, and applications for use by government agencies and partners to meet their mission needs. Through this Geospatial platform, users will have access to:

- Authoritative data to support informed decision-making;
- Problem solving applications (services) that are built once and used many times across multiple Federal agencies and other organizations;
- A shared cloud-computing infrastructure to host data and applications;
- A National and Federal focal point where governmental, non-governmental, private, and public data and applications can be visualized together to inform and address national and regional issues;

This Platform will significantly expand access to high quality data; enabling users to improve problem solving and streamline mission critical operations. We expect that increased sharing and reuse of resources facilitated by the Geospatial Platform will reduce costs, result in savings and wise investments, and improve decision making while stimulating innovation. On balance, the integrated approach of the Geospatial Platform will mean that the federal portfolio of geospatial data will be better managed, service a broader audience, and be easier to use.

The target audience for this Platform could be various departments inside the Federal agencies, State, and local, governments, private sector, academia, non-governmental organizations, and public.

The traditional schema of activities considers the work of map producers in various disciplines as well as map users as separated. Most of the authorities act as Geospatial information users and define the characteristics of the maps, while other map producers apply the users' needs and release hard copies of their products or digital copies different file formats such as DGN, DWG, and PDF etc.... Therefore, in this schema map, users do not have the possibility to modify their maps contents in case of need but they have to ask back other map producers even for simple modifications such as color schemes, symbol schemes, data styling, scale factor, and bounding box. Moreover, map users cannot reuse the data that are part of the map for other representations nor spatial analysis unless performing an annoying operation of re-digitizing.

In very recent years, especially after the severe disaster, that was the earthquake in Haiti on January 12, 2010, humanitarian agencies, civil protection departments and other aid structures started expressing the need of having data beyond the maps, in order for them to be possible to reuse the data themselves. In that, particular case there was a strong interest in damage assessment data, such as closed roads and collapsed buildings, but also base reference data such as elevation, transportation, and ground cover.

At the same time initiatives for promoting the importance of geospatial data sharing in order to better face natural disasters were born. Furthermore, such an initiative was accompanied by the development of an operational tool that allows data sharing over the internet, the GeoNode.

**Key criteria for selecting GeoNode are:**

- 1) *Its Functionality; Completely Support for all tasks that are defined for the establishment of a SDI*
- 2) *Assembled and therefore acting as an Integrated package software;*
- 3) *Support of common data distribution standards (e.g. OGC, ISO, CEN standards);*
- 4) *Supported platforms (Windows vs. Linux, etc.);*
- 5) *Software reliability, according to the implemented cases which we will discover inside this chapter;*
- 6) *Options for customization;*
- 7) *Distribution costs,*
- 8) *Installation and maintenance effort (incl. costs),*
- 9) *Training and support options including pricing;*
- 10) *Reliable community pf developer for solving the probable issues*

For a first evaluation of the software it is recommended that adopters make use of GIS distribution packages (for Linux), or Virtual Machine.

The licenses used by free and open source products ensure a low acquisition cost (typically no cost) for the software itself, and ensure that the software is customizable and adaptable to the SDI context. Hence, and with respect to the latter point, free and open source software often implement a wide set of (OGC) standards (See2.1), and if not, at least permit the implementation/addition of components that are OGC/ISO standard compliant. The use of open source licenses allows an adopter to deploy SDI components to other locations at no additional cost, e.g., for horizontal scaling of a system. Finally, we note that helpful user and developer communities exist, and that support and maintenance options are offered by various companies, which are similar to those currently offered by proprietary software vendors. In summary, we see that FOSS4GIS software can provide a viable alternative to proprietary products - and we hope that our review helps to assess the utility of FOSS4GIS for SDIs. In Next Chapter, there will be a detailed review over the existing software to cover all the tasks that has been defined in this chapter for implementation of SDI.

In this chapter, the GeoNode platform is introduced, moreover, technical details on the main functionalities and an overview of the main software components are provided which is the result of the previous chapter in selection of Open Source Software and the answer to the criteria that were defined for such software according to the above-mentioned goal as geospatial platform. GeoNode introduction

GeoNode is an open source platform that facilitates the creation, sharing and collaborative use of geospatial data. The project aims to provide and create a spatial data infrastructure by implementation of GIS and cartographic tools (Balbo 2013).

At its core, the GeoNode is based on open source components: GeoServer, GeoNetwork, Django, and GeoExt that provide a platform for web browser enabled spatial analysis and visualization. Map composer and viewer along with analysis and reporting tools are integrated in this platform.

To promote collaboration, the GeoNode is designed on Web 2.0<sup>1</sup> principles to:

- make it simple to share data and control the process;
- easily add comments, ratings, tags;
- Make connection between GeoNode and existing GIS tools and other data store.

To secure distribution, the GeoNode enables:

- simple installation and distribution;
- automatic metadata creation;
- Search through catalogues and search engines, such as Google, OpenStreetMap etc...

Moreover, to promote data collection, the GeoNode aims at encouraging and creation of a productive and rich Spatial Data Infrastructure in order to:

- align efforts so that amateur, commercial, NGO and governmental data producer all naturally collaborate;
- figure out workflows, tools and licenses that work to assure data quality;
- to promote living, constantly evolving, authoritative and always up to date data;

The idea is to create a full featured platform for helping decision makers easily compose and share stories told with spatial data (Geonode 2013).

### 3.2 GEONODE FUNCTIONALITIES

The GeoNode provides the user with a series of functionalities in the field of geo-spatial data, which are typical of a desktop GIS application, such as creating and printing maps. The capability to access information throughout the web is functionalities, which have been accessible by desktop applications for many years and is provided by many companies; for example the availability of

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<sup>1</sup>Web 2.0 is the term given to describe a second generation of the World Wide Web that is focused on the ability for people to collaborate and share information online. Web 2.0 basically refers to the transition from static HTML Web pages to a more dynamic Web that is more organized and is based on serving Web applications to users. Other improved functionality of Web 2.0 includes open communication with an emphasis on Web-based communities of users, and more open sharing of information. Over time Web 2.0 has been used more as a marketing term than a computer-science-based term. Blogs, wikis, and Web services are all seen as components of Web 2.0

common office applications offered by Google<sup>1</sup>. This is so called Software as a Service, which is expected to increase in near future to achieve the common strategy of desktop applications. The aim is to simplify the management of desktop computers, moving workload towards computer servers, and to promote sharing among users, while data are centralized and can be easily accessed from many computer users even in parallel mode.

### 3.2.1 DATA SHARING

The promotion of data sharing is among the first objectives of the community of GeoNode developers. On one hand, data sharing means that a user is in condition of being able to upload data into the system and to give other users the possibility of exploring these data. On the other hand the user is provided with the capacity of taking advantage of data shared by others either through online tools or by downloading them locally in formats suitable for desktop applications.

### 3.2.2 DATA UPLOADING

Data can be uploaded by registered users through a simple web interface; with the last official release, GeoNode permits to upload geo-spatial data in the following formats:

*GeoTIFFs*, it is a file format for storing georeferenced raster data;

*Shapefile*, it is the *ESRI* format for georeferenced vector data, a standard format among the GIS community.

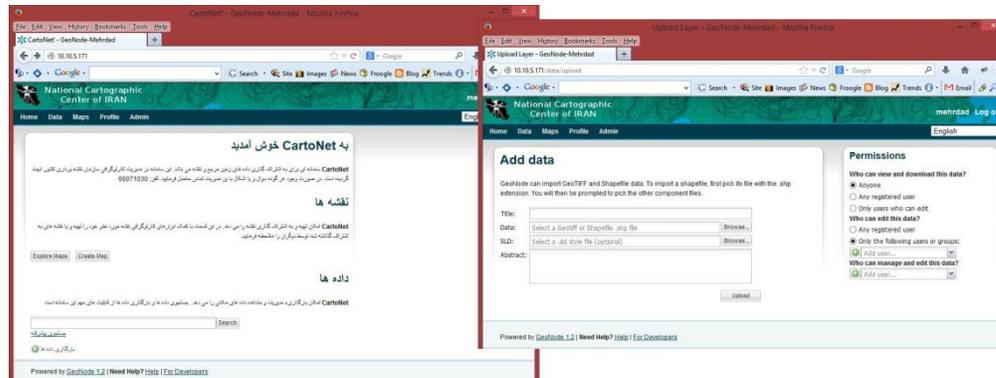


Figure 9: Screenshot of the webpage designed for data uploading. Note that permissions on data viewing and editing can be assigned to users and groups by means of the commands implemented on the right-hand side of the page. This page belongs to the projects done in ITHACA for MALAWI in Africa

Moreover, for each data the web interface permits also to upload the description of the style to be used during graphical rendering of the data themselves, encoded into an open format, which is called *SLD* that is *Styled Layer Descriptor*. Furthermore, during the upload process data are converted and then stored into the server in formats suitable for efficient storing and future retrieving: this step is invisible to the user. A screenshot of the web page developed for data uploading is showed in Figure 9.

<sup>1</sup> <http://support.google.com/docs/bin/answer.py?hl=en&answer=49008>

### 3.2.3 DATA DOWNLOADING

Data can be found on the platform by exploiting the embedded search engine, which allows combining classical search on a keyword basis with spatial search, by graphically defining a bounding box on a computer screen. (See Figure 10)

Once interesting data have been found, the user is prompted to the so called *data page*: it is a web page where data are graphically rendered in a frame, over a base layer that is retrieved dynamically from available free web services, for example Google Maps, Open Street Map and NASA Blue Marble. This frame contains also tools for zooming and panning the spatial content as well as a querying tool for data semantic content.

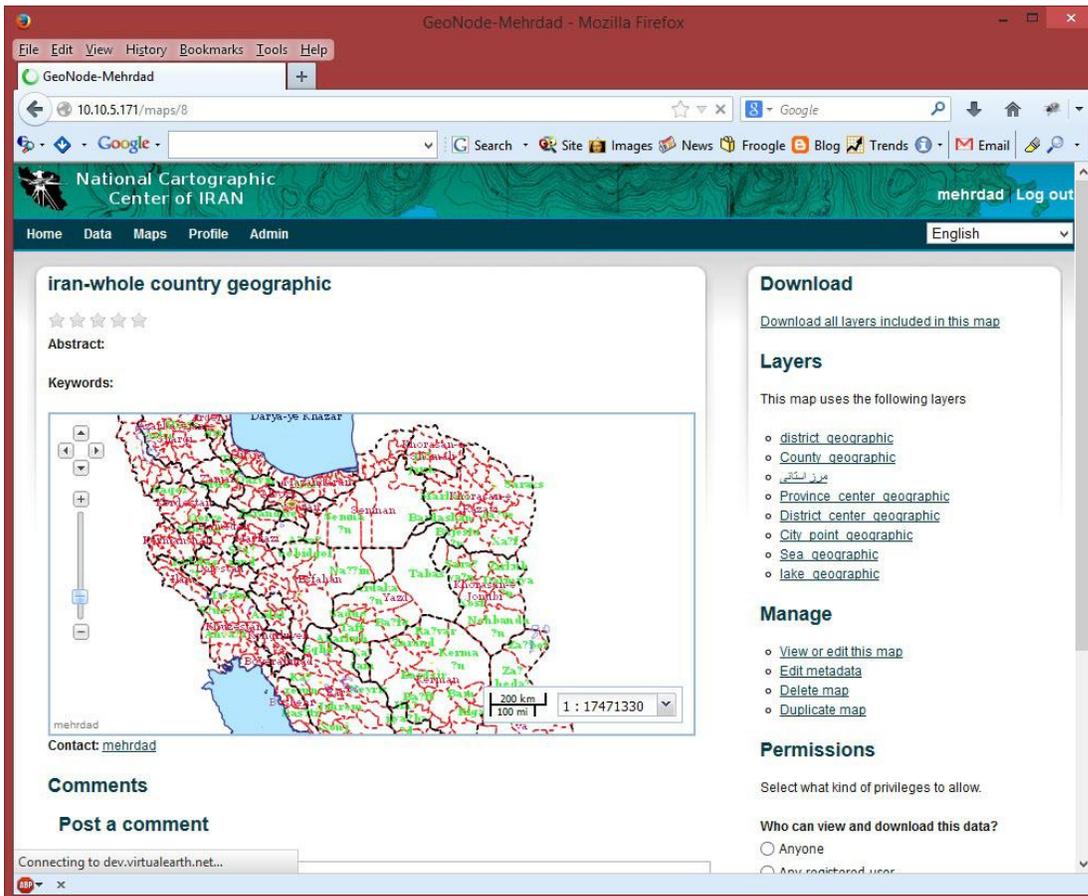


Figure 10: screenshot of the webpage designed for data uploading. Note that permissions on data viewing and editing can be assigned to users and groups by means of the commands implemented on the right-hand side of the page

The graphical rendering is generated by GeoServer, that is a Web Mapping Server able to serve data and maps in an efficient and powerful way and can convert data into different formats upon request. The user can take advantage of this technology and download data by simply clicking on the specific link on the right-hand side of the data page. With the latest release of the GeoNode, raster data can be downloaded as GeoTIFFs, JPEG, PDF, PNG, KML and vector data as shapefile, GML, CSW, Excel, GeoJSON, JPEG, PDF, PNG, KML.

Other interesting elements displayed in the *data page* are the metadata, which are showed partially on top and partially under the above-mentioned frame, and the style manager application that allows changing the way data are displayed. Furthermore, if the current user has been given the required

permissions by the data owner, several links for data management and permission assignment are displayed on the right-hand side. A screenshot of the mentioned *data page* is showed in

Figure 11: Screenshot of the GeoNode map page: it contains preview of the map with the respective title and abstract on the left-hand side of the page; while the list of layers comprehended in the map and some management tools are implemented on the right-hand side

### 3.2.4 MAP CREATING

Registered users can create web maps by collecting a number of data of interest and styling them in the favorite way. Maps in GeoNode are ordered collection of layers, which are rendered to a protocol suitable for visualization in a web browser. The web interface for map creation make this operation similar to the most common desktop GIS applications: This is GeoExplorer. Once a map is created, it can be saved and stored into the platform, in order to be easily retrieved, explored, and potentially modified in the future. Maps can also be easily published on blogs and other websites and they can be printed to a pdf format.

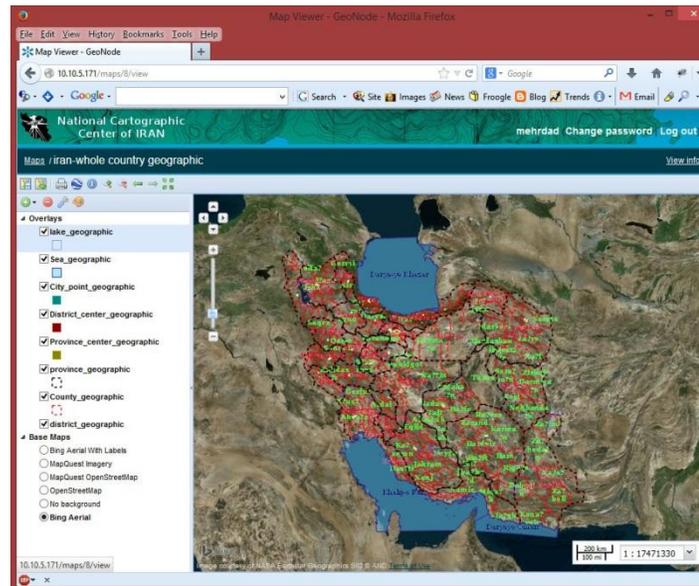


Figure 12: Creation of Map using several data layers

Moreover, maps existent on the platform can be searched by means of a search engine based on keywords; when a map of interest is found, the user is prompted to the so-called map page. This web page shows a preview of the map itself in a frame on the left-hand side of the screen and on top of it, the map title and an abstract are displayed. Furthermore, the list of layers in the map as well as the link for data downloads is displayed on the right-hand side of the screen. Finally, similar to data, special commands for map management and permission assignment are showed in case, the current user has been enabled by the map owner. A screenshot of the GeoNode map page, that represents New York City map, is reported in Figure 12.

### 3.2.5 METADATA MANAGEMENT

When uploading data the user is prompted to fill in a metadata form that will be showed to the users who will look for those data in the future. The same form can be used in every following time to

update the metadata content in case of need: The screenshots showing how to reach the on-line form for metadata editing are contained in Figure 13 and Figure 14 .

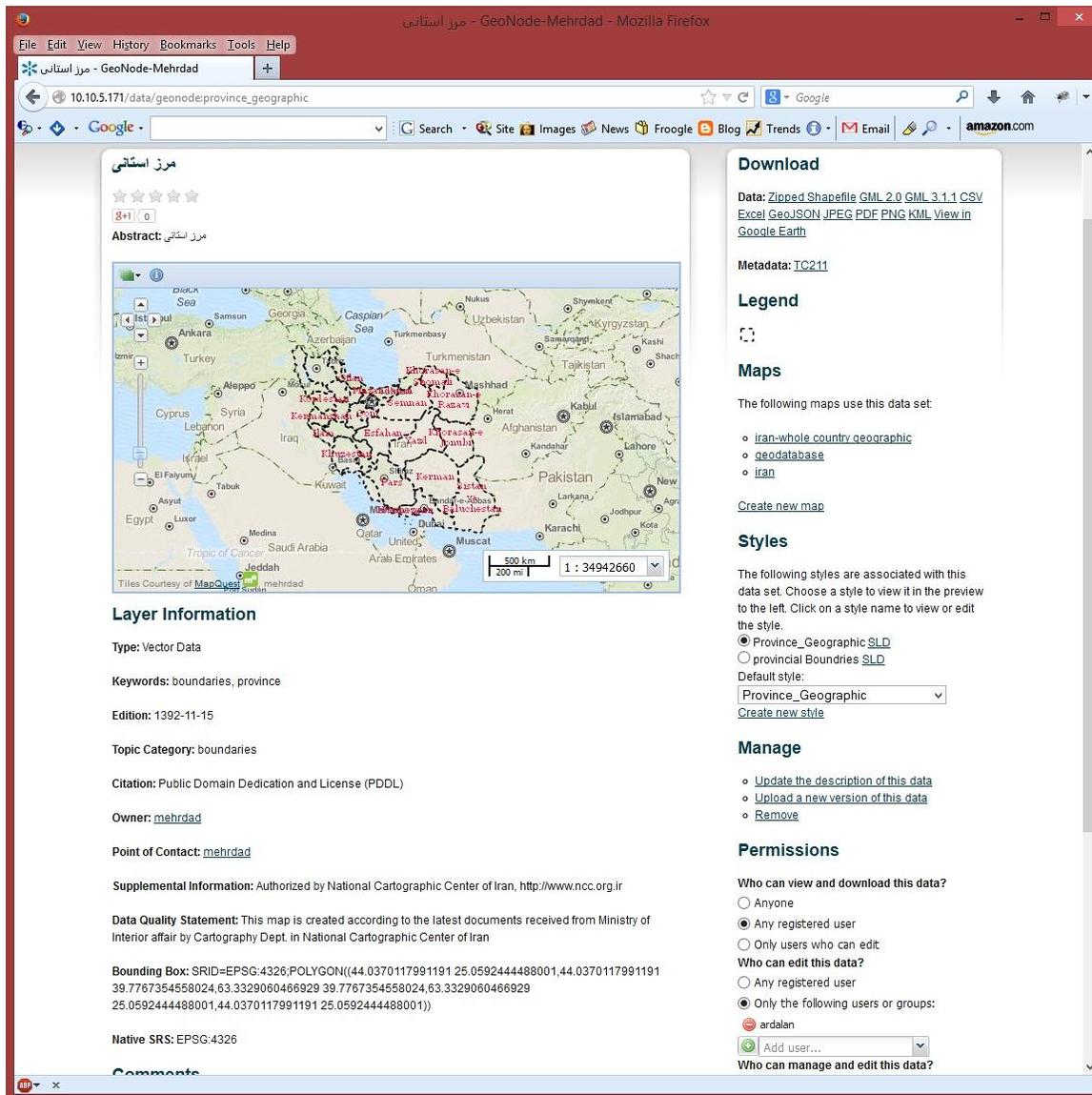


Figure 13: The process for Managing and editing data layer's metadata

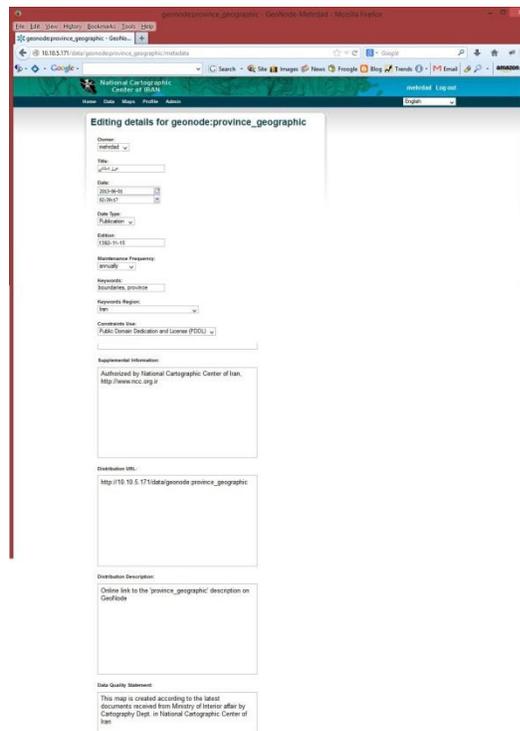


Figure 14: window for editing metadata

The last release of GeoNode can manage a metadata form, which contains a subset of the collection of fields suggested in the ISO standards for geo-spatial data. The metadata form can be developed in order to match the requirements defined in INSPIRE or any other specific requirements.

### 3.2.6 DATA SENSITIVITY

Data sensitivity is a key issue in every environment that involves data exchange on a web platform. It has to be guaranteed especially in case of spatial data related to emergency management.

The GeoNode implements a framework of users, groups, and permissions typical of a DBMS; this is due to the Django framework that ensures fast, direct and reliable reading and writing to a DBMS, which runs in support of the web platform.

Every user can access and potentially edit only data, which he is allowed to see and manage. On the other hand, the user who uploads data can assign permissions on his data to other users and groups. The system administrator has the possibility and the responsibility of making changes to the permissions in case of need.

## 3.3 GEONODE AND THE MAPPING ORGANIZATION

In order to build an effective mapping organization, mapping managers, policy-makers and the public must have access to the right data and information to take good decisions. Examples of such decisions include how to make a touristic thematic map and add the latest information with best available data, how to insure the public where the point of interest located, how to reach that

attraction sites and what is special with that point. Sharing data and creating open systems promotes transparency, accountability, and ensures a wide range of actors is able to participate in the challenge of making proper map with reference to its purpose and definition.

Mapping organization apart from their size and characteristics (Governmental, private sector) aims to collect data, process into information and present it to their audiences or clients. Data sources could be collected directly from the field or from existing databases or sources. Like all the other businesses, a successful organization is the one who reduce the costs (leading to more economic output) and increase the quality of the final product. To reduce the product costs one of the most significant action could be elimination of parallel task and optimization of cost effective part of the job, which is data collection.

It is important to note that in a mapping organization due to the variety of tasks and dealing subjects there are many issues and data inside one of the departments or sections that could be obscure to the eyes of the others as well as their own managers. Therefore, GeoNode can provide a solution by establishment of Databases, Database management systems (DBMS) as well as catalogue service managers accessible by all departments and stakeholders throughout the web.

A mapping organization can improve the quality and cost of production by data sharing according to very clear policy and consequently reduce the access time from the point of production up to the user's computer. Of course the definition of user does not necessarily implies outsiders of the organization, and would include whoever (Internally and externally) that needs those product for their own purpose. Internal user means various departments inside the organization involved in different task such as Cartography, Photogrammetry, Control & Supervision, or service department, etc. External user can be municipality, Disaster management organization, or Cadastre organization etc...

### 3.4 GEONODE COMPONENTS

When the GeoNode initiative was conceived other useful projects in the field of geo-spatial data had already been developed and were in production serving by many companies around the world. On one hand, several companies had been developing software for decades in geospatial data management, with proprietary formats and procedures. On the other hand, the Open Geospatial Consortium had been defining several open standards for geospatial data for years, on top of which open source software's both on the desktop and on the server side had been developed by developer communities and software houses. The GeoNode initiative builds upon the useful open source softwares already developed and combines them together in order to take advantage of their functionalities in an integrated manner (Figure 15)

In particular, the GeoNode is made of the following components:

- PostgreSQL;
- PostGIS;
- GeoServer;
- GeoNetwork;
- GeoExplorer;
- OpenLayers;
- Django

In the following sections, the mentioned components are introduced and their role in the platform is described.

**GeoNode Component Architecture**

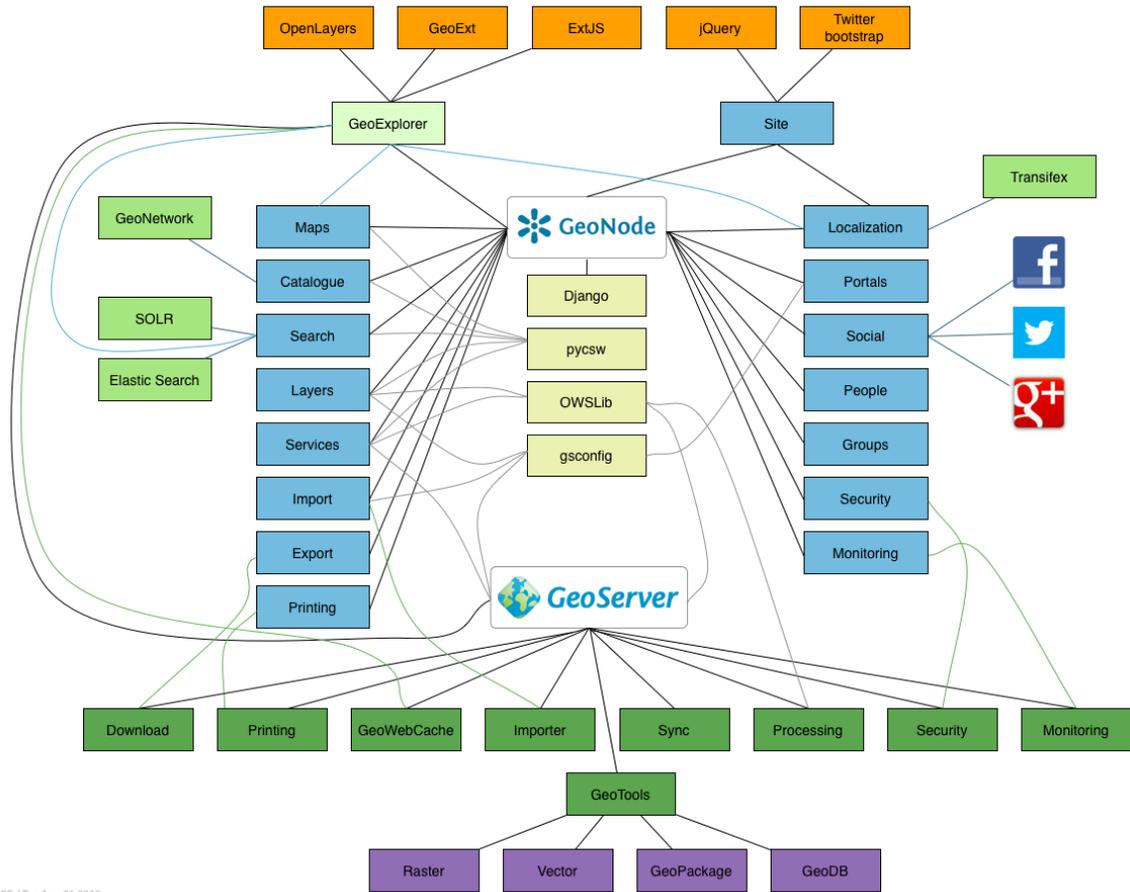


Figure 15: GeoNode Components architecture

**3.4.1 GEONODE AND POSTGRESQL/POSTGIS**

PostGIS is an extension to PostgreSQL, developed by a spatial Database Technology Research Project, which allows GIS objects to be stored into the database.

In GeoNode PostgreSQL is used with a double function: on one side it works in support of the GeoNode website, being the place where all the information about users and groups is stored and the instrument that assure the adherence to the user permissions. Moreover it contains also all the information that regards specifically the dynamic content of the website such as sentence translations in various languages. On the other side, it works as data repository for geospatial data by mean of the PostGIS extension, in particular for vector data. Relevant advantages can be detected when storing vector data in PostGIS, rather than storing them in file system, both in terms of performances in data selection and loading and in data management. On the contrary, even if the last PostGIS version allows raster storage, there is not a relevant advantage for raster data; therefore, they are stored in the file system.

### 3.4.2 GEOSERVER

GeoNode uses GeoServer for providing OGC services. GeoNode configures GeoServer via the REST API, and retrieves and caches spatial information from GeoServer. This includes relevant OGC service links, spatial metadata, and attributes information. In summary, GeoServer contains the layer's data and GeoNode's layer model extends what metadata is present in GeoServer with its own.

- GeoNode can discover existing layers published in a GeoServer via the WMS capabilities document;
- GeoServer delegates authentication and authorization to GeoNode;
- Data uploaded to GeoNode is first processed in GeoNode and finally published to GeoServer (or ingested into the spatial database);

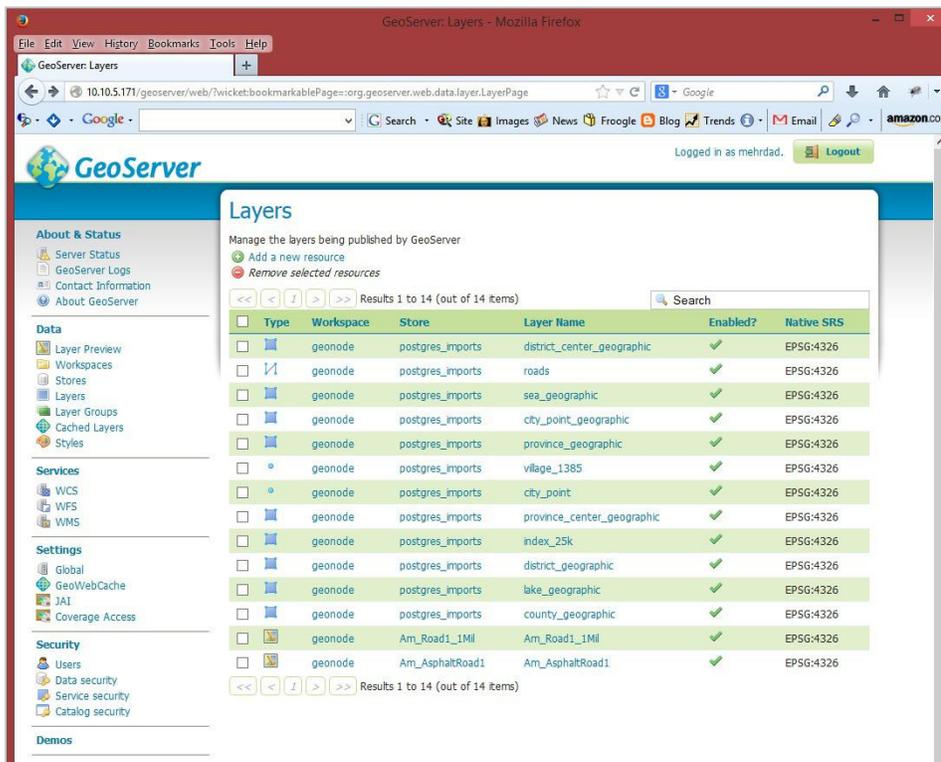


Figure 16: Index page of the GeoServer administration site; the software can be controlled from remote by mean of a web browser

### 3.4.3 GEONETWORK

GeoNetwork OpenSource is a standard based and decentralized spatial information management system, designed to enable access to geo-referenced databases and cartographic products from a variety of data providers through descriptive metadata, enhancing the spatial information exchange and sharing between organizations and their audience, using the capacities and the power of the Internet. The system provides a broad community of users with easy and timely access to available spatial data and thematic maps from multidisciplinary sources, that may in the end support informed decision-making. The main goal of the software is to increase collaboration within and between organizations for reducing duplication and enhancing information consistency and quality to improve the accessibility of a wide variety of geographic information along with the associated information,

organized and documented in a standard and consistent way. A screenshot of an archive instance of GeoNetwork OpenSource is contained in FIGURE 17.



FIGURE 17: screenshot of an active instance of geonetwork opensource that shows the metadata of a surface hydrology dataset

The main GeoNetwork features are:

- instant search on local and distributed geospatial catalogues;
- uploading and downloading of data, documents, *PDFs* and any other content;
- an interactive Web map viewer that combines WMS services from distributed servers around the world;
- online map layout generation and export in *PDF* format;
- online metadata editing with a powerful template system;
- scheduled metadata harvesting and synchronization between distributed catalogues;
- groups and users management;
- fine grained access control;

Specifically the GeoNode takes advantage of two main functionalities that are implemented in GeoNetwork: the two search engines.

The first is a typical web search engine and works on the basis of some keywords that are assigned to each dataset and then retrieved when submitted in the search string. The second is a spatial search engine by mean of which it is possible to search for data covering a determined area of interest, based on its geographic extent. An example screenshot of the two search engines,

Implemented into a GeoNode page, is shown in Figure 18.

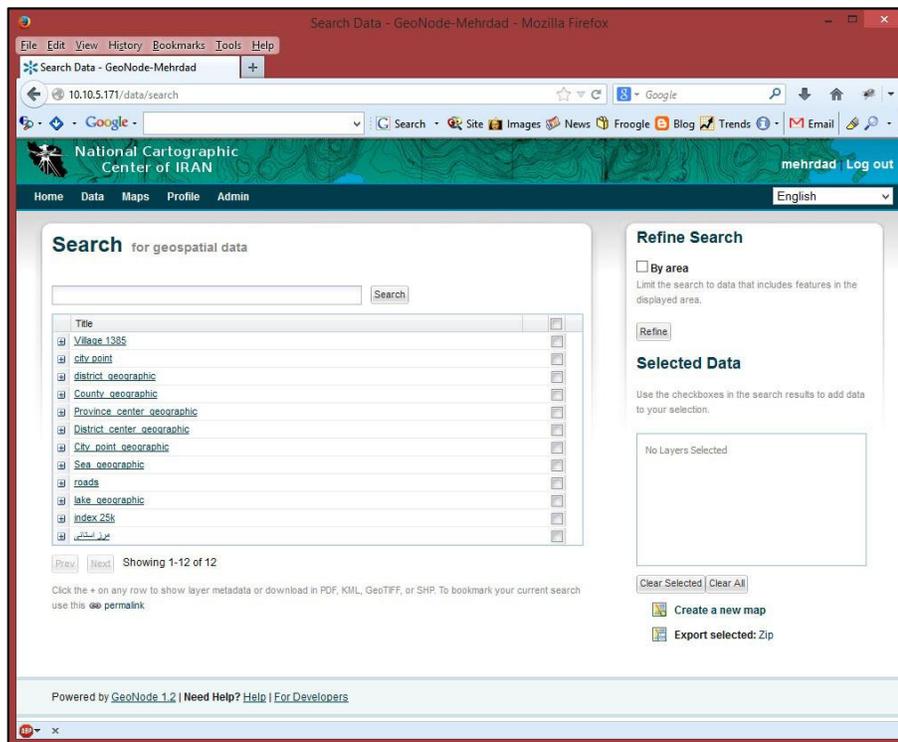


Figure 18: Screenshot taken from the GeoNode instance set up specifically as MASDAP project, that shows the page containing the two search engines; on the left the search engine based on keywords is showed, while on the right the search engine based

### 3.4.4 GEOEXPLORER

One of the key GeoNode functionalities is the possibility to create and edit Web maps, by taking advantage via a Web browser with some capabilities typically offered by desktop GIS applications. This is allowed by an open source application called GeoExplorer, developed for this purpose by an American software house called<sup>1</sup>.

GeoExplorer is a web application, based on the GeoExt<sup>2</sup> framework, for composing and publishing web maps with OGC and other web based GIS Services. GeoExplorer is used inside GeoNode to provide many of the GIS and cartography functions that are a core part of the application.

The goal of GeoExplorer is to make it easy for anyone to assemble a browser based mapping application. GeoExplorer includes basic layer browsing capabilities and it can be used in any compliant WMS software. GeoExplorer takes advantage of the GeoExt toolkit and take advantageous of the user interface power of ExtJS.

<sup>1</sup> <http://suite.opengeo.org/opengeo-docs/geoexplorer/>

<sup>2</sup> <http://geoext.org/>

In particular, from the user's points of view, GeoExplorer is composed by a large map canvas where geospatial data are rendered as maps and a table of content on the left-hand side of the screen where the list of layers present in the map is showed as well as tools for controlling each representation layer and styling, which are embedded. Furthermore, a set of tools, aimed at controlling the zoom and pan functionality as well as the printing and publishing modules and a get-info function, is integrated in buttons located in the upper part of the window. An example of the GeoExplorer user interface is showed Figure 19. The GeoExplorer can access all the layers stored in the PostGIS database connected to the same GeoNode instance; moreover it can access every layer provided through WMS services by a network-connected server.

### 3.4.4.1 GEOEXT

GeoExt is an open source JavaScript toolkit aimed at building rich web mapping applications. It brings together the geospatial OpenLayers with the Savvy of ExtJS user interface to help building powerful GIS desktop style apps on the web with JavaScript.

On one hand, GeoExt extends Ext JS, a rich library of web UI widgets and helper classes. In particular, it is a JavaScript framework for building rich application in web browsers that enables developers to use a model-view-controller architecture when building their application, and offers a wide range of user interface widgets such as scalable grids, trees, and menus [<http://www.sencha.com/>].

On the other hand, the OpenLayers mapping library is the key component of GeoExt, performing the core map-related functions of every GeoExt-based application.

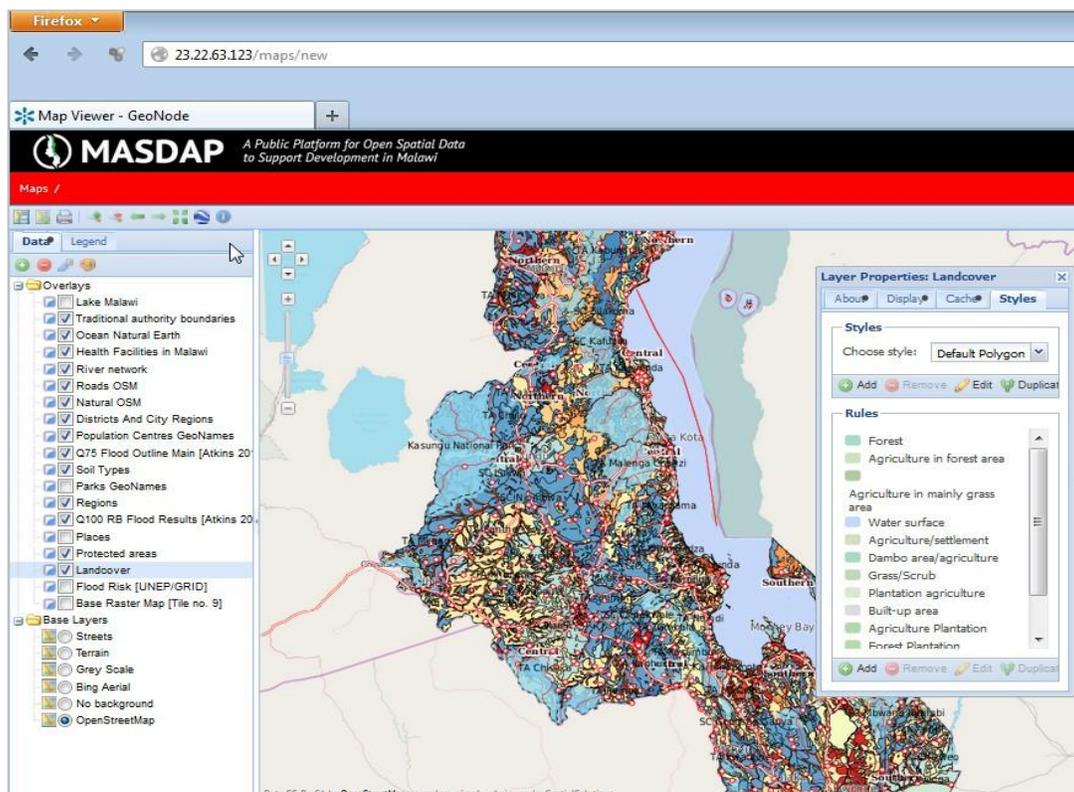


Figure 19: A GeoExplorer screenshot shows the main components: on the right is a map canvas where geospatial data are displayed; on the left a table of contents allows the layer management; on the top buttons implement functions related to zoom, pan, printing and

### 3.4.5 OPENLAYERS

OpenLayers is a pure JavaScript library for displaying map data in most modern web browsers; it does not have any server-side dependencies, and is developed and supported by a number of organizations around the world. In particular, it implements a JavaScript API for building rich web-based geographic applications and is completely free and open source<sup>1</sup>.



OpenLayers has been developed to further the use of geographic information of all kinds; it makes it easy to put a dynamic map in any web page and can display map tiles and markers loaded from any source.

OpenLayers is used in GeoNode on the client side, in particular in the web pages that show cartographic representation of data and maps; in respect to what said previously and in section 0, OpenLayers is used in the GeoNode data and map page and in GeoExplorer, which is the map builder application. Examples of OpenLayers functions are the zoom and map options in the map visualization.

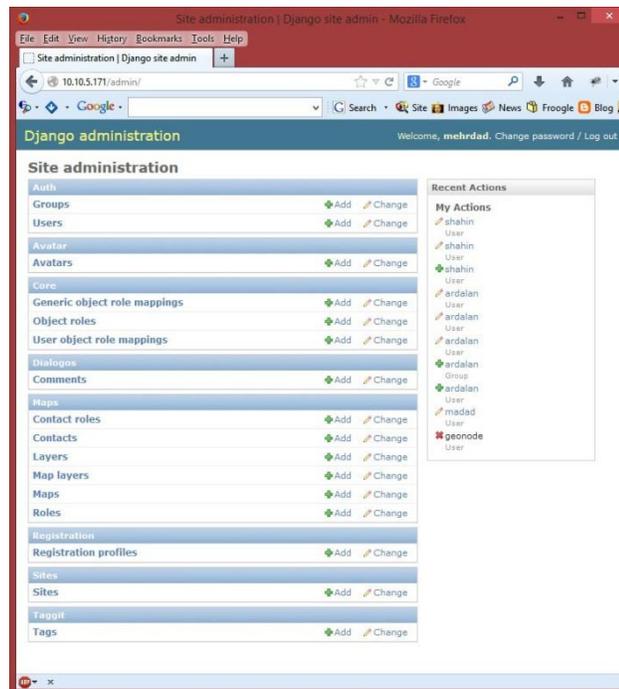
### 3.4.6 DJANGO

As stated previously, GeoNode combines many software products, which are already existing and sufficiently stable according to wide community of users. As a web platform, the main GeoNode component is the code that describes the website logic. This code is written in Python programming language and takes advantage of a framework for web development as so-called “Django.”

Django applies the DRY principle. The DRY principle, which is an acronym of “Don't Repeat Yourself,” states that, “every piece of knowledge must have a single, unambiguous, authoritative representation within a system”.

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<sup>1</sup> <http://www.openlayers.org/>



A mechanical, textual duplication is accepted as long as the authoritative source is well known; the user tries to identify the single, definitive source of every piece of knowledge used in your system and then use that source to generate applicable instances of that knowledge, which can be code, documentation, and tests.

### 3.4.6.1 THE MVC PATTERN AND RESPECTIVE MODULES

Moreover, Django adheres to the MVC software architecture that is the acronym of Model-View-Controller (Figure 20), an architectural pattern used in software engineering that isolates the application logic for the user from the user interface, permitting independent development, testing, and maintenance of each part.

The model manages the behaviour and data of the application domain, responds to requests for information about its state from the view, and responds to instructions to change state from the controller. A model is the single, definitive source of data about the data contained into a web site; it contains the essential fields and behaviours of the data stored into the DBMS that supports the website.

The view renders the model into a form suitable for interaction that is a user interface element; multiple views can exist for a single model that responds to different purposes.

The controller receives user input and initiates a response by making calls on model objects; a controller accepts input from the user and instructs the model and a view port to perform actions based on that input.

An example of control flow is the following<sup>1</sup>:

<sup>1</sup> [http://en.wikipedia.org/wiki/Model,\\_view,\\_controller](http://en.wikipedia.org/wiki/Model,_view,_controller)

1. the user interacts with the user interface in some way, typically by pressing a button or issuing a command;
2. the controller handles the input event from the user interface and converts the event into an appropriate user action, understandable for the model;
3. the controller notifies the model of the user action, possibly resulting in a change in the model state;
4. A view queries the model in order to generate an appropriate user interface. The view gets its own data from the model;
5. the user interface waits for further user interactions, which restarts the control from cycle;

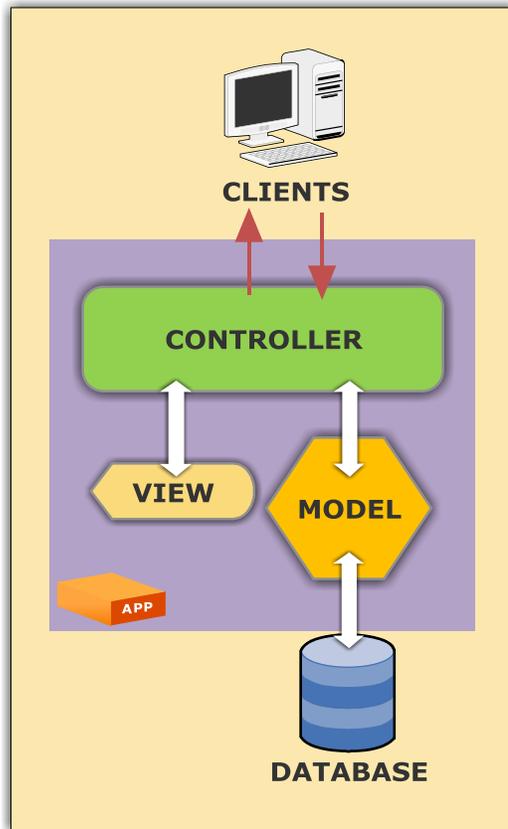


Figure 20: Logical schema of the Model-View-Controller architectural pattern for software development (source: Wikipedia)

The implementation of the MVC model in Django is realized in three Python modules that are automatically generated by the software when a new application is issued; `models.py` and `views.py` contain the homonymous components, while the controller is implemented into the template files. These are template web pages written partially with HTML language and partially with Python code: when the template is called by a view, the missing part of the HTML itself is generated by the Python code and then the web page is ready for being sent to the client.

As previously mentioned, Django provides support and API for managing a DBMS without the need of dealing directly with SQL language. Many different DBMS can be used, two examples of which are *PostgreSQL* and *SQLite*.

### 3.4.6.2 IMPORTANT DJANGO MODULES

Other two key Django modules are the *settings* and the *URLconf* module. The first contains all the important configuration of the Web site and the Django installation. Since it is a Python module, the configurations are expressed as variables at the module level and it must not contains syntax errors. Among the variables, some of the most important are:

*DEBUG*: it is the condition of the site whether in debugging mode or production mode; if in debugging mode the software communicates the stack trace of the errors when in site development phase;

*SITEURL*: the *URL* of the website we are working on;

*ADMINS*: it contains the website administrator name;

*DATABASE\_ENGINE*, *DATABASE\_NAME*, *DATABASE\_USER*, *DATABASE\_PASSWORD*, *DATABASE\_HOST*, *DATABASE\_PORT*: are a set of variables that describe the DBMS in support to the website and the keywords to get data from and to it, such as name, user, password, connection host and connection port;

*TIME\_ZONE*: it is the time zone of reference of the website;

*MEDIA*: describes the path that holds the media component;

*TEMPLATE\_DIRS*: the path to the template directory;

*INSTALLED\_APPS*: the list of the Django applications installed;

*GEOSERVER\_BASE\_URL*: specific of the GeoNode platform, it defines the *URL* followed by Django in order to interoperate with the GeoServer;

*GEONETWORK\_BASE\_URL*: specific of the GeoNode platform, it defines the *URL* followed by Django in order to interoperate with the GeoNetwork.

The *settings* module contains also the path of the *URLconf* module: this contains the *URL* configuration and is responsible for correctly linking the requests submitted by the client machine against the functions that have to be run by the server machine. The Python contains a simple mapping between *URL* patterns to Python callback functions: that mapping is stored in a variable called *urlpatterns*, in the form of a list of tuples. The *URL* patterns are stored as regular expressions while the callback functions are Python methods stored in the views.

When a user types an *URL* address into the address bar of a Web browser, he sends a request to the server. In case the respective Web site is powered by Django, it loads the Python module that contains the variable *urlpatterns*, runs through each *URL* pattern following the order, and stops at the first one that matches the request. Once the regular expression has matched, the view contained in the tuple is called and the Python function executed. The view gets passed a request for returning an *HTTP* response as first argument and any values captured in the regular expression as remaining arguments.

To sum up, the Django framework can be considered as the core of the GeoNode platform because it is responsible for keeping together all the other components and allows them to be interoperable and efficient. Furthermore, it is the engine of the entire Web platform because it supports all the operations called by the users from remote. Therefore, the Python programming language and the Django framework are the instruments of the GeoNode development: they are a requirement for every modification, improvement, configuration, and customization of the Web platform itself.

### 3.5 MALAWI DISASTER AND NATURAL RESOURCES SPATIAL DATA SHARING PLATFORM

In partnership with the World Bank's Open Data for Resilience Initiative (OpenDRI), the Shire River Basin Management Technical Team and the Department of Disaster Management Affairs have decided to launch an online platform to help ensure that the data created by a number of past or ongoing projects is maintained in an online platform. Therefore, this information remains accessible and useful to the Government of Malawi.

The consultancy foresaw the creation of a web-based data-sharing tool, managed by the National Spatial Data Center with the participation of the other members of the Shire River Basin Management Program Technical Taskforce. This platform is based on the free and open-source software, GeoNode, which is being used in a number of other OpenDRI projects in the region and around the world (<http://geonode.org/>).

The project is composed of the following components:

- Installation and configuration of an instance of GeoNode on servers owned or managed by the National Spatial Data Center. ITHACA provided hosting recommendations (remote vs. in country) and necessary support during the procurement process. Once installed, the software was customized to achieve basic branding goals including relevant logos, the name, and description of the project, and a custom theme. The theme includes a categorical entry point to the available tools of the portal, including entry points to spatial tools and maps, the spatial data catalogue, and a knowledge sharing entry point which provides a user-friendly content management system to upload experiences, images and videos and navigate this user-generated content on a map interface;
- Population of the GeoNode with available spatial datasets relevant to climate and disaster risk in the country; Specifically, ITHACA was responsible for:
  1. Uploading identified spatial data layers (See 3.2.2) ;
  2. Ensuring metadata is entered into the platform, in compliance with World Bank GeoSpatial Metadata standards (based on ISO 19115:2003)(See 3.2.5);
  3. Styling of uploaded datasets using the SLD format to allow for basic visualization on the platform;
  4. Creation of a suite of basic “mashups” or maps with data made available on the platform in close collaboration with the National Spatial Data Center and relevant stakeholders(See 3.2.4) ;
  5. End user training to illustrate the potential of the system developed to facilitate decision making in a spatial context:
    - Basic training (overview of the software, map and data viewing, data uploading, with focus on data types, Coordinate Systems, ISO standard for metadata). Map creating (focus on Styling, printing and web publication). Data downloading (focus on various available formats), assigning permissions to maps and data, overview of the main components installed with GeoNode (Tomcat server applet, Apache web server), overview of GeoNetwork (focus on interactions with GeoNode), GeoServer main functionalities and objects, Django Admin interface (focus on users and groups management and DBMS interaction), overview of PostgreSQL and PostGIS and data storage.
    - Advanced training (Interaction between the different GeoNode components, SLD – Style Layer Descriptor in xml format and examples, SLD generation through offline tools such as Atlas Styler, ArcMap to SLD, WMS, WCS, WFS web services for data publication, map generation by means of third

part web services, use of GeoNode Documents application, Django web framework overview and MVC pattern.

### 3.6 CONCLUSION

GeoNode is a platform for the management and publication of geospatial data. It brings together mature and stable open-source software projects under a consistent and easy-to-use interface allowing users, with little training, to quickly and easily share data and create interactive maps.

GeoNode's data management tools allow for integrated creation of data, metadata, and map visualizations. Each dataset in the system can be shared publicly or restricted to allow access to only specific users. Social features like user profiles and commenting and rating systems allow for the development of communities around each platform to facilitate the use, management, and quality control of the data the GeoNode instance contains<sup>1</sup>.

The GeoNode community is very active in proposing new improvements and functionalities

The GeoNode is the reference software of the GFDRR Open Data for Resilience Initiative that aims to reduce the impact of disasters by empowering decisions-makers with better information and the tools to support their decisions. Several GeoNode instances are running in countries such as Haiti, Grenada, Saint Vincent, the Grenadines, The Saint Lucia in the Caribbean region, in Kenya, in the Horn of Africa Region, in Malawi (Central Africa). This tool enables individuals and organizations to download as well as contribute with their own data, thereby promoting collaboration around the management of the information needed for reconstruction and development.

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<sup>1</sup> [www.geonode.org](http://www.geonode.org)

## 4. REVIEW OF AVAILABLE OPEN SOURCE GEOSPATIAL DATA

### 4.1 INTRODUCTION

This chapter is consisted of an investigation and searching of available geospatial data with a global extent, by mean of bibliographic review, technical documentation and web search engines. The public domain datasets have a priority rank rather than commercial data; the use of commercial datasets can be optional and postponed for gaps filling and quality increase purposes. This choice allows getting an operational product in shorter terms by avoiding the management of time-consuming licensing issues as well as other existing political measures.

Data quality assessment is another stage necessary for the evaluation of the suitable available Geographic Data Sources. The concept of data quality is defined based on the relationship between the reality and its representation drawn by data itself. The closer to the reality data collected during the inventory phase are, the more useful they are; if data does not pass a threshold of closeness to the reality they cannot be considered useful reference data. Logically the data user is going to choose the one that had better modeled the real conditions for his purpose.

Data quality has to be defined by identifying a set of quality indicators: then they have to be applied to the data in order to get a quality assessment.

Therefore, data quality assessment implies firstly the definition of data quality in terms of the identification of a set of indicators; secondly the definition of a protocol for applying this indicator to the dataset selected during the inventory phase; finally the publication of the results of the protocol application to the real datasets, that is a data quality statement.

### 4.2 INVENTORY OF AVAILABLE GLOBALLY CONSISTENT DATA SOURCES

With reference to the general topographic feature list as core data, as well as Meteorological, Geological, Socio-economic and disaster as thematic data, this chapter aims at identifying the potentially exploitable sources for the geographic data to be considered as the open source data Table 3 and Table 4.

For this purpose, a review of available data holders has been performed. In particular, the following sources have been considered as a starting point:

- the data sources identified by UNGIWG(The United Nations Geographical Information Working Group (UNGIWG) 2013) TG1<sup>1</sup> and, particularly, those described in the Inventory Report (the results of this report date back to 2007);
- Queries performed in the metadata catalogues of the major organizations that deal with geographic data (i.e. UNEP GRID<sup>2</sup>, FAO).

Identified data fulfill two major requirements:

- global consistency with respect to the geographic extent;
- Absence or limitation of constraints on their access and use in the project; only datasets freely accessible and available free-of-charge or at reproduction cost, have been considered.

Moreover, for the purposes of the data sources review, and activity performed in this chapter, initial efforts have focused only on globally consistent and well-established geographic datasets.

From a methodological point of view, if subsequent data quality and consistency analyses highlight the need of geospatial data with different features from the selected ones (i.e. data with larger scale or for specific needs in different projects), the methodology for data sources review activity, can be easily adapted and refined.

*Table 3: Core Data – Topics and Sub-Topics*

TOPIC	SUB – TOPIC
<b>Boundaries: costal, administrative and areas of special interest</b>	Coastlines and Maritime Boundaries; Country Political Level 0 Boundaries and Area of Dispute Boundaries; Sub-national Boundaries (from 1st Level on); Areas of conflict; Parks, conservancies, and Protected areas

<sup>1</sup>The United Nations Geographical Information Working Group (UNGIWG) is a voluntary network of UN professionals working in the fields of cartography and geographic information science. UNGIWG was formed in 2000 to address common geospatial issues - maps, boundaries, data exchange, standards - that affect the work of UN Organizations and Member States. UNGIWG also works directly with non-governmental organizations, research institutions and industry to develop and maintain common geographic databases and geospatial technologies to enhance normative and operational capabilities.

Specifically UNGIWG aims to:

- Improve the efficient use of geographic information for better decision-making;
- Promote standards and norms for maps and other geospatial information;
- Develop core geospatial data to avoid duplication;
- Build mechanisms for sharing, maintaining and assuring the quality of geographic information;
- Provide a forum for discussing common issues and emerging technological advances.

<sup>2</sup> UNEP/GRID is the new generation of PREVIEW initiated in 1999 by UNEP/GRID-Geneva. The Global Risk Data Platform has now evolved following all standards for Spatial Data Infrastructures (SDI) and providing all the web services in compliance with the Open Geospatial Consortium (OGC). This application allows the visualization of data on natural hazards, exposure (both human and economical), and risk. The dataset browse by hazards (Cyclones, Droughts, Earthquakes, Fires, Floods, Landslides, Tsunamis, and Volcanoes).

TOPIC	SUB – TOPIC
<b>Surface hydrology: surface water bodies, water points, drainage and watersheds</b>	Drainage, Rivers and Flow Routing; Surface Water Bodies (SWB); Watersheds and River Basins; Water Points
<b>Human population: population centres and distributions</b>	Population Centres; Urban and Rural Population Density and Distribution
<b>Transportation: roads, railways, airports, harbors and nautical routes</b>	Roads; Railway lines, Stations, and Marshalling Yards; Airport; Harbors; Nautical Routes
<b>Bathymetry and terrestrial elevation</b>	Bathymetry; Terrestrial Elevation
<b>Points of Interest</b>	

*Table 4 Thematic Data – Topics and Sub-Topics*

TOPIC	SUB - TOPIC
<b>Geology</b>	Geology; Geo-morphology; Hydro-geology; Soils and Soil Properties
<b>Satellite imagery, land cover/use and vegetation</b>	Satellite Imagery; Land Cover/Use and Forests; Vegetation
<b>Socio-economic</b>	Demography; Economy; Society; Poverty; Environment
<b>Natural disasters</b>	Earthquake data; Volcanic eruptions data; Flood data; Fires data

This classification took also into account proposal of spatial data themes needed for environmental applications addressed by the directives<sup>1</sup>.

The review started from an initial data list provided together with queries performed in the metadata catalogues of the major organizations that deal with geographic data, such as UNEP GRID and FAO.

<sup>1</sup> <http://inspire.jrc.ec.europa.eu/>

Further review has been performed with Web search engines and using specific technical documentation. (Boccardo P. et.al. 2012)

The results of the review were further filtered with some restrictions as was mentioned before; As a result global datasets free of charge for access and use in academic, research and other non commercial uses constitutes most of the review.

The review activities provided an inventory of the available and globally consistent data sources, grouped according to the predefined topics and sub-topics and organized as tables with useful information for the following steps of the project, such as:

The identification of the institution, organization, or company responsible for the production and maintenance of the dataset, the geometry data type, the reference scale, the date of the last edition as well as the procedures needed to obtain the datasets and potential access constraints. For more details about datasets, refer to **Error! Reference source not found.**

#### 4.2.1 THE VMAP0, VMAP1:

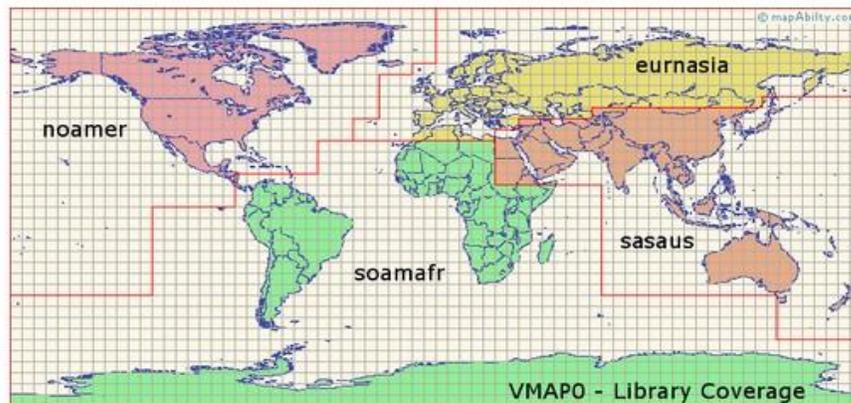
is a global vector database at 1:250,000 scale with the same structure of VMAP0. VMAP1 data are divided into a mosaic made of 234 geographic zones. Only 57 selected zones are released free of charge; on the contrary many countries consider maps and cartography a state monopoly for business or security reasons, therefore data for those countries are not released.

International Vector Data (VMAP1) covers the entire world seamlessly. VMAP1 is an updated and improved version of the National Imagery and Mapping Agency's (NIMA) Digital Chart of the World. The primary source for the database is the 1:1,000,000 scale Operational Navigation Chart (ONC) series co-produced by the military mapping authorities of Australia, Canada, United Kingdom, and the United States. VMap Level 0 includes major road and rail networks, hydrologic drainage systems, utility networks (cross-country pipelines and communication lines), major airports, elevation and depth contours, coastlines, international boundaries, vegetation, populated places and more.



#### VMAP0 DOWNLOADS

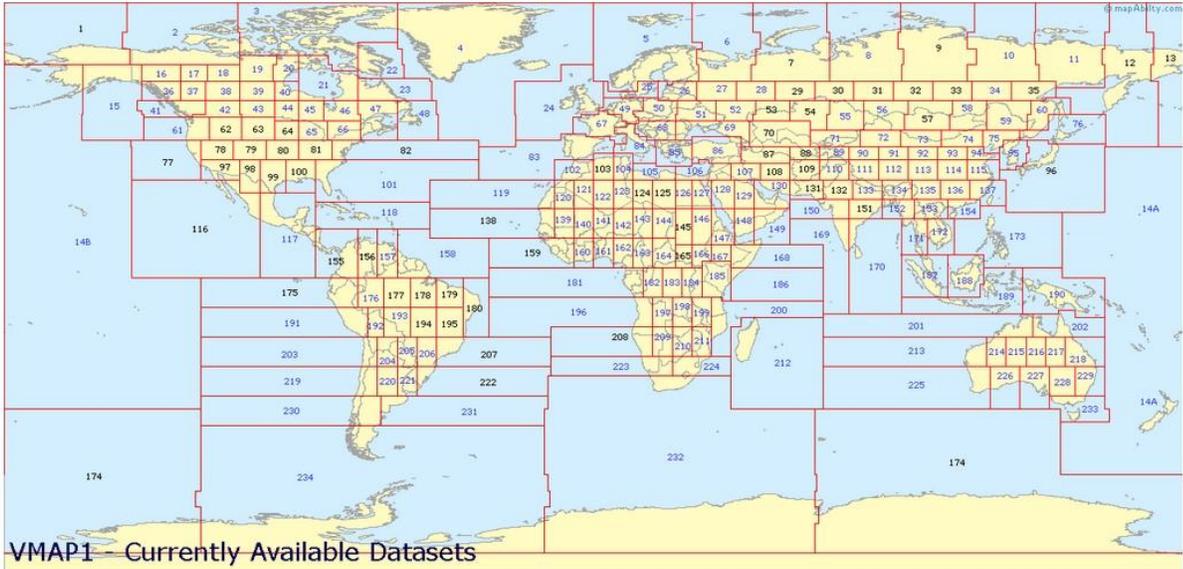
× This pages tells you where to download and how to install the VMAP0 data sets.



VMAP0 is divided into four libraries based on geographic areas. The above map shows these coverage areas. Each library is on one CD-ROM or Zip-file as follows: Disk 1 North America (noamer), Disc 2 Europe and North Asia (eurnasia), Disc 3 South America, Africa, and Antarctica (soamafr), and Disc 4 South Asia and Australia (sasaus). In an effort to be helpful, the main NIMA website has a nice map interface and plenty of options, but if you just want to rush in and download the VMAP0 data, it can be rather confusing to actually locate the files that you want. To simplify this, here are the 4 links that take you straight to the files...

**VMAP1 DOWNLOADS**  
 ✦ This pages tells you where to download and how to install the VMAP1 data sets.

VMAP1 data is divided into a rather complex global mosaic of 234 geographic zones, with each available on a single CD-ROM. However, as mentioned in the introduction page, only 57 of these zones are currently available for public download. In an effort to be helpful, the main NIMA website has a nice map interface and plenty of options, but if you just want to rush in and download the VMAP1 data, it can be rather confusing to actually locate the files that you want. To simplify this, I have provided the links that take you straight to the files - you can find them below the map.



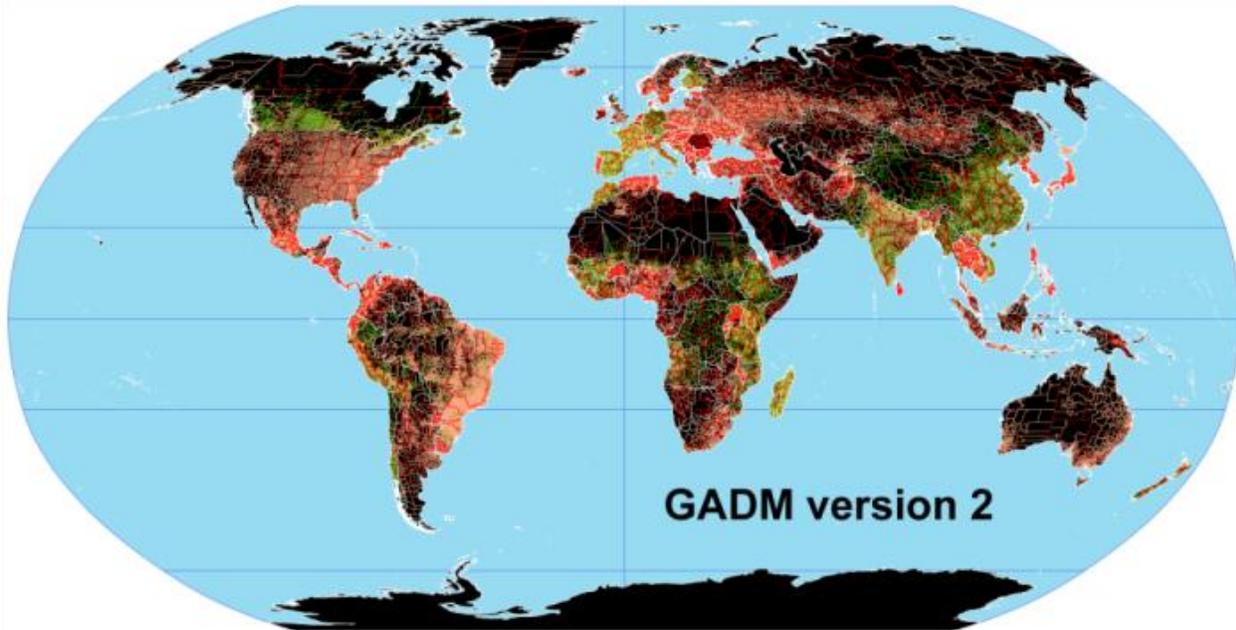
Layer Name	Description
Airports	Airport/Airfield
Barriers	Walls
Canals	Aqueducts/Canals/Flumes
Bathymetry	Depth Contours
City Areas	Built-Up Area
City Points	Built-Up Area
CoastLines	Coastline/Shoreline
Contours	Contour Lines - 700'
Crops	Cropland
Danger Points	Rock/Wreck
Fish Hatchery	Fish Hatchery/Fish Farm/Marine Farm
Grass	Grassland/Scrub/Brush
Industry Areas	Mine/Quarry, Oil/Gas Field, Salt Evaporator
Industry Points	Mine/Quarry, Oil/Gas Field, Salt Evaporator, Well
Lakes	Lakes
Ice - Land	Snow Field/Ice Field
Ice - Sea	Pack Ice/Polar Ice/Ice Shelf
Misc Industry Points	Processing Plant/Treatment Plant, Oil/Gas Facilities
Misc Pop Points	Settlement, Building, Ruins, Native Settlement, Camp..

<b>Misc Trans Lines</b>	Pier/Wharf/Quay, Aerial Cableway Lines/Ski Lift Line
<b>Misc Water Lines</b>	Seawall, Dam/Weir
<b>Misc Water Points</b>	Island, Spring/Water Hole, WaterFall, Dam/Weir, Rapids..
<b>Native Settlements</b>	Native Settlement
<b>Oceans Seas</b>	Water - NonInland
<b>PipeLines</b>	Pipeline/Pipe
<b>PlaceNames</b>	Points of Interest
<b>PoliticalBoundaries</b>	Administrative Area
<b>Power Plants</b>	Power Plant, Substation/Transformer Yard, Pumping Station
<b>RailRoads</b>	Railroad
<b>RailRoad Yards</b>	Railroad Yard/Marshalling Yard
<b>Rivers</b>	River/Stream
<b>Roads</b>	Primary and Secondary Routes
<b>Sand</b>	Sand, Distorted Surface, Lava
<b>Spot Elevations</b>	Spot and Inland Water Elevation
<b>Storage Points</b>	Tank, Storage Depot, Water Tower
<b>Swamps</b>	Marsh/Swamp, Bog
<b>Trails</b>	Trail
<b>Transportation Lines</b>	Bridge/Overpass/Viaduct, Tunnel, Ferry Crossing
<b>Transportation Points</b>	Bridge/Overpass/Viaduct, Ferry Crossing
<b>Trees</b>	Evergreen, Deciduous, Mixed Trees
<b>Tundra</b>	Tundra
<b>Utility Lines</b>	Power Transmission Line

#### 4.2.2 GADM DATABASE OF GLOBAL ADMINISTRATIVE AREAS

GADM is a spatial database of the location of the world's administrative areas (or administrative boundaries) for use in GIS and similar software. Administrative areas in this database are countries and lower level subdivisions such as provinces, departments, bibhag, bundeslander, daerah istimewa, fivondronana, krong, landsvæðun, opština, sous-préfectures, counties, and thana. GADM describes where these administrative areas are (the "spatial features"), and for each area it provides some attributes, such as the name and variant names.

The current version is 2.0 (January 2012)



Compared to Version 1, GADM Version 2 has, among other things, more detailed data for Belgium, Bosnia and Herzegovina, Croatia, Cuba, Dominican Republic, Luxembourg, Estonia, France, Hungary, Nepal, Turkey, Switzerland, Syria, Uzbekistan, and Venezuela. Sudan was split in two and a few Caribbean islands were split or rearranged. With only a few exceptions, the second level subdivision has now been mapped for all countries (see these maps by level of subdivision). The current version of GADM delimits 556,049 administrative areas (or 218,238 if you count only the lowest level for each country).

The data are available as shapefile, ESRI geodatabase, RData, and Google Earth kmz format. Shapefiles can be used for most mapping and "GIS" software. You can download a free program such as QGIS or DIVA-GIS. The RData files can be used in R with the 'sp' package loaded.

You can download the data by country or for the whole world.

The goal is to map the administrative areas of all countries, at all levels.

### 4.2.3 THE GAUL:

is an initiative implemented by FAO and funded by the European Commission. It aims at disseminating and compiling the most reliable spatial information on administrative units for all the countries in the world, providing a contribution to the standardization of the spatial dataset representing administrative units. The GAUL always maintains global layers with a unified coding system at country, first and second administrative levels. It is released once a year and the target beneficiary is the UN, the Universities and other authorized international and national institutions and agencies; a disclaimer should always accompany any use of the GAUL data.

1	Albania	34	Maldives
2	Algeria	35	Liechtenstein
3	Andorra	36	Malaysia

4	Austria	37	Malta
5	Bahrain	38	Moldova, Republic of
6	Belarus	39	Mongolia
7	Belize	40	Netherlands
8	Botswana	41	New Zealand
9	Brunei Darussalam	42	Papua New Guinea
10	Burkina Faso	43	Poland
11	Canada	44	Puerto Rico
12	Croatia	45	Qatar
13	Cyprus	46	Republic of Korea
14	Czech Republic	47	Romania
15	Dem People's Rep of Korea	48	Russian Federation
16	Dominican Republic	49	Saint Kitts and Nevis
17	Egypt	50	Saint Lucia
18	Equatorial Guinea	51	Saudi Arabia
19	Falkland Islands (Malvinas)	52	Singapore
20	Greenland	53	Slovakia
21	Hungary	54	Sudan
22	Iceland	55	Swaziland
23	Iraq	56	Switzerland
24	Ireland	57	Tajikistan
25	Israel	58	The Former Yugoslav Republic of Macedonia
26	Jamaica	59	Trinidad and Tobago
27	Japan	60	Tunisia
28	Jordan	61	Turkmenistan
29	Kazakhstan	62	Ukraine
30	Kuwait	63	United Arab Emirates
31	Latvia	64	Uzbekistan
32	Liberia	65	Western Sahara
33	Libyan Arab Jamahiriya	66	Yemen

#### 4.2.4 THE WVS+

World Vector Shoreline Plus (WVS+) is a seamless worldwide database that includes coastlines; bathymetry and country-level boundaries. The data was derived primarily from 1:250,000 scale Joint Operations Graphics and coastal nautical charts from the U.S. Defense Mapping Agency (DMA). The data is based on the World Geodetic System (WGS 84) with the projection being Geographic (latitude/longitude). The data exists at scales of 1:250,000, 1:1,000,000, 1:3,000,000, 1:12,000,000, 1:40,000,000, and 1:120,000,000. Each scale contains country lines (including boundaries, shorelines, and gridlines) and country points (including country names only). Countries are NOT represented by polygons. Bathymetry is shown at scales 1:3,000,000, 1:12,000,000 and 1:40,000,000. There are no attributes associated with the bathymetry layers. This data set is useful for simple global or national views with country borders and labels.

This data originated from the National Geospatial-Intelligence Agency (NGA) and it is available through Land Info Worldwide Mapping LLC.

WVS+ is available in ArcView shapefiles (\*.shp).

#### 4.2.5 THE GLOBAL MAP

is a database resulted from a global project promoted by the government of Japan with the aim of bringing all nations and concerned organizations together in order to collaboratively develop and provide easy and open access to worldwide geographic information at a scale of 1:1,000,000. At present data for 71 countries and 4 regions are available. *Boundaries* are one out of the 8 themes of the database. The first version of the database was released in 2000 and it is mainly based on existing global geographic data, such as VMAPO.

Global Mapping Project is an international cooperation initiative through voluntary participation of National Mapping Organizations (NMOs) in the world, aiming to develop digital geo-information framework datasets ensuring spatial resolution at 1 km. Primary objective of the Project is to contribute to sustainable development, environmental conservation and natural disaster mitigation through provision of basic geo-information framework datasets.

The Project was initially proposed by Ministry of Construction of Japan (present Ministry of Land, Infrastructure, Transport, and Tourism of Japan) in 1992, in conjunction with the adoption of Agenda 21 at United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro. Preparatory works for concretization of the proposal thereafter eventually resulted in the establishment of the International Steering Committee for Global Mapping (ISCGM) in 1996.

#### 4.2.6 THE RELATIONAL WORLD DATA BANK II (RWDBII)

is an update (1995) of the older *CIA World Data Bank II (WDBII)*, compiled between 1972 and 1977. This appears to be available only by purchase on CD-ROM, with licensing terms unclear. While the nominal scale of maps used for *WDBII* was 1:3,000,000, parts of Europe, Central America, Southeast Asia, and the Middle East were digitized at 1:1,000,000, and the former Northeastern USSR and Antarctica at 1:4,000,000. The data were originally digitized by the U.S. Central Intelligence Agency (CIA) from ONC and other source maps.

With the release of the *DCW/Vmap0*, the *WDBII* data library has to some degree treated as a legacy database. Due to this, the *WDBII* has not been utilized as fully for either base mapping at scales ranging from 1:2 million through 1:5 million or for continental analysis, which the database can support. A number of *WDBII* derivative databases have been created over time, however, a fully revised edition of these data was released in 2001 employing ESRI shapefile format. This edition of the *WDBII* will be referred to as the *Relational World Data Bank II Database in Shapefile format v1.1* or *RWDBII-Sv1.1*.

The *RWDBII-Sv1.1* database contains several datasets (points, lines, and polygons data types available) that can be summarized into six themes : Population (2 datasets), Transport (8 datasets), Hydrology (7 datasets), Coastlines (4 datasets), Administrative (4 datasets), Miscellaneous (3 datasets).

These data are available on demand, but the source is not clear; only coastline data are freely available from the *NGDC coastline extractor* website.

In the framework of AWRD, some data have been revised and distributed through FAO GeoNetwork. These data have been inserted in the Data Inventory under the name of *AWRD*.

#### 4.2.7 THE GSHHG

The GSHHG is a high-resolution geography data set, amalgamated from two databases in the public domain: World Vector Shorelines (WVS) and CIA World Data Bank II (WDBII). The former is the basis for shorelines while the latter is the basis for lakes, although there are instances where differences in coastline representations necessitated adding WDBII islands to GSHHG. The WDBII source also provides all political borders and rivers. GSHHG data have undergone extensive processing and should be free of internal inconsistencies such as erratic points and crossing segments. The shorelines are constructed entirely from hierarchically arranged closed polygons.

GSHHG combines the older GSHHS shoreline database with WDBII's rivers and borders, available for file download in either ESRI shapefile format or in a native binary format. The GSHHG geography data come in five different resolutions: crude(c), low (l), intermediate (i), high (h), and full (f). Shorelines are further organized into 4 hierarchical levels: boundary between land and ocean (L1), boundary between lake and land (L2), boundary between island-in-lake and lake (L3), and boundary between pond-in-island and island (L4). The primary GSHHG web site (<http://www.soest.hawaii.edu/pwessel/gshhg/>) contains additional information.

#### 4.2.8 SRTM WATER BODY DATA (SWBD)

The **SRTM Water Body Data (SWBD)** is a geographical dataset encoding high-resolution worldwide coastline outlines in a vector format, published by NASA, designed for use in geographic information systems, and mapping applications. It was created by BAE Systems ADR for the US National Geospatial-Intelligence Agency (NGA) as a complementary product during editing of the digital elevation model database of the Shuttle Radar Topography Mission (SRTM). SWBD data covers the Earth's surface between 56° southern latitude and 60° northern latitude. It is distributed in ESRI shapefile format, divided into 12,229 files, each covering one 1°-by-1° tile of the Earth's surface.

SWBD data is in the public domain and is made available online for free download by NASA.

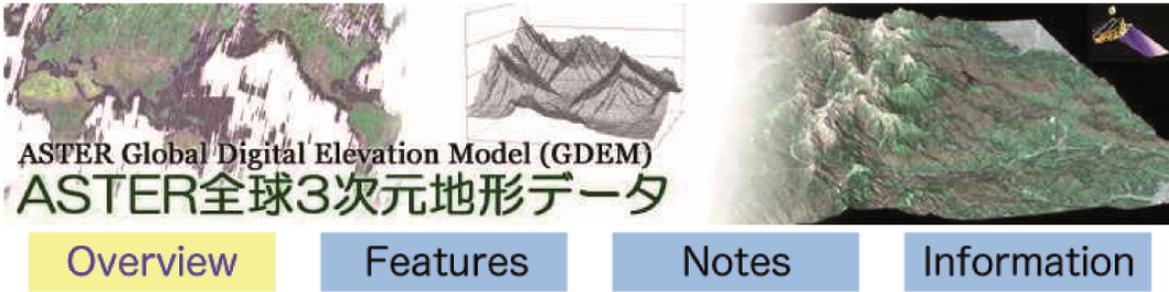
#### 4.2.9 ASTER DEM<sup>1</sup>

The ASTER Global Digital Elevation Model (ASTER GDEM) is a joint product developed and made available to the public by the Ministry of Economy, Trade, and Industry (METI) of Japan and the United States National Aeronautics and Space Administration (NASA). It is generated from data collected from the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), a spaceborne earth observing optical instrument.

The ASTER GDEM is the only DEM that covers the entire land surface of the Earth at high resolution. Since the release of the Version 1 on June 29, 2009 (\*1), the ASTER GDEM has been widely used by many users (\*2) and it has greatly contributed to the global earth observing community.

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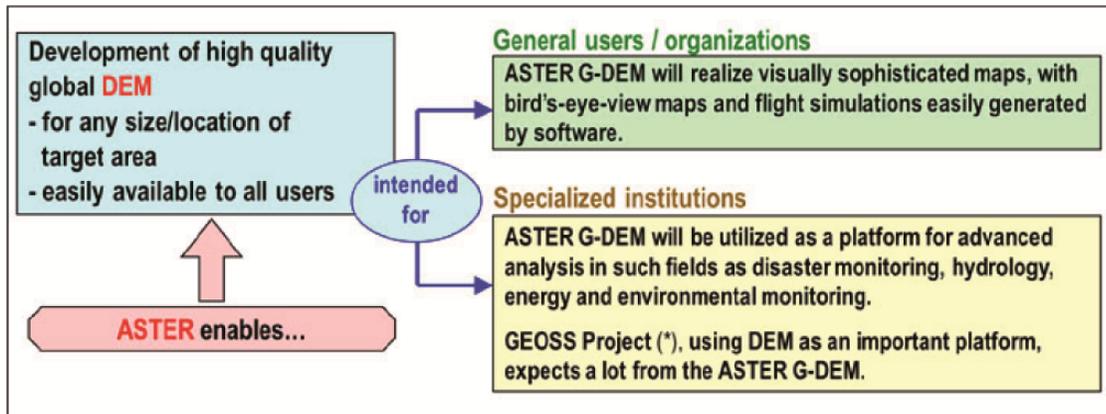
<sup>1</sup> <http://www.jspacesystems.or.jp/ersdac/GDEM/E/1.html>



**ASTER GDEM**

ASTER GDEM is an easy-to-use, highly accurate DEM covering all the land on earth, and available to all users regardless of size or location of their target areas.

Anyone can easily use the ASTER GDEM to display a bird's-eye-view map or run a flight simulation, and this should realize visually sophisticated maps. By utilizing the ASTER GDEM as a platform, institutions specialized in disaster monitoring, hydrology, energy, environmental monitoring etc. can perform more advanced analysis. (See another page, "[Application](#)")



**4.2.10 LANDSCAN**

Using an innovative approach with Geographic Information System and Remote Sensing, ORNL's LandScan™ is the community standard for global population distribution. At approximately 1 km resolution (30" X 30"), LandScan is the finest resolution global population distribution data available and represents an **ambient population** (average over 24 hours). The LandScan algorithm, an R&D 100 Award Winner, uses spatial data and imagery analysis technologies and a multi-variable dasymmetric modeling approach to disaggregate census counts within an administrative boundary. Since no single population distribution model can account for the differences in spatial data availability, quality, scale, and accuracy as well as the differences in cultural settlement practices, LandScan population

distribution models are tailored to match the data conditions and geographical nature of each individual country and region<sup>1</sup>.

Firefox

web.ornl.gov/sci/landscan/index.shtml

LandScan Home

OAK RIDGE NATIONAL LABORATORY managed by UT-Battelle for Department of Energy

CSE Division CCS Directorate ORNL

GIST  
Geographic Information Science and Technology

Computational Sciences & Engineering Division

Home

Data Availability

Documentation

Frequently Asked Questions

Related References

Sample Dataset

LandScan Usage

References

Credits/Disclaimers

FOR TRIAL ACCESS

Contact East View

**LandScan™**

Using an innovative approach with Geographic Information System and Remote Sensing, ORNL's LandScan™ is the community standard for global population distribution. At approximately 1 km resolution (30" X 30"), LandScan is the finest resolution global population distribution data available and represents an **ambient population** (average over 24 hours). The LandScan algorithm, an R&D 100 Award Winner, uses spatial data and imagery analysis technologies and a multi-variable dasymmetric modeling approach to disaggregate census counts within an administrative boundary. Since no single population distribution model can account for the differences in spatial data availability, quality, scale, and accuracy as well as the differences in cultural settlement practices, LandScan population distribution models are tailored to match the data conditions and geographical nature of each individual country and region.

Please see the [Data Availability](#) page for access to the latest available LandScan™ dataset.

**HIGHLIGHTS**

**Mapping Technology Aids Tsunami Recovery...**  
Relief agencies assist victims of the Asian tsunami using a demographic database developed at ORNL.

**RESEARCH AREAS**

- Download Citation in .RIS Format
- Geographic Information Science and Technology (GIST)

**DOWNLOADS**

- Download Citation in .RIS Format

LS2011 | LS2010 | LS2009  
LS2008 | LS2007 | LS2006  
LS2005 | LS2004 | LS2003  
LS2002 | LS2001 | LS2000  
LS1998

#### 4.2.10.1 DATA DESCRIPTION

**Format and extent:** The data is distributed in both an ESRI grid format and an ESRI binary raster format. The dataset has 20,880 rows and 43,200 columns covering North 84 degrees to South 90 degrees and West 180 degrees to East 180 degrees.

**Data values** The values of the cells are integer population counts representing an average, or ambient, population distribution. An ambient population integrates diurnal movements and collective travel habits into a single measure (Dobson et al. 2000). Since natural or man made emergencies may occur at any time of the day, the goal of the LandScan model is to develop a population distribution surface in totality, not just the locations of where people sleep. Because of

<sup>1</sup> <http://web.ornl.gov/sci/landscan/>

this ambient nature, care should be taken with direct comparisons of LandScan data with other population distribution surfaces.

**Resolution and Coordinate System:** The dataset has a spatial resolution of 30 arc-seconds and is output in a geographical coordinate system - World Geodetic System (WGS) 84 datum. The 30 arc-second cell, or 0.008333333 decimal degrees, represents approximately 1 km<sup>2</sup> near the equator. Since the data is in a spherical coordinate system, cell width decreases in a relationship that varies with the cosine of the latitude of the cell. Thus a cell at 60 degrees latitude would have a width that is half that of a cell at the equator ( $\cos 60 = 0.5$ ). The height of the cells does not vary. The values of the cells are integer population counts, not population density, since the cells vary in size. Population counts are normalized to sum to each sub-national administrative unit estimate. For this reason, projecting the data in a raster format to a different coordinate system (including on-the-fly projections) will result in a re-sampling of the data and the integrity of normalized population counts will be compromised. Also prior to all spatial analysis, users should ensure that extents are set to an exact multiple of the cell size (for example 35.25, 35.50, 35.0) to avoid “shifting” of the dataset.

**Data Revisions:** The database is updated annually by incorporating new spatial data and imagery analysis into the distribution algorithms. Comparing different versions of the dataset on a cell-to-cell basis may result in misleading conclusions. Some of the differences between LandScan dataset versions are due to recently developed urban or suburban expansion. However, there are many cases where a village identified with high-resolution imagery may have existed for years, but was neither represented nor identified in a correct location in various spatial data products

## 4.2.11 CORE DATASETS

### 4.2.11.1 BOUNDARIES: COSTAL, ADMINISTRATIVE AND AREAS OF SPECIAL INTEREST

#### COUNTRY POLITICAL LEVEL 0 BOUNDARIES

In the sub-topic, *Country Political Level 0 Boundaries* the following datasets (for further information about datasets see: **Error! Reference source not found.**) have taken part of the assessment:

- VMAP0(VMAP0);
- Sample of VMAP1(VMAP1);
- Global Administrative Areas (GADM);
- Global Administrative Unit Layers (GAUL);
- Sample of World Vector Shoreline Plus (WVS+);
- Sample of Global Map;

#### COASTLINE AND MARITIME BOUNDARIES

In the sub-topic, *Coastline and Maritime Boundaries* the following datasets have been considered as candidates and then submitted to the assessment process:

- Sample of Global Map;
- Global Self Consistent, Hierarchical, High-Resolution Shoreline Data Base (GSHHS);
- Sample of the Shuttle Radar Topography Mission, Surface Water Body Dataset (SRTM SWBD);
- Vlaams Institute Voor De Zee, Flanders Marine Institute, Maritime Boundaries Geodatabase (VLIZ);
- VMAP0(VMAP0);

- Sample of VMAP1(VMAP1);
- Sample of World Vector Shoreline Plus (WVS+);

## SUB-NATIONAL BOUNDARIES

As far as the *Sub-nationals boundaries* sub-topic is concerned, the following datasets have been considered for the quality assessment:

- VMAP0(VMAP0);
- VMAP1(VMAP1), sample of the entire dataset;
- Global Administrative Areas (GADM);
- Global Administrative Unit Layers (GAUL);
- Second Administrative Level Boundaries (SALB), sample of the entire dataset;
- Global Map (sample of the entire dataset);

## AREAS OF CONFLICT

In the sub-topic *Areas of conflict or disputed boundaries*, the following datasets took part in the assessment:

- GAUL;
- Natural Earth;
- World Databank;
- ACLED;
- Conflict Site Dataset;

The following datasets, GAUL, Natural Earth, and World Databank reports information uniquely about *disputed boundaries*. The others are datasets of armed conflicts, whose classification can give also information about the dispute over a territory. The datasets were therefore evaluated together only where possible.

## PARKS, CONSERVANCIES AND PROTECTED AREAS

In the topic *parks, conservancies and protected areas* the following datasets have taken part of the assessment:

WDPA - World database on Protected Areas;

FGGD - Poverty and Environment Global GIS Database Protected Areas

PA - Protected Areas (Millennium Ecosystem Assessment)

WDPA started in 1981 by a joint project of UNEP and IUCN, produced by UNEP-WCMC and the IUCN World Commission on Protected Areas working with governments and collaborating NGOs.

The FGGD protected areas map is a global raster data layer with a resolution of 5 arc-minutes. Each pixel is classified as protected area where agriculture should not be occurring, protected area where agriculture could be occurring, or non-protected area.

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This dataset is contained in Module 5 "Land use patterns and land cover" of Food Insecurity, Poverty and Environment Global GIS Database<sup>1</sup>.

The FGGD Digital Atlas consists of more than 100 global databases that allow analyzing food insecurity and poverty in relation to the environment.

PA by Millennium Ecosystem Assessment aims at providing a baseline set of data for the year 2000 that could be used for future research and analysis into the condition and trends in ecosystems and ecosystem services.

### 4.2.11.2 SURFACE HYDROLOGY: SURFACE WATER BODIES, WATER POINTS, DRAINAGE AND WATERSHEDS

#### DRAINAGE, RIVERS AND FLOW ROUTING

In the sub-topic *Drainage, Rivers and Flow routing* the following datasets (according to the data inventory outcomes) have been considered for the quality assessment:

- NGA VMAP0(VMAP0);
- NGA VMAP1(VMAP1);
- RWDB2 – Relational World Database;
- Hydro1k;
- Hydro SHEDS;
- Global Map;

#### SURFACE WATER BODIES

In the sub-topic, *Surface Water Bodies* the following datasets have taken part of the assessment:

- VMAP0(VMap0);
- VMAP1(VMap1);
- Food Insecurity, Poverty and Environment Global GIS Database (FGGD);
- Shuttle Radar Topography Mission (SRTM) Water Body Data (SWBD);
- Natural Earth database (NE);
- Global MODIS 250 m land-water mask (MODIS);
- Global Self Consistent, Hierarchical, High-Resolution Shoreline DB (GSHHS);
- Global Lakes and Wetlands Database (GLWD);
- Global Reservoir and Dam database (GRanD);
- Global Map

#### WATERSHEDS AND RIVER BASINS

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<sup>1</sup> Food Insecurity, Poverty and Environment Global GIS Database (FGGD)

As part of the **Poverty Mapping Project**, FAO prepared a **Food Insecurity, Poverty and Environment Global GIS Database (FGGD)** for global analysis of food insecurity and poverty in relation to environment.

<http://geonetwork3.fao.org/fggd/>

In the sub-topic, *Watersheds and River Basins* the following datasets (according to the data inventory outcomes) have been considered for the quality assessment:

- Hydro1k;
- Hydro SHEDS;
- UNH/GRDC Runoff Data
- WRI Major Watersheds of the World Delineation;

## WATER POINTS

The data inventory about water points featured several datasets, each one including a very mixed set of point categories. A common category has been chosen in order to perform a tighter analysis of the available data.

In this case, the points representing *dams* have been chosen, and the following datasets have been considered for the assessment:

- VMAP0(VMAP1)
- Global Reservoir and Dam (GRanD) database
- WWDRII
- GeoNames geographical database
- NGA GNS Geographic Names Database

### 4.2.11.3 HUMAN POPULATION: POPULATION CENTERS AND DISTRIBUTION

#### POPULATION CENTERS

In the sub-topic, *Population Centres* the following datasets have taken part of the assessment:

- Global Rural-Urban Mapping Project: the interesting dataset of this project describes rural and urban area distribution. It is a raster dataset, which represents the earth surface divided in 2 classes, rural and urban areas.
- Vector Smart Map Level 0: the interesting datasets are *Builtup*, which stands for built up areas and *Mispop*, which stands for miscellaneous data regarding population. Both datasets are provided with point geometry and with polygon geometry: the first is the result of a process of generalization of the other.
- Vector Smart Map Level 1: As in VMAP0, the interesting datasets are *Builtup* and *Mispop*. It contains also one more interesting dataset which is *build* and represents the most important buildings in point and polygon geometries.
- Global Map: the interesting datasets are the same as in VMAP0
- GeoNames: the database contains several datasets of interest. There are three datasets representing cities, which are filtered based on the population number, in particular: *cities15000* represents the cities with more than 15000 inhabitants, *cities1000* and *cities5000* represents cities filtered with similar approach. The three mentioned datasets are the result of queries performed on the main *GeoName* table. The geometry type is point.
- Relational World Database II: dataset analyzed is *rwdb\_ppl*. It has point geometry and represents a set of populated places (cities, towns, villages etc.).

The *GeoNames* data source is not specific to population centres. Data regarding population centres have been extracted by performing a selection on the entire database of the records with a Feature Class code<sup>1</sup> equal to P, which stands for *city, village...*

## URBAN AND RURAL POPULATION DENSITY AND DISTRIBUTION

In the sub-topic, *Urban and Rural Population Density and Distribution*, the following datasets have taken part of the assessment:

FGGD (Food Insecurity, Poverty and Environment Global GIS Database);

- GPW (Gridded Population of the World);
- GRUMP (Global Rural-Urban Mapping Project);
- WWDRII (World Water Development Report II);
- EOS (World Resources Institute);
- LandScan;

The candidates' data sources are not specific to population density and distribution. Population data have been extracted according to the following rules:

FGGD; Rural population density accessed through FAO GeoNetwork portal<sup>2</sup>;

WWDRII; Population density and distribution raster accessed through specific website;

All the datasets listed are raster with a global coverage: they show the higher or lower presence of population in a certain area of the world. The cell values usually represent an estimation of the number of people present in the correspondent area on the ground. The spatial coordinates of all of them are expressed in the Geographic Coordinate System WGS84.

An improvement to the data information content is provided by some of the datasets, which divide the earth's surface in rural and urban areas: the population distribution and the population density are in this case provided for urban areas and for rural areas in separate files.

### 4.2.11.4 TRANSPORTATION: ROADS, RAILWAYS, AIRPORTS, HARBORS AND NAUTICAL ROUTES

#### TRANSPORTATION - ROADS

In the sub-topic *transportation - roads* the following datasets have taken part of the assessment:

- VMAP0;
- VMAP1;
- Global Map;
- OpenStreetMap (OSM);
- SDI-T;

The first three candidate data sources have specific road layers inside a more complete dataset; OSM is a collaborative mapping project having specific road layer too, whereas SDI-T is a transport-specific component of a broader project (UNSDI) and contains specific objects dedicated to roads.

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<sup>1</sup> [www.geonames.org/export/codes.html](http://www.geonames.org/export/codes.html)

<sup>2</sup> <http://www.fao.org/geonetwork/>

The following datasets, even if identified as potential candidates during the data inventory process, have been excluded from the data quality assessment as data are provided in a form not suitable for the project's aim:

- Global GIS Database: Fee paying – road layer coming from VMAP1;
- NGA - labels extracted from road layers in VMAP0 – considered in POI topic;
- GeoNames: labels extracted from road layers in VMAP0 – considered in POI topic.

## RAILWAYS

In the sub-topic, *Railways* the following datasets took part in the assessment:

- Vector Smart Map Level 0;
- VMAP1(sample of the entire dataset);
- Global GIS Database;
- Global map (sample of the entire dataset);
- OpenStreetMap (OSM);
- Relational World Data Base 2;
- SDI-T;

Global GIS Database was initially considered but then not included in the assessment due to the access constraint (fee-paying resource). GeoNames and NGA GEOnet Names Server are point layers and therefore they were not considered in the assessment, which is aimed at comparing linear ones.

VMAP0, SDI-T, and OpenStreetMap include point layers concerning stations and rail yards and therefore they have been excluded from the analysis.

## AIRPORTS

In the sub-topic *Airports*, following datasets have taken part of the assessment:

- VMAP0(VMAP0);
- Vector Smart Map Level 1(VMAP1 - sample of the entire dataset);
- Relational World Data Base 2 (RWDBII);
- Global Airports Database (GAD);
- Global Airports Database and DAFIF;
- World Airport Codes;
- The Geography of Transport Systems;
- GeoNames;
- NGA GEOnet Names Server ;

World Airport Database, World alias Airport Codes and GeoName data was initially considered and evaluated but, has been eliminated from this list because of missing one of the fundamental requirements since it is a paying resource.

## HARBORS

In the sub-topic *Harbors*, the following datasets have taken part of the assessment:

Relational World Database II;

NGA GEOnet Names Server;

- GeoNames;

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- World Port Index;
- SDI-T;

The first three candidate data sources are not harbours-specific datasets. Harbour data has been extracted according to the following rules:

Relational World Database II. RWDB1 ports and harbors' shapefile accessed through FAO GeoNetwork portal<sup>1</sup>;

NGA GEOnet Names Server; Extraction of the records corresponding to the following feature codes:

HBR: harbor(s), a haven or space of deep water so sheltered by the adjacent land as to afford a safe anchorage for ships;

MAR: marina, a harbor facility for small boats, yachts, etc.;

PRT: port, a place provided with terminal and transfer facilities for loading and discharging waterborne cargo or passengers, usually located in a harbor;

RDST: roadstead, an open anchorage affording less protection than a harbor;

GeoNames; Extraction of the records corresponding to the following feature codes:

H.HBR: harbor(s), a haven or space of deep water so sheltered by the adjacent land as to afford a safe anchorage for ships;

S.MAR: marina, a harbor facility for small boats, yachts, etc.;

L.PRT: port, a place provided with terminal and transfer facilities for loading and discharging waterborne cargo or passengers, usually located in a harbor;

H.RDST: roadstead, an open anchorage affording less protection than a harbor;

SDI-T is a transport-specific component of a broader project (UNSDI) and contains specific objects dedicated to harbors, ports and their main characteristics.

The following datasets, even if identified as potential candidates during the data inventory process, have been excluded from the data quality assessment as data are provided in a form not suitable for a Spatial Data Infrastructure: they are only accessible through specific search tools embedded in respective web pages:

- Maritime-Database.com - Ports database;
- Marine World Database;

### 4.2.11.5 BATHYMETRY AND TERRESTRIAL ELEVATION

#### BATHYMETRY

In the sub-topic *Bathymetry*, the following datasets have taken part of the assessment:

GMRT Global Multi-Resolution Topography

GEBCO General Bathymetric Chart of the Oceans

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<sup>1</sup> [http://www.fao.org/geonetwork/srv/en/resources.get?id=29042&fname=rwdb\\_port.zip&access=private](http://www.fao.org/geonetwork/srv/en/resources.get?id=29042&fname=rwdb_port.zip&access=private)

### ETOPO 1 Earth Topography Digital Dataset

"Smith and Sandwell Global Seafloor Topography (or Smith and Sandwell predicted bathymetry or Smith and Sandwell measured and estimated seafloor topography)"

### VMAPO

The listed datasets are raster and vector data with a global coverage. For raster datasets, the cell values usually represent an estimation of the ground elevation or bathymetry. VMAPO is a vector dataset, containing contour lines. The spatial coordinates of all of them are expressed in different Coordinate System.

## TERRESTRIAL ELEVATION

In the sub-topic *Terrestrial Elevation*, the following datasets have taken part of the assessment:

- ASTER GDEM (Advanced Space-borne Thermal Emission and Reflection Radiometer Global Digital Elevation Model);
- SRTM3 (Shuttle Radar Topography Mission);
- GTOPO30;

All the datasets listed are Digital Elevation Model built using several techniques and each pixel represents the average altitude in the corresponding area on the ground. They are available in different format while spatial coordinates of all of them are expressed in the Geographic Coordinate System WGS84.

Dataset below was initially considered but then not included in the quality assessment following the analysis of their data source.

- SRTM30 (Shuttle Radar Topography Mission);
- CGIAR-CSI SRTM (Consortium for Spatial Information of the Consultative Group for International Agricultural Research Shuttle Radar Topography Mission data);
- SRTM30 PLUS (Shuttle Radar Topography Mission Plus);
- HYDRO1k;
- Hydro SHEDS (Hydrological data and maps based on Shuttle Elevation Derivatives at multiple scales);
- GLOBE (Global Land One-km Base Elevation Project);
- ETOPO 1;
- Global Map;

Finally, point layers include in the data inventory phase are not considered in this assessment because of the aim at comparing raster ones.

### 4.2.11.6 POINTS OF INTEREST

The data inventory about water points featured several datasets:

- VMAPO
- Vector Smart Map Level 1
- GeoNames geographical database (GeoNames)
- NGA GNS Geographic Names Database
- OpenStreetMap (OSM)
- TomTom points of interests

Some early conclusions can be derived right after a look at the datasets and their own databases:

- VMAP0 and Level 1 can be excluded from the analysis due to the extremely limited choice of categories available (mainly industry-related categories);
- TomTom points of interests were excluded due to the huge variety of non controlled sources of data, and due to the consequent non-homogeneity of information carried by their “constellation” of databases;
- The NGA GNS Geographic Names Database, despite including a wide range of interesting categories (from public services, to infrastructures) features less than 70.000 elements for all the world;
- GeoNames is a bigger one, including 370.000 facility points, but more than 275.000 in USA only, failing to stand as a really comprehensive and homogenic dataset;
- OSM databases (single country based) are covering many countries in an extensive way, but, while each dataset realize a complete and extended coverage of each country, some other ones are not covered, and, the databases feature a few extra details.
- 
- Based on these evaluations, the full analysis has not been performed, due to the scarce attitude for comparison of the available datasets.
- Anyway, the alternate (or joint) use of NGA GNS, GeoNames, and OpenStreetMap databases on a selective basis can be suggested.

### 4.2.12 THEMATIC DATASETS

#### 4.2.12.1 GEOLOGY

##### GEOLOGY

In the sub-topic *Geology*, the following datasets have taken part in the assessment:

- OneGeology Portal (OneGeology);
- World Mineral Deposits (GSC World);
- World Geologic Maps (WGM);

OneGeology Portal (OneGeology) is an international initiative of the geological surveys of the world. This initiative involves many different stakeholders working together (i.e. Geological Map of the World (CGMW), International Union of Geological Sciences (IUGS) and UNESCO). The project's aim is to create dynamic digital geological map data for the world. This data will be made available from a portal via the Internet.

The Geological Survey of Canada (GSC) has been compiling the database Mineral Deposits for major metallic mineral deposits on Canada and worldwide scale over a three-decade period. Five easy-to-use thematic world geology datasets provide generalized geological context for the global databases.

The World Geologic Maps (WGM) was created by the U. S. Geological Survey World Energy Project. It conducts geologic studies that provide an understanding of the quantity, quality, and geologic distribution of world oil and gas resources. The geologic studies have led to realization to geologic maps of countries and continents at different scales.

##### HYDRO-GEOLOGY

In the sub-topic *Hydrogeology*, the following datasets have been considered as candidates and then submitted to the assessment process:

- World-wide Hydrogeological Mapping and Assessment Program (WHYMAP);
- Global groundwater information system (GGIS);
- Water Consumption and Resources (WCR);

The Worldwide Hydrogeological Mapping and Assessment Program (WHYMAP) compiles data on groundwater from national, regional, and global sources, and visualizes them as printed maps, web map application, and web map service. The objective is providing maps, which show groundwater resources, recharge areas, areas of low rainfall and areas of saline groundwater.

The Global Groundwater information system (GGIS) was created by International Groundwater Resources Assessment Centre (IGRAC), an initiative of UNESCO and WMO, and was first launched at the "Fifth International Conference on Hydrology" in February 1999. The System GGIC is envisaged as an interactive and transparent portal to groundwater-related information and knowledge. The GGIS is publicly accessible through the internet.

Water Consumption and Resources (WCR) was created by AQUASTAT, FAO's global information system on water and agriculture, developed by the Land and Water Division. The main mandate of the program is to collect, analyze and disseminate information on water resources, water uses, and agricultural water management.

## SOILS AND SOIL PROPERTIES

In the sub-topic *Soils and Soil Properties*, only the datasets containing mainly soil type information have taken part of the assessment:

- Harmonized World Soil Database (HWSD);
- WRB Map of World Soil Resources (WSR);
- Digital Soil Map of the World (DSMW);
- Stuaab\_Rosen\_GISS (GISS).

### 4.2.12.2 SATELLITE IMAGERY, LAND COVER/USE, FORESTS AND VEGETATION

#### SATELLITE IMAGERY

The following data sources have been taken into account in the Subtopic, Satellite *Imagery* and considered during the assessment:

- ASTER;
- MOD 02;
- MOD 09;
- GLS;
- Landsat Legacy Collections;
- Landsat Archive Collections;
- EO-1;
- AVHRR;

#### LAND COVER/USE, FORESTS AND VEGETATION

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The following data sources have been taken into account in the Subtopic, *Land Cover/Use, Forests and Vegetation* and considered during the assessment:

- GLC 2000;
- GLCC;
- AVHRR Global Land Cover Classification;
- MOD 12;
- ESA Glob cover;
- FGGD;
- Global Map;
- Land Use System database;
- Global Land Use Database (SAGE);
- Global Land Use Data Sets (NASA);

### 4.2.12.3 SOCIO-ECONOMIC

The topic socioeconomic is divided into 5 subtopic:

SOCIETY

ECONOMY

DEMOGRAPHY

ENVIRONMENT

POVERTY

The candidate datasets were found during the data inventory, each of them includes several datasets related to more than one of the cited subtopics. In order to avoid redundancies the assessment was performed, wherever possible, based on the databases instead of datasets.

The following databases were evaluated:

- Global Administrative Areas;
- Food insecurity, poverty and environmental Global GIS Database;
- Geographic Information Systems in Sustainable Development;
- GEO Data Portal;
- Atlas of the biosphere - Human Impact;
- World Data Center for Biodiversity and Ecology;
- Global distribution of poverty;
- Food for education global atlas initiative;

In the following table the list of datasets, aggregated by database provenance, is presented:

*Table 5 Candidate datasets aggregated by databases*

<b>Dataset</b>	<b>Database</b>
Infant Mortality Rate Life Expectancy Population Growth Rate	Atlas of the biosphere- Human Impact

Dataset	Database
Human Development Index (MAP 1A) Human Development Index in WFP countries (MAP 3) Adult literacy Rate in WFP countries (MAP 12) Percentage of net enrolment in primary education (2002-2003) (MAP 2A) Percentage of net enrolment in primary education (2002-2003) in WFP countries (MAP 13) HIV prevalence rate (15-49 years) in WFP countries (MAP 33) Poverty and Hunger Index (PHI) in WFP countries (MAP 19) Life expectancy at birth in WFP countries (MAP 4) Demographic growth 2000-2005 in WFP countries (MAP 5) Percentage of population living on less than 1USD/day (MAP 5A) People living on less than 1US\$/day in WFP countries (MAP 23) Prevalence of underweight among under-fives (MAP 8A) Prevalence of underweight among under-fives in WFP countries (MAP 39)	Food for education global atlas initiative
DEGREE OF HUMAN DEVELOPMENT, BY COUNTRY, 2000 (FGGD) Occurrence of forest SHARE OF POPULATION UNDERNOURISHED, BY COUNTRY, 2000-2002 SHARE OF POPULATION LIVING IN EXTREME POVERTY, BY COUNTRY, VARYING YEARS	Food insecurity, poverty and environmental Global GIS Database
Net Enrolment Ratios in Primary Education Improved Drinking Water Coverage - Total Population Improved Sanitation Coverage - Total Population Human Development Index (HDI) Human Poverty Index for Developing Countries (HPI-1) Aid - Percent of GNI Energy use (kg oil equivalent) per \$1,000 GDP (Constant 2005 PPP \$) Gross Domestic Product Gross National Income Agriculture Value Added - Percent of GDP Crude Birth Rate Crude Death Rate Healthy Life Expectancy (HALE) Life Expectancy Infant Mortality Rate Under-five Mortality Rate Population Growth Rate Emissions of CO2 per GDP (PPP) Ecological Footprint Forest Area	GEO Data Portal

Dataset	Database
Forest Average Annual Change Total Forest Extent Total Health Expenditure - Percent of GDP Percentage of Population Below US \$ 1.25 per Day Consumption Percentage of Population Below US \$ 2 per Day Consumption	
Dietary energy supply Economic importance of agriculture Food production growth Food import dependency Population growth Forests and other wooded lands Food aid Chronic undernutrition	Geographic Information Systems in Sustainable Development
WBINCOME; WBDEBT	Global Administrative Areas
Infant Mortality Rates Prevalence of Child Malnutrition	Global distribution of poverty
Forest mask Areas of deforestation	World Data Center for Biodiversity and Ecology

#### 4.2.12.4 NATURAL DISASTERS

##### VOLCANIC ERUPTIONS DATA

In the Sub-topic *Volcanic Eruptions Data*, the following datasets have taken part of the assessment:

- CHRR Centre for hazards and risk research - Columbia University
- Global Hazards Information Network (GHIN) - Pacific Disaster Center
- The collapse caldera database - Grupo de vulcanologia de Barcelona

The Center for Hazards and Risk Research (CHRR) draws on Columbia's acknowledged expertise in Earth and environmental sciences, engineering, social sciences, public policy, public health and business. The mission is to advance the predictive science of natural and environmental hazards and the integration of science with hazard risk assessment and risk management. The CHRR produced the core dataset of Natural Disaster Hotspots – A global risk analysis, which contains 4 libraries of data: Hazard Frequency and/or Distribution; Hazard Mortality Risks and Distribution; Hazard Total Economic Loss Risk Deciles; Hazard Proportional Economic Loss Risk Deciles for each natural disaster.

The Global Hazards Information Network (GHIN) (powered by Pacific Disaster Center) is a collection of information by Smithsonian Institution volcanologists summarizing 1,511 volcanoes active in the last 10,000 years. Adapted from Simkin and Siebert, 1994 "Volcanoes of the World: an Illustrated Catalog of Holocene Volcanoes and their Eruptions" and produced digitally by the Smithsonian Institution's Global Volcanism Program.

The final aim of the CCDB - Collapse Caldera Database is to update the current field based knowledge on calderas, by merging the databases and complementing them with the existing peer-reviewed articles on calderas. The rationale behind constructing this new database is to create a comprehensive catalogue including all known or identified collapse calderas. This extensive data

compilation should be an accessible and useful tool for studying and understanding caldera collapse processes.

## FLOOD DATA

In the topic, *Flood Data* the following datasets have taken part for the assessment:

- CHRR Center for hazards and risk research - Columbia University;
- UNEP/GRID - Global Risk Data Platform;
- Dartmouth Flood Observation - Global Active Archive of Large Flood Events;
- Centre for Research on the Epidemiology of Disasters (CRED) - Emergency Events Database (EM-DAT);

The Center for Hazards and Risk Research (CHRR) draws on Columbia's acknowledged expertise in Earth and environmental sciences, engineering, social sciences, public policy, public health and business. The mission is to advance the predictive science of natural and environmental hazards and the integration of science with hazard risk assessment and risk management. The CHRR produced the core dataset of Natural Disaster Hotspots – A global risk analysis, which contains 4 libraries of data: Hazard Frequency and/or Distribution; Hazard Mortality Risks and Distribution; Hazard Total Economic Loss Risk Deciles; Hazard Proportional Economic Loss Risk Deciles for each natural disaster.

The Global Risk Data Platform – UNEP/GRID is the new generation of PREVIEW initiated in 1999 by UNEP/GRID-Geneva. The Global Risk Data Platform has now evolved following all standards for Spatial Data Infrastructures (SDI) and providing all the web services in compliance with the Open Geospatial Consortium (OGC). This application allows the visualization of data on natural hazards, exposure (both human and economical), and risk. The dataset browse by hazards (Cyclones, Droughts, Earthquakes, Fires, Floods, Landslides, Tsunamis, and Volcanoes).

The Global Active Archive of Large Flood Events (Dartmouth Flood Observation) is derived from news, governmental, instrumental, and remote sensing sources. The archive is "active" because current events are added immediately. Each entry in the table and related "area affected" map outline represents a discrete flood event. The listing is comprehensive and global in scope. Deaths and damage estimates for tropical storms are totals from all causes, but tropical storms without significant river flooding are not included.

The Emergency Events Database (EM-DAT) database is compiled from various sources, including UN agencies, non-governmental organizations, insurance companies, research institutes and press agencies. The main objective of the database is to serve the purposes of humanitarian action at national and international levels. It is an initiative aimed to rationalize decision making for disaster preparedness, as well as providing an objective base for vulnerability assessment and priority setting. Dataset accessed through GEO Data Portal<sup>1</sup>.

## FIRES DATA

In the SUB-topic *Fires Data*, the following datasets have taken part of the assessment:

- UNEP/GRID - Global Risk Data Platform;

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<sup>1</sup> <http://geodata.grid.unep.ch/>

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- Centre for Research on the Epidemiology of Disasters (CRED) - Emergency Events Database (EM-DAT);
- The Fire Locating and Modelling of Burning Emissions (FLAMBE');
- MOD 14 - Thermal Anomalies - Fires and Biomass Burning;
- EUMETSat ;
- The Fire Information for Resource Management System (FIRMS);
- AATSR World Fire Atlas (WFAA) ESA ;

The Global Risk Data Platform – UNEP/GRID is the new generation of PREVIEW initiated in 1999 by UNEP/GRID-Geneva. The Global Risk Data Platform has now evolved following all standards for Spatial Data Infrastructures (SDI) and providing all the web services in compliance with the Open Geospatial Consortium (OGC). This application allows the visualization of data on natural hazards, exposure (both human and economical), and risk. The dataset browses by hazards (Cyclones, Droughts, Earthquakes, Fires, Floods, Landslides, Tsunamis, and Volcanoes).

The Emergency Events Database (EM-DAT) database is compiled from various sources, including UN agencies, non-governmental organizations, insurance companies, research institutes, and press agencies. The main objective of the database is to serve the purposes of humanitarian action at national and international levels. It is an initiative aimed to rationalize decision making for disaster preparedness, as well as providing an objective base for vulnerability assessment and priority setting. Dataset can be accessed through GEO Data Portal<sup>1</sup>.

The Fire Locating and Modeling of Burning Emissions (FLAMBE') is a program to model biomass burning emissions, transport, and radiation effects in a global prognostic meteorology model. Initiated by the US Navy, National Aeronautics and Space Administration (NASA), National Oceanic and Atmospheric Administration (NOAA), and the University of Alabama, FLAMBE' is a multi-disciplinary program drawing from a broad range of expertise and resources.

The MODIS Thermal Anomalies product includes fire occurrence (day/night), fire location, the logical criteria used for the fire selection, and an energy calculation for each fire. Produced from both the Terra and Aqua MODIS-derived daily surface reflectance inputs, the algorithm analyzes the daily surface reflectance dynamics to locate rapid changes, and uses that information to detect the approximate date of burning, mapping the spatial extent of recent fires only. The product consists of two suites of science data sets: MODIS Thermal Anomalies/Fire and MODIS Burned Area.

The main purpose of the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) is to deliver weather and climate-related satellite data, images and products– 24 hours a day, 365 days a year. EUMETSAT provides an evolving range of meteorological and climate monitoring data and products that reflect the needs of the user community, in this case the topic Land provides information on the state of the land and on land processes. This information is of considerable benefit for agriculture, forestry, surface transport management, and the monitoring of ecological and hydrological systems.

The Fire Information for Resource Management System (FIRMS) integrates remote sensing and GIS technologies to deliver global MODIS hotspot/fire locations and burned area information to natural resource managers and other stakeholders around the World. FIRMS is funded by NASA and it

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<sup>1</sup> <http://geodata.grid.unep.ch/>

delivers active fires detected using the MODIS active fire locations processed by NASA's LANCE (Land, Atmosphere, near real-time Capability for EOS). FIRMS present two dataset: hotspot/active fire data and Burned Area Product (derived from MOD14).

The AATSR World Fire Atlas (WFAA) ESA is being processed in Near Real Time since the beginning of February 2006. It provides data processed for hot spot detection and the output file containing the coordinates of the hot spots is merged immediately with the other hot spots detected since the beginning of the current month.

## EARTHQUAKE DATA

In the SUB-topic *Earthquake Data*, the following datasets have taken part of the assessment:

- CHRR Centre for hazards and risk research - Columbia University;
- UNEP/GRID - Global Risk Data Platform;
- IRIS - Incorporated Research Institutions for Seismology;
- CSEM-EMSC Centre Sismologique Euro-méditerranéen;

The Center for Hazards and Risk Research (CHRR) draws on Columbia's acknowledged expertise in Earth and environmental sciences, engineering, social sciences, public policy, public health and business. The mission is to advance the predictive science of natural and environmental hazards and the integration of science with hazard risk assessment and risk management. The CHRR produced the core dataset of Natural Disaster Hotspots – A global risk analysis, which contains 4 libraries of data: Hazard Frequency and/or Distribution; Hazard Mortality Risks and Distribution; Hazard Total Economic Loss Risk Deciles; Hazard Proportional Economic Loss Risk Deciles for each natural disaster.

The Global Risk Data Platform – UNEP/GRID is the new generation of PREVIEW initiated in 1999 by UNEP/GRID-Geneva. The Global Risk Data Platform has now evolved following all standards for Spatial Data Infrastructures (SDI) and providing all the web services in compliance with the Open Geospatial Consortium (OGC). This application allows the visualization of data on natural hazards, exposure (both human and economical), and risk. The dataset browse by hazards (Cyclones, Droughts, Earthquakes, Fires, Floods, Landslides, Tsunamis, and Volcanoes).

Founded in 1984 with support from the National Science Foundation, IRIS is a consortium of over 100 US universities dedicated to the operation of science facilities for the acquisition, management, and distribution of seismological data. The IRIS database contains events from different earthquake catalogs including several from NEIC as well as the ISC, dating from the early 1960s to the present.

CSEM-EMSC - Centre Sismologique Euro-Méditerranéen collects data (from 2004 to present) provided by several seismological networks. The collected data are automatically archived in a database and displayed on the web site. The collected data are automatically merged to produce automatic locations, which are sent to several seismological institutes in order to perform quick moment tensors determination.

## 4.3 CONCLUSION

As discussed, the public domain datasets have a priority rank rather than commercial data and the use of commercial datasets can be optional and postponed for gaps filling and quality increase purposes. This choice allows getting an operational product in shorter terms by avoiding the management of time-consuming licensing issues as well as other existing political measures.

There are some other points necessary to mention apart from the quality aspects of the data sets:

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- Here it is needed to stress out the fact that selection of right datasets which is correct, update and accurate is one of the most important tasks of the data collection process in every mapping and GIS project. It provides the necessary prerequisite step for the every project, but requires the right implication of those data in the system.
- One of the key issues to mention is when the data are very rare and there are very few options to support decision makers. In other words, the value of the data would increase for subjects or places that are unknown to user in some undeveloped areas. For example, The LandScan Datasets can provide very precious information regarding population distribution around the world like central Africa, or any other parts like deserts. In Cartographic aspects of mapping sometimes in a map we have no other option except adding some key features that perhaps does not fit into the specification of that map in terms of scale or accuracy.
- The thematic data are the complimentary information to positional data as semantic information to feed non-GIS community using maps for their own disciplines and job. In fact the thematic data related to other disciplines like population, rainfall, Geologic and seismologic information can play a very important role in other types of project such as Early warning system, Environmental impact of various phenomena, Drought monitoring, Flood mapping and etc...
- Using some datasets like GeoNames in different areas needs very cautious consideration, especially in areas that may exist, racial or political conflicts. It is very easy to find places that can have different names due to the neighboring political differences, either nationally or internationally. For example, the islands located between China and Japan, or the Punjab areas in located in the boundaries between India and Pakistan. There are many controversial International examples as well as national cases. These types of differences can be originated from ownership cases (International) to budget allocations (National). However using the proper names is one of the key issues that must be considered prior to any types of name placement in mapping.

## 5. OPEN SOURCE DATA QUALITY ASSESSMENT PROTOCOL

### 5.1 DATA QUALITY DEFINITION

Geospatial data are a “model of reality”: every map or database is therefore a model. During the modeling process, a series of factors may cause errors in the data that are lately produced. All geospatial data are then, at different levels, imprecise, inaccurate, out-of-date, and incomplete.

Several authors distinguished two definitions of spatial data quality: *internal quality* and *external quality*. On one hand, *internal quality* corresponds to the level of similarity that exists between the data produced and the “perfect” data that should have been produced, that are also called “nominal ground”. In practice the evaluation of *internal quality* does not use the nominal ground that has no real physical existence since it is an “ideal” dataset, but uses a dataset of greater accuracy than the data produced, which is called “control data” or “reference data”(Devillers R., Jeansoulin R. 2006).

On the other hand, the concept of *external quality* corresponds to the level of concordance that exists between a product and user needs, or expectations, in a given context. It is also often defined as “fitness for use” or “fitness for purpose”. The evaluation of *external quality* can imply criteria that describe *internal quality*.

The ISO 19113 standard on geospatial data quality recommends the use of the following criteria to describe internal quality (ISO-TC 211-19113 2002):

- *Completeness*: presence and absence of features, their attributes and relationships;
- *Logical consistency*: Logical consistency is an assessment of how well the logical relationships between items in the dataset, or spatial objects in the dataset, are maintained;
- *Positional accuracy*: Positional accuracy is an assessment of the closeness of the location of spatial objects in the dataset in relation to their true positions on the earth's surface;
- *Temporal accuracy*: accuracy of the temporal attributes and temporal relationships of features;
- *Thematic accuracy*: accuracy of quantitative attributes and the correctness of non-quantitative attributes and of the classifications of features and their relationships;
- User defined data elements can be defined in order to be added to this quality listing.

Finally, data quality can be defined also by mean of the denotation, which is a fundamental quality aspect of geographical data: we use the word “denotation” to designate the original, fundamental function of any representation. What represents is a sign toward what happens to be represented, a sign, which expresses both the presence and the intensity of the phenomenon at stake (Devillers R., Jeansoulin R. 2006).

When geographical data are produced, the resulting denotation may depart from the expected denotation, and consequently from the geographic features which happen to be represented. The following are the sources for fluctuations in denotation:

- Modeling and realization of the model of the world: the construction of the model of the reality;
- Modeling and realization of the operations: the act of processing the initial data;
- *Space; geometry and topology*: While geometry is the numerical location of an object, the topology is the invariant in the geometrical properties of objects;
- *Time; date and chronology*: They're the analogous of geometry and topology in the time dimension;
- *Value; semantic and semiology*: They regard the expression of the thematic values of objects.

## 5.2 DATA QUALITY ASSESSMENT PROTOCOL

An assessment on denotation quality requires some general principles: assessment is based on *comparison* of produced data to the real world. Elementary *measures* on objects and *statistics* are made, validity of measured characteristics may be pronounced on their inclusion within *confidence intervals*. Eventually, *reporting* of the results is required (Devillers R., Jeansoulin R. 2006).

The user needs assessment in terms of specifications on geographic extent, dataset reference scale, and updates; the call specifications in terms of license conditions;

A data quality process (Boccardo P., et.al. 2012) has been performed on the spatial dataset collected in the Review of available open source geographic data (see chapter 4): the process ran separately for each data sub-topic's available open source chosen in that chapter. This process is consisted of the following steps:

- Twelve quality indicators are defined on the basis of the user needs assessment, the ISO specifications (ISO-TC 211-19113 2002) (ISO-TC211-19115 2004);
- Several confidence intervals are set for each indicator;
- Each confidence interval is associated to a score between 1 and 5;
- A value for each indicator is obtained through measurements and statistics performed on each candidate dataset;
- A score is assigned to each dataset by comparing the value obtained with the fixed confidence intervals;
- A Quality Matrix, containing all the information on the internal quality, is created for every sub-topic as a result of the previous steps;
- A weight included in the range 0-1 is then assigned to each indicator at the sub-topic level, thus expressing the importance attributed by a hypothetical user;
- The defined weights are collected together into the so called Vector of Weights, that is the implementation of the external quality definition;
- A vector of the total scores for each considered dataset is calculated as the result of an ordinary matrix product between the Quality Matrix and the Vector of Weights;
- Finally, a ranking of the datasets, based on their quality score, is set up.

In the following pages, all quality indicators are described and the requirements for each of them are thoroughly explained: finally the total score calculation is introduced.

## 5.3 DATA QUALITY INDICATORS DEFINITION

### 5.3.1 GEOGRAPHIC EXTENT

The geographic extent of a dataset consists of the size of the bounding box containing all its features. Usually datasets with large nominal scale have a small extent and vice versa. Where a wide field of view is needed, the extent could be insufficient to cover the area of interest and therefore a time consuming operation of merging different neighboring datasets is necessary. Consequently, issues such as the integration and linking of different datasets arise in cross border situations.

On the purpose of creating a global service, the larger is the extent of a dataset the higher is the score. Table 6 resumes the requirements and the respective scores.

Score	Requirements
1	Local
2	Sub national
3	National
4	Continental
5	Global

Table 6 Proposed values for the indicator: Geographic Extent and respective scores

### 5.3.2 LICENSING AND CONSTRAINTS

Table 7 PROPOSED VALUES FOR THE INDICATOR LICENSING AND CONSTRAINTS AND RESPECTIVE SCORES

Score	Requirements
1	Commercial data with limitations
2	Commercial data
4	Free data with limitations
5	Public domain data

Different data holders deliver their spatial data under various license agreements. Two different elements are taken into consideration: the cost of the data and their possible limitation of use. Table 7 contains several models of data distributions that are taken into consideration, and their respective scores.

### 5.3.3 SCALE DENOMINATOR

In most of the applications and software, a digital map can be visualized at different scales using the zoom buttons: this does not mean that the information contained in the map is adequate at all visualization scales. Actually, geospatial data have their own nominal scale, which is the larger scale at which they can “lawfully” be visualized or printed. From this point of view the possibility of zooming the map at larger scale than the nominal one has to be interpreted as an occasion of reading better the information that it contains, but not an occasion of reading more.

In particular, the concept of nominal scale is deeply linked with the degree of precision and accuracy of the content. The visualization tolerance of a map or spatial data can be derived from the nominal

scale: the Italian topographic tradition defines the accuracy as the value of 0.2 mm at the nominal scale, which is derived from the smallest thickness of a printed map line (Comoglio G. 2004). Furthermore, at the international level, the National Map Accuracy Standards (NMAS<sup>1</sup>) defines a less restrictive tolerance, that corresponds to the value of 1/50" at the nominal scale for map scale smaller than 1:20.000. In the framework of the project NMAS's thresholds have been revised according to the National Standard for Spatial Data Accuracy (NSSDA) guidelines, using formulas proposed in the Appendix 3-D of the "Geospatial Positioning Accuracy Standards" document (FGDC 1998). Specifically, NSSDA uses root-mean-square error to estimate positional accuracy. RMSE thresholds are reported in the "RMSE NSSDA" column in Table 8. Accuracy thresholds adopted for the quality evaluation are reported in ground distances; at the 95% confidence level in the "Accuracy NSSDA" field in Table 8.

The indicator "Scale Denominator" can assume the values in: the evaluation is based on the metadata or on the information published by the data holders. In case this information is not provided, some geo-processing operations can be performed in order to give an estimation of the scale: for example as far as linear datasets is concerned, an analysis of the line segments length is carried out and a statistical distribution graph is drawn. A value of the dataset tolerance can be estimated as the smallest value of length with a statistical importance: then using the relations reported below, a value of reference scale is calculated.

Another approach to estimate the scale denominator is to carry out a relative comparison with datasets with a defined map scale. Similar operations can be performed in order to verify the information provided in metadata or published by the data holders.

Score	Requirements	ACCURACY NMAS (1/50"*SD - CE 90%)(m)	RMSE NSSDA (NMAS/1.5175) (m)	ACCURACY NSSDA (RMSE NSSDA*1.7308 - CE 95%) (m)	Approximate GSD (m)
1	> 1.000.000	> 508	> 335	> 579	> 320
2	>500.000 - <=1.000.000	254-508	167-335	290-579	160-320
3	>250.000 - <=500.000	127-254	84-167	145-290	80-160
4	>100.000 - <=250.000	51-127	33-84	58-145	30-80
5	<= 100.000	51	33	58	< 30

Table 8: Proposed values for the indicator Scale Denominator and respective scores

As far as raster datasets are concerned, approximate reference values of spatial resolution, that is Ground Sample Distance (GSD) expressed in meters, are reported in the last column of Table 8, taking into account both achievable accuracy and proper viewing.

<sup>1</sup> the United States National Map Accuracy Standards (NMAS)

### 5.3.4 UPDATE

Different dataset may have different update rate: the more recently the data has been updated, the more reliable the data is assumed to be.

Score	Requirements
1	More than 5 years ago
2	From 3 to 5 years ago
3	In the past 2 years
4	Annually (planned)
5	Continuous

Table 9 Proposed values for the indicator Update and consequent scores assigned to the datasets

The evaluation is performed using the information provided on the metadata or directly by the data holders. Random controls can be performed if the time reference is provided feature per feature, for instance in a field of the attribute table of the dataset.

The indicator *Update* can assume the values contained in

Score	Requirements
1	More than 5 years ago
2	From 3 to 5 years ago
3	In the past 2 years
4	Annually (planned)
5	Continuous

Table 9.

### 5.3.5 TEMPORAL EXTENT

The indicator *Temporal Extent* is applicable only in case of time series data. It refers to the period between the first available release of the data and its last update; details are contained in Table 10.

Score	Requirements
1	Months
2	Years
3	10 years
4	Fifty years
5	Hundreds of years

Table 10: Proposed value for the indicator Temporal Extent and respective scores

### 5.3.6 FITNESS FOR USE

Score	Requirements
1	Need of significant pre-processing
2	Need of solid pre-processing

Score	Requirements
3	Need of average pre-processing
4	Need of slight pre-processing
5	No need of pre-processing

Table 11 Proposed values for the indicator *Fitness for Use* and respective scores

The generic concept of fitness for use varies based on the applications in which the data is exploited. Current indicator aims to evaluate pre-processing requirements in order to provide data in a format suitable and optimized for data maintenance, analysis, and display, both for map preparation and for data display on desktop and WebGIS applications. Table 11 contains the values that can be assumed by the indicator *Fitness for Use*, and the evaluation is performed in a relative way, taking into consideration the characteristics of all the candidates for each sub-topic.

### 5.3.7 THEMATIC RICHNESS

Score	Requirements
1	Low
2	...
3	Medium
4	...
5	High

Table 12 PROPOSED VALUES FOR THE INDICATOR THEMATIC RICHNESS AND RESPECTIVE SCORES

The indicator *Thematic Richness* corresponds to the amount of information provided by each candidate dataset. It can be referred and calculated proportionally both to the number of available fields' providing relevant information for the analyzed sub-topic and to the level of adherence of the theme represented by the dataset to the respective sub-topic.

Table 12 contains the values that can be assumed by the indicator *Thematic Richness*: the evaluation is performed in a relative way, taking into consideration the characteristics of all the candidates for each sub-topic.

### 5.3.8 INTEGRATION

One of the most challenging issues in the implementation of a geospatial data service is the need for a perfect integration among datasets, both in the same and in different sub-topics; the most significant example is the comparison between surface hydrology and elevation data. The issue is even bigger if the datasets have different nominal scales, extents, geometrical and thematic structures.

Score	Requirements
1	Stand alone dataset
3	Part of thematic database
5	Part of comprehensive database

Table 13: PROPOSED VALUES FOR THE INDICATOR INTEGRATION AND RESPECTIVE SCORES

Based on this assumption, the datasets are considered more useful if they’re already integrated into a thematic or multipurpose database, since the relationship issues between datasets are already solved by data holders; see Table 13 for details.

### 5.3.9 DATA INTEGRITY

Data integrity implies the respect of topological relationship by the geometric shape of the features belonging to a dataset: some topological rules can be defined at sub-topic level based on their specific role.

The evaluation is performed by mean of processing operations with computer software, in the present case the *ESRI ArcGIS Desktop*. This software can manage several topological rules both in phase of data production and in phase of data quality controls: several controls can be applied to different geometry type of data, such as points, lines or polygons.



Figure 21 Description of two of the topological rules defined during the evaluation process (courtesy of esri)

- The evaluation process consists of the following steps:
- definition of the appropriate topological rules for each dataset: examples are in Figure 21;
- validation of the topology: each feature is compared with the others involved in the topology, and their spatial relationship is controlled in order to find violations of the rules;
- investigation of the results: the errors are studied in order to understand the nature of the violation and the effective presence of the violations themselves;

Score	Requirements
1	> 5
2	2 – 5
3	0.5 – 2
4	0.1 - 0.5
5	< 0.1

Table 14: 14Proposed values for the indicator Data Integrity and consequent scores

- Building of the resume table: for each dataset and for each topological rule, a table record is filled in with the results of the validation and with some notes and comments.

The indicator *Data Integrity* consists in the percentage of the sum of the errors, for all controls performed on a dataset, over the number of features observed in that dataset: datasets are given a score in compatibility with the values reported Figure 20.

### 5.3.10 POSITIONAL ACCURACY

Score	Requirements (% of errors)
1	Coarse (80-100)

2	Low (60-80)
3	Intermediate (40-60)
4	High (20-40)
5	Fine (0-20)

Table 15: Values that the indicator *Positional Accuracy* can assume

It is represented by the mean value of the positional uncertainties for a set of positions, where the positional uncertainties are defined as the distance between a measured position and what is considered as the corresponding true position.

Free-released spatial data rarely come with the definition of a value of *Positional Accuracy* in their metadata: this value is deeply related with the reference scale and is derived from it, using an approach, which is the opposite of the one presented in section *Scale Denominator* 5.3.3.

In both the ways the value of the positional accuracy is obtained, it is used to draw a buffer around a set of sample features randomly extracted from the entire dataset under evaluation. These buffers are then put in visual comparison with a dataset that has a higher positional accuracy, of at least an order of magnitude. If a buffer does not contain a feature from the most accurate dataset, this is considered as an error of the dataset: the final percentage of errors in the dataset is used as indicator of the *Positional Accuracy* of the dataset itself. It can assume values from coarse to fine as summarized in Table 15.

### 5.3.11 THEMATIC ACCURACY

Score	Requirements (% of errors)
1	Coarse (80-100)
2	Low (60-80)
3	Intermediate (40-60)
4	High (20-40)
5	Fine (0-20)

Table 16: Proposed values for the indicator *Thematic Accuracy* and consequent scores

*Thematic accuracy* controls are random controls performed on attribute values: a number of feature is investigated in order to verify the correctness of what reported in the fields of the attribute table of the respective dataset. The percentage of the number of errors found over the number of features observed constitutes the quality indicator *Thematic Accuracy*.

The indicator *Thematic Accuracy* can assume values from coarse to fine as summarized in Table 16.

### 5.3.12 COMPLETENESS

The absence of gaps in spatial data is one of the major requests arose from the user needs assessment. Datasets are randomly investigated in order to reveal missing features by mean of inter-comparison with other datasets of the same sub-topic: the percentage of missing features over the number of features observed constitutes the indicator *Completeness*. The reference confidence intervals are reported in Table 17.

Score	Requirements
1	> 5
2	2 – 5
3	0.5 – 2
4	0.1 - 0.5
5	< 0.1

Table 17: Proposed values for the indicator Completeness and respective scores

## 5.4 OVERALL EVALUATION

### 5.4.1 QUALITY MATRIX

After the quality assessment is performed on all datasets belonging to a specific sub-topic, the results can be conveniently resumed in a matrix where each row contains the scores assigned to a dataset for each indicator, while every column contains all the scores given to a specific indicator. The matrix described is called Quality Matrix: a template is provided in Table 18.

Dataset	Geographic Extent	Licensing and Constraints	Scale Denominator	Update	Temporal Extent	Fitness For Use	Thematic Richness	Integration	Data Integrity	Positional Accuracy	Thematic Accuracy	Completeness
Dataset 1	Scores (from 1 to 5)											
...												
Dataset n												

Table 18 Example of a Quality Matrix

### 5.4.2 VECTOR OF WEIGHTS

Parameter	Weight
Geographic Extent	values in the range 0 to 1
Licensing and Constraints	
Scale Denominator	
Update	
Temporal Extent	
Fitness For Use	
Thematic Richness	
Integration	
Data Integrity	
Positional Accuracy	

Thematic Accuracy	
Completeness	

The indicators previously defined may not have the same importance in absolute terms; furthermore, relative importance is normally significantly different according to the application in which data are used. For instance the end user may prefer to deal with spatial data that have high scores for some of the indicators, while he could not mind if the same data have low scores for the other indicators, according to the requirement of the application he is dealing with.

Table 19: ASSIGNMENTS OF WEIGHTS TO THE QUALITY INDICATORS: TEMPLATE OF VECTOR OF WEIGHTS

On the basis of the experience and sensibility of the data analysts, a weight for each quality indicator is established as a hypothesis of the needs of a potential user, working in the field of emergency management: it is a positive number between 0, if the indicator is not important at all, and 1, if it has the maximum importance. A *Vector of Weights* for the indicators can be set up with the chosen values (see Table 19).

The *Vector of Weights* constitutes the implementation of the general concept of *external quality* in the protocol. Although a first approach definition of the weights is given by the contractor, a real end user could define and apply his own weights according to the specific current needs. The contractor commits himself to publish all the partial quality scores in order to facilitate these operations.

It is important to highlight that the definition of the *Vector of Weights* must be done at a sub-topic level, in order to ease the process of choosing best quality data for each data category.

### 5.4.3 FINAL SCORES AND RANKING

The final step of the assessment process is the calculation of the total score for each dataset. The vector of total scores is the result of an ordinary matrix product between the *Quality Matrix* and the *Vector of Weights*; it consists of a weighted sum of the scores assigned to each dataset.

Based on the quality final scores, datasets can be ordered in a ranking that reveals, for each sub-topic, the best data able to match end user’s need.

## 5.5 CONCLUSIONS ON THE PROTOCOL

In this chapter, the concept of geospatial data quality has been introduced and a protocol for data quality assessment has been proposed. It involves the definition of 12 indicators; each of them can assume values in different ranges: possible values are divided in 5 categories with the introduction of some confidence intervals. It also involves the assignment of a score to the datasets for each indicator, based on the values assumed by the single indicator for every single dataset. Finally, a total score of quality is calculated by mean of a sum of the partial scores based on the weights set for the indicators.

During the GMES<sup>1</sup> RDA, project activities the definition of the weights was performed by the contractor data analysts, in the attempt of interpreting the end user's needs and translating them into numerical values. Instead, in the ideal world this operation has to be done directly by the end user. Since this requires further considerable efforts to the end user, such as performing the calculation himself maybe arranging a targeted spreadsheet, a Web application able to extract the dataset of best quality, based on the defined weights, has been developed and is introduced in chapter 6.

During protocol application to datasets gathered in the inventory phase, data analysts experienced difficulties in exploiting the proposed range of values and requirements for some indicators: in these cases, alternative values and requirements have been defined and applied. The modifications of the general protocol should be studied case by case in order to highlight limits of the protocol itself and to come to a better definition of the protocol itself as a recursive process.

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<sup>1</sup> **Global Monitoring for Environment and Security** is the European Programme for the establishment of a European capacity for **Earth Observation**

## 6. DATA QUALITY ASSESSMENT PROCESSING AND RESULTS

### 6.1 INTRODUCTION

The geospatial data quality and consistency assessment protocol that has been developed and described in the CHAPTER 5 has been actually applied to the identified datasets.

In the following pages, the data analysis related to the identified quality and consistency indicators is applied over the identified dataset, described in details and the results are presented: the current chapter contains the whole analysis over two important features: Transportation and bathymetry and for the rest of the sub topics would suffice to the overall evaluation result.

It is important to note that due to the limitations there will be only two subtopics evaluation with all details, including, Transportation; (Roads) and Bathymetry( Bathymetry and terrestrial elevation). For the rest of the sub-topics there will be only the final Scores and Ranking.

This chapter is organized according to the data categories proposed in chapter 4, Table 1 and Table 2.

### 6.2 NOTES ON THE PROTOCOL APPLICATION

The process of data quality assessment is based on applying a set of indicators to a selection of candidate datasets for each sub-topic. The result of the analysis consists of a numeric value for each dataset, which is derived from the contribution of each indicator, weighted based on its importance in relation to the sub-topic itself. As mentioned before, the *Vector of Weights* have been identified by the contractor data analysts or user itself.

With respect to the definition of *Thematic* datasets reported in section 5.1, if the user interest is more focused on the semantic content of the data rather than on the geometric and geographic content, the quality assessment of the semantic content's task requires an in depth knowledge in a specific field. It is not possible to evaluate correctly the subjective indicators such as, *Data Integrity*, *Positional Accuracy*, *Thematic Accuracy*, and *Completeness* without having a proved topic-related expertise.

Therefore, the protocol states the application of all the quality indicators to the *Core* datasets whilst the application of the first 8 quality indicators relates to the *Thematic* parts of the Datasets: so their overall assessment is based on the objective quality indicators that can be assessed analyzing the available metadata, without applying the weight vector.

## 6.3 BOUNDARIES: COSTAL, ADMINISTRATIVE AND AREAS OF SPECIAL INTEREST

### 6.3.1 COUNTRY POLITICAL LEVEL 0 BOUNDARIES

In the sub-topic, *Country Political Level 0 Boundaries* the following datasets have taken part of the assessment:

- VMAP0(VMAP0);
- Sample of VMAP1(VMAP1);
- Global Administrative Areas (GADM);
- Global Administrative Unit Layers (GAUL);
- Sample of World Vector Shoreline Plus (WVS+);
- Sample of Global Map;

Dataset	Final Score
VMAP1	45.5
VMAP0	44.5
Global Map	43
GADM	41.5
GAUL	39.5
WVS+	39.5

Table 20: RESULTS OF THE QUALITY ASSESSMENT: FOR THE SUB-TOPIC COUNTRY POLITICAL LEVEL 0 BOUNDARIES

### 6.3.2 COASTLINE AND MARITIME BOUNDARIES

In the sub-topic, *Coastline and Maritime Boundaries* the following datasets have been considered as candidates and then submitted to the assessment process:

- Sample of Global Map;
- Global Self Consistent, Hierarchical, High-Resolution Shoreline Data Base (GSHHS);
- Sample of the Shuttle Radar Topography Mission, Surface Water Body Dataset (SRTM SWBD);
- Vlaams Institute Voor De Zee, Flanders Marine Institute, Maritime Boundaries Geodatabase (VLIZ);
- VMAP0(VMAP0);
- Sample of VMAP1(VMAP1);
- Sample of World Vector Shoreline Plus (WVS+);

Dataset	Final Score
VMAP1	46.5
VMAP0	44.5
Global Map	44
GSHHS	43
WVS+	42

Dataset	Final Score
VLIZ	39.5
SRTM SWBD	37.5

Table 21: RESULTS OF THE QUALITY ASSESSMENT FOR THE SUB-TOPIC COASTLINE AND MARITIME BOUNDARIES

### 6.3.3 SUB-NATIONAL BOUNDARIES

As far as the *Sub-nationals boundaries* sub-topic is concerned, the following datasets have been considered for the quality assessment:

- VMAP0(VMAP0);
- VMAP1(VMAP1), sample of the entire dataset;
- Global Administrative Areas (GADM);
- Global Administrative Unit Layers (GAUL);
- Second Administrative Level Boundaries (SALB), sample of the entire dataset;
- Global Map (sample of the entire dataset);

Dataset	Final Score
VMAP1	42,0
Global Map	41,0
VMAP0	38,5
GADM	37,5
SALB	36,5
GAUL	32

Table 22: RESULTS OF THE QUALITY ASSESSMENT FOR THE SUB-TOPIC: SUB-NATIONAL BOUNDARIES

### 6.3.4 AREAS OF CONFLICT

In the sub-topic *Areas of conflict or disputed boundaries*, the following datasets took part in the assessment:

- GAUL;
- Natural Earth;
- World Databank;
- ACLED;
- Conflict Site Dataset;

Dataset	Final Score
GAUL	28,5
Natural Earth	29
World Databank	23,5
ACLED	24,5
Conflict Site Dataset	24,5

Table 23: Results of the quality assessment: total scores for SUB-TOPIC AREA OF CONFLICT

### 6.3.5 PARKS, CONSERVATIONS AND PROTECTED AREAS

In the topic *parks, conservancies and protected areas* the following datasets have taken part of the assessment:

- WDPa - World database on Protected Areas;
- FGGD - Poverty and Environment Global GIS Database Protected Areas
- PA - Protected Areas (Millennium Ecosystem Assessment)

Dataset	Final Score
WDPa	32.5
PA	28.5
FGGD	26.5

Table 24: RESULT OF QUALITY ASSESSMENT: TOTAL SCORES FOR PARKS, CONSERVATIONS AND PROTECTED AREA

## 6.4 SURFACE HYDROLOGY: SURFACE WATER BODIES, WATER POINTS, DRAINAGE AND WATERSHEDS

### 6.4.1 DRAINAGE, RIVERS AND FLOW ROUTING

In the sub-topic *Drainage, Rivers and Flow routing* the following datasets (according to the data inventory outcomes) have been considered for the quality assessment:

- NGA VMAP0(VMAP0);
- NGA VMAP1(VMAP1);
- RWDB2 – Relational World Database;
- Hydro1k;
- Hydro SHEDS;
- Global Map;

Dataset	Final Score
VMAP1	26.5
VMAP0	26.0
Global Map	26.0
RWDB2	26
Hydro SHEDS	22.5
Hydro1k	22.5

Table 25: Results of the quality assessment: total scores for SUB-TOPIC DRAINAGE, RIVER, AND FLOW ROUTINGS

### 6.4.2 SURFACE WATER BODIES

In the sub-topic, *Surface Water Bodies* the following datasets have taken part of the assessment:

- VMAP0(VMap0);
- VMAP1(VMap1);
- Food Insecurity, Poverty and Environment Global GIS Database (FGGD);

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- Shuttle Radar Topography Mission (SRTM) Water Body Data (SWBD);
- Natural Earth database (NE);
- Global MODIS 250 m land-water mask (MODIS);
- Global Self Consistent, Hierarchical, High-Resolution Shoreline DB (GSHHS);
- Global Lakes and Wetlands Database (GLWD);
- Global Reservoir and Dam database (GRanD);
- Global Map;

Dataset	Final Score
VMap1	30.5
SWBD	26.5
VMap0	26
MODIS	25.5
GLWD	25.5
GRanD	24.5
Global Map	23.5
FGGD	22.5
NE	22
GSHHS	20.5

Table 26: RESULTS OF THE QUALITY ASSESSMENT: TOTAL SCORES FOR EACH DATASET ON SURFACE WATER BODIES

### 6.4.3 WATERSHEDS AND RIVER BASINS

In the sub-topic, *Watersheds and River Basins* the following datasets (according to the data inventory outcomes) have been considered for the quality assessment:

- Hydro1k;
- Hydro SHEDS;
- UNH/GRDC Runoff Data
- WRI, Major Watersheds of the World Delineation.

Dataset	Final Score
HydroSHEDS	29.75
Hydro1k	26.75
WRI Major Watersheds of the World Delineation	21.50
UNH/GRDC Runoff Data	20.75

Table 27 Results of the quality assessment: total scores for each dataset ON WATERSHEDS AND RIVER BASINS

### 6.4.4 WATER POINTS

The data inventory about water points featured several datasets, each one including a very mixed set of point categories. A common category has been chosen in order to perform a tighter analysis of the available data.

In this case, the points representing *dams* have been chosen, and the following datasets have been considered for the assessment:

- VMAP0(VMAP1)
- Global Reservoir and Dam (GRanD) database
- WWDRII
- GeoNames geographical database
- NGA GNS Geographic Names Database

The final step of the evaluation process is the calculation of a total score for each dataset. The vector of total scores is the result of an ordinary matrix product between the quality matrix and the vector of weights; it consists in a weighted sum of the scores assigned to each dataset.

Based on the quality final scores, datasets can be ordered in a ranking that reveals the best data able to satisfy end user's need.

Dataset	Final Score
VMAP0	34
GRanD	38
WWDRII	28.5
GeoNames	39
NGA GNS	33.5

Table 28: RESULTS OF THE QUALITY OF THE ASSESSMENT: TOTAL SCORES FOR EACH DATASET ON WATER OINTS

## 6.5 HUMAN POPULATION: POPULATION CENTRES AND DISTRIBUTION

### 6.5.1 POPULATION CENTRES

In the sub-topic, *Population Centres* the following datasets have taken part of the assessment:

- Global Rural-Urban Mapping Project
- V Map0;
- VMAP1;
- Global Map;
- GeoNames;
- Relational World Database II;

Dataset	Final Score
GeoNames	41
VMAP1	37.5
VMAP0	36.5
Global Map	36.5
GRUMP	31
RWDBII	30

Table 29: RESULTS OF THE QUALITY ASSESSMENT: TOTAL SCORES FOR EACH DATASET ON POPULATION CENTER

### 6.5.2 URBAN AND RURAL POPULATION DENSITY AND DISTRIBUTION

In the sub-topic *Urban and Rural Population Density and Distribution*, the following datasets have taken part of the assessment:

FGGD (Food Insecurity, Poverty and Environment Global GIS Database);

- GPW (Gridded Population of the World);
- GRUMP (Global Rural-Urban Mapping Project);
- WWDRII (World Water Development Report II);
- EOS (World Resources Institute);
- Land Scan;

The candidate’s data sources are not specific to population density and distribution. Population data have been extracted according to the following rules:

FGGD: Rural population density accessed through FAO GeoNetwork portal<sup>1</sup>.

WWDRII: Population density and distribution raster accessed through specific website.

All the datasets listed are raster with a global coverage: they show the higher or lower presence of population in a certain area of the world. The cell values usually represent an estimation of the number of people present in the correspondent area on the ground. The spatial coordinates of all of them are expressed in the Geographic Coordinate System WGS 84.

An improvement to the data information content is provided by some of the datasets, which divide the earth’s surface in rural and urban areas: the population distribution and the population density are in this case provided for urban areas and for rural areas in separate files.

Dataset	Final Score
Land scan	32
GPW	29
GRUMP	29
WWDRII	28
EOS	27
FGGD	24

Table 30: RESULTS OF THE QUALITY ASSESSMENT: TOTAL SCORES FOR EACH DATASET ON POPULATION CENTER

## 6.6 TRANSPORTATION: ROADS, RAILWAYS, AIRPORTS, HARBORS AND NAUTICAL ROUTES

### 6.6.1 ROADS

In the sub-topic *transportation - roads* the following datasets have taken part of the assessment:

- VMAP0(VMAP0);
- VMAP1(VMAP1);
- Global Map;
- OpenStreetMap (OSM);
- SDI-T;

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<sup>1</sup> <http://www.fao.org/geonetwork/>

The first three candidate data sources have specific road layers inside a more complete dataset; OSM is a collaborative mapping project having specific road layer too, whereas SDI-T is a transport-specific component of a broader project (UNSDI) and contains specific objects dedicated to roads.

### 6.6.1.1 INDICATOR EVALUATION

#### GEOGRAPHIC EXTENT

The analysis has been done through the reading of the metadata and of the information published by the respective data holders and an activity of visual control of the data with desktop GIS software (in the present case ESRI ArcGIS Desktop). The latter part has been repeated few times during the analysis of the rest of the indicators in order to potentially modify the previously given score with more experience.

It must be pointed out that datasets Global Map and VMAP1 even if they are global project do not have a global coverage yet for what concerns roads. All the results are resumed in Table 31.

<b>Dataset</b>	<b>Requirements</b>	<b>Score</b>
VMAP0	Global	5
VMAP1	Global	5
Global Map	Global	5
OSM	Global	5
SDI-T	Global	5

*Table 31: Summary of scores given the datasets for the parameter Geographic Extent*

#### LICENSING AND CONSTRAINTS

Metadata or the information provided by data holders furnished enough elements to perform the evaluation; VMAP0, OSM, and SDI-T datasets can be considered of public domain while the VMAP1 is not free of charge for subsets regarding many countries around the world. Global Map is free of charge only for non-commercial use. Table 32 contains the given scores.

<b>Dataset</b>	<b>Requirements</b>	<b>Score</b>
VMAP0	Public Domain Data	5
VMAP1	Free data with limitations	4
Global Map	Free data with limitations	4
OSM	Public Domain Data	5
SDI-T	Public Domain Data	5

*Table 32: Scores for the indicator Licensing and Constraints*

#### SCALE DENOMINATOR

The evaluation process is based initially on metadata and the other information provided by data holders (VMAP0 – VMAP1 – Global Map).

OSM derives from pre-existing data sources and from specifically acquired data; globally, it can be considered having a scale factor between 1/100.000 and 1/250.000.

SDI-T derives from pre-existing data sources and from specifically acquired data; globally, it can be considered having a scale factor between 1/100.000 and 1/250.000.

The scores are reported in Table 33.

Dataset	Requirements	Score
VMAPO	1.000.000	2
VMAP1	250.000	4
Global Map	500.000	3
OSM	100.000 <sc <= 250.000	4
SDI-T	100.000 <sc <= 250.000	4

Table 33: Summary of scores given for the indicator Scale Denominator

## UPDATE

The evaluation regarding this parameter has been carried out on the basis of the metadata and the information published by data holders: an assessment of the indicator *Update* based on single features is not possible on this data since there are not devoted fields in the attribute tables. OSM and SDI-T are updated continuously, on a voluntary basis. The results are resumed in Table 34.

Dataset	Requirements	Score
VMAPO	In the past 2 years	3
VMAP1	In the past 2 years	3
Global Map	In the past 2 years	3
OSM	Continuous	5
UNSDI-T	Continuous	5

Table 34: Summary of scores given for the indicator Update

## TEMPORAL EXTENT

Temporal extent indicator is not significant for roads sub-topic.

## FITNESS FOR USE

The evaluation has been carried out taking into consideration the effort needed to exploit different candidate datasets in a GIS environment and through the analysis of their metadata. Results are shown in Table 35.

VMAPO is distributed in shapefile format, divided into 4 tiles.

VMAP1 is distributed in shapefile format, divided into about 56 tiles.

Global Map is distributed in shapefile format, divided into about 73 countries; Global Map uses different filenames for road layers among different countries.

OSM dataset is ready to use for drawing and printing in a map: it is possible to use it on-line (view, plan a route, and print map images), to use it as WMS in desktop or web application, or download the data to use in local projects. Data is available in XML format and specific tools make it possible to import it in PostgreSQL-PostGIS databases: a specific table contains information about roads.

SDI-T is maintained in a spatially enabled database format, structured with a master table and several related tables. All datasets can be easily imported in GIS environments; some time has to be spent to import different tiles (especially where there are many): to speed it up some scripting may be needed. Global Map gets a lower score as uses different filenames for road layers among different countries.

OSM takes time to be downloaded and imported in a GIS environment, but that is expected because of the huge amount of information; besides no scripting development is needed, as tools are available for conversions.

SDI-T is available as a database connection. The results of the evaluation are resumed in Table 35.

Dataset	Requirements	Score
VMAPO		5
VMAP1		5
Global Map		4
OSM		5
UNSDI-T		5

Table 35: Summary of scores for the indicator Fitness for Use in Cartographic Representation

## THEMATIC RICHNESS

VMAPO, VMAP1 and Global Map, adopts a similar data structure; OSM and SDI-T adopt each a specific data structure. Here it is tried to evaluate the content of these different data models.

VMAPO contains a classification of roads (primary 25%, secondary 60%, unknown 15%), some quality fields (e.g. a rough estimate of the accuracy of the survey of the element (accurate 85% - approximate 15 %), and the information that is operational (most are operational: 85%).

VMAP1 contains a classification of roads (primary 5%, secondary 10%, motorway 2%, unknown 83% ), some quality fields (e.g. a rough estimate of the accuracy of the survey of the element, although >99% have 'accurate' value), the operational information (although >99% have 'operational' value). The name of the road (89% missing), if it is paved (2% missing, 26% unpaved, 72% paved )and an estimate about the possibility of usage of the road in relation to the season and weather conditions (all seasons 72%, unknown 2%)

GLOBAL MAP contains, a classification of roads (18% missing), some quality fields (e.g. a rough estimate of the accuracy of the survey of the element; 94% accurate – 5% approximate – 1% no data), the operational information (98% are operational), paved (27% lack this information) and an estimate about the period of the year in which it is possible to use. (All, year 66%, unknown 31%).

OSM adopts a detailed road classification (>20 categories<sup>1</sup>): it can be assumed that the classification is comprehensive of other kind of information that does not have a specific field in the data structure. It is estimated that it includes the surface type and its smoothness, beside the fact the road is operational, that it is accurately surveyed, and if there can be seasonal problems in using it; OSM also gives the name of the road (% of information missing varies on continent min 32% max 74% med 46%)<sup>2</sup>

SDI-T has a complex table structure: it contains the name of the road (84% missing), a detailed classification (7 % unclassified, including road width - >99% missing, number of lanes - >99% missing, type of road surface - >99% missing), detailed information about actual situation (accessibility, safety, surface situation, but >95 % data is missing). See Table 36

<sup>1</sup> [http://wiki.openstreetmap.org/wiki/Map\\_Features](http://wiki.openstreetmap.org/wiki/Map_Features) for detailed description

<sup>2</sup> OSM analysis doesn't take into account Europe and North America data, to speed tests up: as a result percentage about missing information may be overestimated.

	CLASSIFICATION	SURVEY ACCURACY	OPERATIONAL	NAME	PAVED	SEASONAL
VMAP0	Y	Y	Y	N	N	N
VMAP1	Y	Y	Y	Y	Y	Y
GLOBAL MAP	Y	Y	Y	N	Y	Y
OSM	Y	N	I	Y	I	I
SDI-T	Y	N	Y	Y	Y	Y

Table 36: Summary thematic richness analysis

Y: there is a specific field - N: information missing - I: included in other fields

The result of the evaluation of the Thematic Richness indicator is summarized in Table 37.

Dataset	Requirements	Score
VMAP0		3
VMAP1		5
Global Map		4
OSM		5
UNSDI-T		5

Table 37: Summary of scores for the indicator Thematic Significance

## INTEGRATION

The information collected on the data holdings and reported in the deliverable D10.1 is enough to face the evaluation for this indicator: the results are reported in Table 38 .

Dataset	Requirements	Score
VMAP0	Part of comprehensive dataset	5
VMAP1	Part of comprehensive dataset	5
Global Map	Part of comprehensive dataset	5
OSM	Part of thematic database	3
SDI-T	Part of thematic database	3

Table 38 Scores for the indicator Integration

## DATA INTEGRITY

Several topological analyses have been performed on the data, whose results are reported in Table 39.

Dataset	INTERSECT	OVERLAP	SELF INTERSECT	SELF OVERLAP
VMAP0	0,0	0,0	0,0	0,0
VMAP1	0,0	0,0	0,0	0,0
GLOBAL MAP	2,6	1,8	0,2	0,2
OSM*	19,8	0,7	0,9	0,1
SDI-T	12,5	2,9	0,2	0,0

Table 39: Synthetic view on topologic analyses

\*North America and Europe were not considered to speed analysis up; this makes error percentage higher as the two continents are covered in detail and have accurate data sources (including data coming from Public Bodies).

Summarizing the result it can be said that the VMAP0 and VMAP1 datasets are excellent from the point of view of the geometric relationship between their features (errors <1%); Global Map has small topologic errors. SDI-T and OSM have worst topologic scenario. Scores are in Table 40: Summary of scores for the indicator Data Integrity.

Dataset	Requirements	Score
VMAP0		5
VMAP1		5
Global Map		2
OSM		1
UNSDI-T		1

Table 40: Summary of scores for the indicator Data Integrity

## POSITIONAL ACCURACY

For positional accuracy indicator, both metadata and GIS analyses are considered.

VMAP0, VMAP1, and Global Map have declared reference scale; SDI-T and OSM have no declared reference scale so are compared to other three datasets as follows:

Test areas are considered in each continent.

In each test area reference scale datasets are considered (VMAP0, VMAP1, Global MAP); each dataset is buffered in relation to its reference scale: buffer1- considers appropriate tolerance value (579m for 1:1.000.000, 290m for 1:500.000, 145m for 1:250.000); buffer 2- 3 times the tolerance value, in order to take into account positional differences due to feature generalization;

Candidate datasets (SDI-T and OSM) are intersected with buffer layers, so that it is possible to consider which reference scale suits it best. Data are analyzed in following way:

- intersection with buffer 2 is meaningful of the % of overlapping features (it highlights which are the roads in common between candidate and reference datasets; percentage takes into account the length of features)
- intersection with buffer 1 divided by intersection with buffer 2 gives the % of features in tolerance of the reference dataset (it highlights the part of common roads that lie in the tolerance area of reference dataset; percentage takes into account the length of features)
- length of candidate dataset features minus length of intersection with buffer 2, gives the length of candidate dataset roads not present in reference dataset (it tries to highlight how candidate dataset is richer than reference one)
- length of reference dataset features minus length of intersection with buffer 2, gives the length of reference dataset roads not present in candidate dataset (it tries to highlight how reference dataset is richer than candidate one)

The result of the positional accuracy analysis is shown in Table 41 and Table 42. In all test areas “%” refers to the total length of OSM or SDI-T roads in test areas.

OSM	% overlapping	% in tolerance	% in OSM AND not in REF	in REF AND not in OSM
VMAP 0	69	62	31	328
VMAP 1	75	63	25	1396*
Global Map	62	40	38	223
SDI-T	% overlapping	% in	% in SDI-T AND not in REF	in REF AND not in OSM

		tolerance		
VMAP 0	72	93	28	-3
VMAP 1	48	48	52	208*
Global Map	20	36	80	29

Table 41: comparison between OSM and SDI-T and reference datasets in test areas

\*in VMAP1 also trails layer is considered; in Asia test area there was a great presence of trails.

Focus on North Africa test area (“%” referring to the total length of OSM or SDI-T roads in test area)

OSM	% overlapping	% in tolerance	% in OSM AND not in REF	in REF AND not in OSM
VMAP 0	60	57	40	-12
VMAP 1	77	70	23	53
Global Map	54	30	46	10
SDI-T	% overlapping	% in tolerance	% in SDI-T AND not in REF	in REF AND not in SDI-T
VMAP 0	91	98	9	0
VMAP 1	50	35	50	199
Global Map	48	37	52	51

Table 42: Comparison of OSM and SDI-T with VMAP0, VMAP1, and Global Map in Algeria

In this test area, networks from different datasets are more similar: it is easier to compare their positional accuracy.

Considering both global data and local ones, OSM dataset can be best compared to VMAP1 reference dataset.

Besides, by overlaying OSM data on Google Earth satellite imagery, 100 % of 50 test roads are within 1:100.000 tolerances the roads present in images.

Considering both global data and local ones, SDI-T dataset can be best compared to VMAP0 reference dataset.

Beside, by overlaying SDI-T data on Google Earth satellite imagery, just some part of the test roads are within 1:100.000 tolerance the roads present in images; most are in a 290 m tolerance.

According to the previous analyses, the following scores have been attributed to each candidate (Table 43).

Dataset	Requirements	Score
VMAP0	579 m	2
VMAP1	145 m	4
Global Map	290 m	3
OSM	58 m	5
UNSDI-T	290m	3

Table 43: Summary of scores given the datasets for the indicator Positional Accuracy

## THEMATIC SIGNIFICANCE AND ACCURACY

Thematic significance and accuracy was estimated by considering how each data field is filled. It completes *thematic richness* indicator by estimating the percentage of missing data.

	CLASSIFICATION [Missing Data %]	SURVEY ACCURACY [Accurate Data %]	OPERATIONAL [Missing Data %]	NAME [Missing Data %]	PAVED [Missing Data %]	SEASONAL [Missing Data %]
VMAP0	15	85	15	-	-	-
VMAP1	83	>99	1	89	2	2
GLOBAL MAP	18	>99	2	-	27	31
OSM	0	100*	0*	46	0*	0*
SDI-T	7	100*	95	84	97	99

Table 44: Results of the thematic significance and accuracy analysis

\*implicit.

To rate the accuracy and significance in relation to different data structures, the focus is given to road classification, as other additional information is widely missing or implicit in classification data. For VMAP1, classification and the surface information are considered together.

According to those missing values, Table 45 has been filled with the appropriate scores.

Dataset	Requirements	Score
VMAP0		4
VMAP1		4
GLOBAL MAP		3
OSM		5
SDI-T		5

Table 45: Summary of scores given the datasets for the indicator Thematic Accuracy

## COMPLETENESS

- VMAP0 has a geographic distribution that is homogeneous and that can be considered global.
- VMAP1 covers only some area in each continent.
- Global Map covers just some countries in each continent
- OSM is a collaborative mapping project; data come from volunteer GPS survey, map digitizing and open data, so in selected countries, it is particularly complete, thus having a good world distribution.
- SDI-T is locally the results of systematic field campaign acquisition and thus, in selected countries, is particularly complete.

Table 46, contains the scores for the Completeness indicator.

Dataset	Requirements	Score
VMAP0		5
VMAP1		2
Global Map		3
OSM		5
UNSDI-T		5

Table 46: Summary of scores for the indicator Completeness

### 6.6.1.2 OVERALL EVALUATION

The results of the analysis described in paragraph 6.6.1.1 can be summarized all together in the single matrix reported in Table 47.

For the indicators of quality and consistency of datasets representing *Roads*, the user needs assessment brought to the definition of weights contained in Table 48. The final scores are calculated as the result of the product between the quality matrix and the vector of weights; then the datasets are ordered according to the final score, in descending order (Table 49).

### QUALITY MATRIX

Dataset	Geographic Extent	Licensing And Constr.	Scale Denom.	Update	Temporal Extent	Fit. For Use	Thematic Richness	Integration	Data Integrity	Positional Accuracy	Thematic Accuracy	Completeness
MAPO	5	5	2	3	n.a.	5	3	5	5	2	4	5
VMAP1	5	4	4	3	n.a.	5	5	5	5	4	4	2
Global Map	5	4	3	3	n.a.	5	4	3	2	3	3	3
OSM	5	5	4	5	n.a.	5	5	3	1	5	5	5
SDI-T	5	5	4	5	n.a.	5	5	3	1	3	5	5

Table 47: Quality matrix for the data sub-topic Harbors

### VECTOR WEIGHTS

Indicator	Weight (0 to 1)
Geographic Extent	1
Licensing and Constraint	0.5
Scale Denominator	1
Update	1
Temporal Extent	0
Fitness For Use	0.5
Thematic Richness	1
Integration	0.5
Data Integrity	0.5
Positional Accuracy	1
Thematic Significance and Accuracy	1
Completeness	0.5

Table 48: Weights assigned to the indicators of quality and consistency for the sub-topic Harbors

### FINAL SCORES AND RANKING

Dataset	Final Score
OSM	38.5
UNSDI-T	36.5
VMAP1	35.5
VMAPO	31.5
Global Map	29.5

Table 49: RESULTS OF THE QUALITY ASSESSMENT: TOTAL SCORES FOR EACH DATASET ON SUB-TOPIC ROADS

## 6.6.2 RAILWAYS

In the sub-topic, *Railways* the following datasets took part in the assessment:

- Vector Smart Map Level 0;
- VMAP1(sample of the entire dataset);
- Global GIS Database;
- Global map (sample of the entire dataset);
- OpenStreetMap (OSM);
- Relational World Data Base 2;
- SDI-T;

Dataset	Final Score
VMAP0	34,5
VMAP1	38
Global Map	34,5
OSM	35,5
RWDBII	28
SDI-T	36

Table 50: RESULTS OF THE QUALITY ASSESSMENT: TOTAL SCORES FOR EACH DATASET ON SUB-TOPIC RAILWAYS

## 6.6.3 AIRPORTS

In the sub-topic *Airports*, following datasets have taken part of the assessment:

- VMAP0(VMAP0);
- Vector Smart Map Level 1(VMAP1 - sample of the entire dataset);
- Relational World Data Base 2 (RWDBII);
- Global Airports Database (GAD);
- Global Airports Database and DAFIF;
- World Airport Codes;
- The Geography of Transport Systems;
- GeoNames;
- NGA GEONet Names Serve ;

Dataset	Score
VMAP0(VMAP0)	37
Vector Smart Map Level 1(VMAP1)	33
Relational World Data Base 2 (RWDBII)	35.5
Global Airports Database (GAD)	31
Global Airports Database and DAFIF	35.5
World Airport Codes	35
The Geography of Transport Systems	36
GeoNames	39,5
NGA GEONet Names Server	39

Table 51: RESULTS OF THE QUALITY ASSESSMENT: TOTAL SCORES FOR EACH DATASET ON SUB-TOPIC AIRPORT

## 6.6.4 HARBORS

In the sub-topic *Harbors*, the following datasets have taken part of the assessment:

- Relational World Database II;
- NGA GEONet Names Server;
- GeoNames;
- World Port Index;
- SDI-T;

Dataset	Final Score
SDI-T	39.5
GeoNames	34.5
World Port Index	32.5
NGA GEONet Names Server	31
Relational World Database II	28.5

Table 52: RESULTS OF THE QUALITY ASSESSMENT: TOTAL SCORES FOR EACH DATASET ON SUB-TOPPIC HARBORS

## 6.7 BATHYMETRY AND TERRESTRIAL ELEVATION

### 6.7.1 BATHYMETRY

In the sub-topic *Bathymetry*, the following datasets have taken part of the assessment:

- GMRT Global Multi-Resolution Topography
- GEBCO General Bathymetric Chart of the Oceans
- ETOPO 1 Earth Topography Digital Dataset
- "Smith and Sandwell Global Seafloor Topography (or Smith and Sandwell predicted bathymetry or Smith and Sandwell measured and estimated seafloor topography)"
- VMAPO

The listed datasets are raster and vector data with a global coverage. For raster datasets, the cell values usually represent an estimation of the ground elevation or bathymetry. VMAPO is a vector dataset, containing contour lines. The spatial coordinates of all of them are expressed in different Coordinate System.

#### 6.7.1.1 INDICATOR EVALUATION

##### GEOGRAPHIC EXTENT

The analysis has been done through the reading of the metadata and of the information published by the respective data holders and an activity of visual control of the data with desktop GIS software (in the present case ESRI ArcGIS Desktop). The latter part has been repeated few times during the analysis of the rest of the indicators in order to potentially modify the previously given score with more experience.

Some datasets have a real global extent, in the sense that they cover the earth's surface from -180 to 180 degrees in longitude and from -90 to 90 degrees in latitude. Some do not cover the area of Arctic and Antarctica (Smith and Sandwell); these datasets are retained as with global extent, but with some

coverage limitation (e.g. latitude thresholds). With this assumption, all the datasets have a global extent, so the score assigned for the respective indicator is the maximum for all (see Table 53).

Dataset	Requirements	Score
GMRT	Global	5
GEBCO 1 min	Global	5
GEBCO 08	Global	5
ETOPO 1	Global	5
Smith and Sandwell	Global	5
VMAP0	Global	5

Table 53: Summary of scores given the datasets for the indicator Geographic Extent

## LICENSING AND CONSTRAINTS

All the dataset listed for the present subtopic are free and available through the internet. They are protected by copyright and there are constraints related to specific use.

It is possible to browse GMRT freely, but it is not possible to circulate or publish materials obtained from the site without accepting the terms of providing adequate citation to the contributing scientists and MGDS ([www.marine-geo.org](http://www.marine-geo.org)).

Data within GEBCO 08 Grid and GEBCO One Minute Grid are subject to copyright and database right restrictions. Reproduction of the gridded bathymetry data sets is derivative form for scientific research, environmental conservation, education or other non-commercial purposes and is authorized without prior permission, providing the source material is properly credited.

ETOPO1 is considered public information and may be distributed or copied, by the use of appropriate line/photo/image credits.

Permission to copy, modify, and distribute any part of this Smith and Sandwell gridded bathymetry at 1 minute resolution for educational, research and non-profit purposes, without fee, and without a written agreement is granted.

Where appropriate, researchers are also encouraged to consider collaboration and/or co-authorship with original investigators.

The scores assigned for all datasets are the following (see Table 54):

Dataset	Requirements	Score
GMRT	Free data with limitations	4
GEBCO 1 min	Free data with limitations	4
GEBCO 08	Free data with limitations	4
ETOPO 1	Public domain ( <a href="http://www.ngdc.noaa.gov/ngdcinfo/privacy.html">http://www.ngdc.noaa.gov/ngdcinfo/privacy.html</a> )	5
Smith and Sandwell	Free data with limitations	4
VMap0	Free data with limitations	4

Table 54: Scores for the indicator Licensing and Constraints

## SCALE DENOMINATOR

Rarely the metadata related to raster data indicate a value of the reference scale because of the nature of the data itself: the indication of the pixel size is more direct and clear.

## Data Quality Assessment Processing And Results

Dataset	Pixel Size	Derived scale denominator	Score
GMRT	100 m	>250.000 - <=500.000	3
GEBCO 1 min	1 minute (2 km)	>1000000	1
GEBCO 08	30 arc sec (1 km)	>1000000	1
ETOPO 1	1 arc minute (2km)	>1000000	1
Smith and Sandwell	1 arc minute (2km)	>1000000	1
VMAPO	/	>500.000 - <=1.000.000	2

Table 55: Summary of scores given for the indicator Scale Denominator without re-adaptation to the scale range.

The pixel size values and the scores assigned are showed in Table 55.

In order to use the full range of scores from 1 to 5, scores have been adapted to the resolution of the available dataset, according to the criteria in Table 56.

Score	scale denominator
1	>3.000.000
2	>2.000.000 - <=3.000.000
3	>1.000.000 - <=2.000.000
4	>500.000 - <=1.000.000
5	<=500.000

Table 56: Summary of Proposed values for the indicator Scale Denominator

The score re-adapted are the ones shown in Table 57.

Dataset	Derived scale denominator	Score
GMRT	<=500.000	5
GEBCO 1 min	>3.000.000	1
GEBCO 08	>2.000.000 - <=3.000.000	2
ETOPO 1	>3.000.000	1
Smith and Sandwell	>3.000.000	1
VMAPO	>500.000 - <=1.000.000	4

Table 57: SUMMARY OF FINAL SCORES GIVEN FOR THE INDICATOR SCALE DENOMINATOR

## UPDATE

The evaluation regarding this indicator has been carried out on the basis of the metadata and the information published by data holders; the results are resumed in Table 58.

Dataset	Requirements	Score
GMRT	Continuously (2011)	5
GEBCO 1 min	2003	1
GEBCO 08	2010	3
ETOPO 1	2008	2
Smith and Sandwell	continuously updated	5
VMAPO	2000	1

Table 58: Summary of scores given for the indicator Update

## TEMPORAL EXTENT

Data cannot be considered as time series: for this reason, the indicator *Temporal Extent* is not significant for bathymetry topic.

## FITNESS FOR USE

The evaluation has been carried out taking into consideration the effort needed to exploit different candidate datasets in a GIS environment and through the analysis of their metadata. Results are shown in Table 59.

The raster data type itself of the dataset listed for this Sub-topic makes them ready and optimized for data maintenance, analysis, and display, on desktop and WebGIS applications.

Some datasets are provided in a format that can require the use of different software or the use of code to read the data.

Dataset	Requirements	Score
GMRT	No need of pre-processing	5
GEBCO 1 min	elaboration of a code to read the data	3
GEBCO 08	elaboration of a code to read the data	3
ETOPO 1	No need of pre-processing	5
Smith and Sandwell	Using of different softwares to read the data. Unusual Projection not manageable in ArcGIS	2
VMAPO	No need of pre-processing	5

Table 59: Summary of scores for the indicator *Fitness for Use*

## THEMATIC RICHNESS

Most of the datasets (only VMAPO is vector) listed for the current Sub Topic are raster data. They provide information about ground bathymetry as pixel value. Furthermore since this is the only content in terms of thematic richness, the evaluation of the indicator is skipped.

## INTEGRATION

In the framework of the Global Maps project and in particular in relation with the data quality assessment activities, a database can be considered as comprehensive when it contains favorite data in different Topics of the project. It is considered as thematic when it contains data interesting for at least more than one Sub-topic.

All raster datasets can be considered as stand alone, while Vmap0 is the only dataset, which contains information interesting for other Topics of the Global Maps project. The results are reported in Table 60.

Dataset	Requirements	Score
GMRT	Stand-alone dataset	1
GEBCO 1 min	Stand-alone dataset	1
GEBCO 08	Stand-alone dataset	1
ETOPO 1	Stand-alone dataset	1
Smith and Sandwell	Stand-alone dataset	1
VMAPO	Part of thematic database	5

Table 60: Scores for the indicator *Integration*

## DATA INTEGRITY

The evaluation process as it was defined cannot be applied to raster data.

## POSITIONAL ACCURACY

Positional accuracy has been evaluated through a procedure that compares the datasets in exam with features referring to the same object but coming from dataset with a higher accuracy (at least an order of magnitude).

Since there is no availability of a free bathymetry dataset at an accuracy higher than one order of magnitude to the examined dataset, positional accuracy has been tested by comparing the coastlines derived from bathymetry dataset to the coast dataset of VMAP1 (only on the available tiles). For raster bathymetry dataset, pixels which are at the borderline between positive and negative values have been defined as coastlines, while in order to define VMAP0 coastlines, the vector coast has been used. The positional accuracy has been calculated by evaluating the portion of the coastlines derived that are included in a buffer, selected according to the scale range of dataset. For the datasets with a ground sample distance (GSD) greater than the one shown in the table. The linear relation between GSD and accuracy has been used is:

$$\text{Accuracy} = 1.8 * \text{GSD}$$

For the datasets GMRT and Smith and Sandwell, it has not been possible to perform the analysis of positional accuracy: for the first because it is only possible to visualize the data, while the second is in a projection non-manageable by ArcGIS and other software that have been used in order to project the data. For this reason to both datasets has been assigned a medium score of 3.

The indicator *Positional Accuracy* can assume values from coarse to fine as summarized in Table 61.

Dataset	Requirements	Score
GMRT	N/A	3
gebco1min	high	4
GEBCO 08	high	4
ETOPO 1	high	4
Smith and Sandwell	N/A	3
VMAP0	intermediate	3

Table 61: Scores assigned for the indicator *Positional Accuracy*

## THEMATIC ACCURACY

Since it was not available a dataset with a higher resolution to test bathymetry data values, it was not possible to test thematic accuracy.

## COMPLETENESS

In order to evaluate completeness of the bathymetry datasets, 2 criteria have been used; detection of areas in which the dataset is not available and research of No-Data values, that correspond to areas for which bathymetry has not been calculated.

According to the first criterion, only Smith and Sandwell dataset doesn't result to be complete, since it doesn't cover regions with a latitude greater than 80.77 degrees and lower than 80.77 (completeness = 0.897)

In order to detect the presence of No-Data values, for all raster datasets a frequency histogram of pixel values has been calculated. From this analysis all the datasets resulted to be complete (Table 62).

Dataset	Requirements	Score
GMRT	< 0.1	5
gebco1min	< 0.1	5
GEBCO 08	< 0.1	5
ETOPO 1	< 0.1	5
Smith and Sandwell	0.5 – 2	3
VMAPO	<0.1	5

Table 62: Summary of scores for the indicator Completeness

### 6.7.1.2 OVERALL EVALUATION

The results of the analysis described in section 5.4.1 can be summarized all together in the single matrix reported in Table 63.

For the indicators of quality and consistency of datasets representing *Bathymetry*, the user needs assessment brought to the definition of weights contained in Table 64. The final scores are calculated as a result of the product between the quality matrix and the vector of weights; then the datasets are ordered according to the final score, in descending order (Table 65).

### QUALITY MATRIX

Dataset	Geographic Extent	Licensing and constraints	Scale Denominator	Update	Temporal Extent	Fitness for Use	Thematic Richness	Integration	Data Integrity	Positional Accuracy	Thematic Accuracy	Completeness
GMRT	5	4	5	5	NA	5	NA	1	NA	3	NA	5
gebco1min	5	4	1	1	NA	3	NA	1	NA	4	NA	5
GEBCO 08	5	4	2	3	NA	3	NA	1	NA	4	NA	5
ETOPO 1	5	5	1	2	NA	5	NA	1	NA	4	NA	5
Smith and Sandwell	5	4	1	5	NA	2	NA	1	NA	3	NA	3
VMAPO	5	4	4	1	NA	5	NA	5	NA	3	NA	5

Table 63: Quality matrix for the data sub-topic bathymetry

### VECTOR OF WEIGHTS

Indicator	Weight (0 to 1)
Geographic Extent	1
Licensing and Constraint	0.5
Scale Denominator	1

Indicator	Weight (0 to 1)
Update	0.5
Temporal Extent	0
Fitness For Use	0.5
Thematic Richness	0
Integration	0.5
Data Integrity	0
Positional Accuracy	0.5
Thematic Accuracy	0
Completeness	1

Table 64: Weights assigned to the indicators of quality and consistency for the sub-topic bathymetry

## FINAL SCORES AND RANKING

Dataset	Final Score
GMRT	24
VMAPO	23
GEBCO 08	19,5
ETOPO 1	19,5
gebco1min	17,5
Smith and Sandwell	16,5

Table 65: Results of the quality assessment: total scores for each dataset

### 6.7.2 TERRESTRIAL ELEVATION

In the sub-topic *Terrestrial Elevation*, the following datasets have taken part in the assessment:

- ASTER GDEM (Advanced Space-borne Thermal Emission and Reflection Radiometer Global Digital Elevation Model);
- SRTM3 (Shuttle Radar Topography Mission);
- GTOPO30;

All the datasets listed are Digital Elevation Model built using several techniques and each pixel represents the average altitude in the corresponding area on the ground. They are available in different format while spatial coordinates of all of them are expressed in the Geographic Coordinate System WGS 84.

Dataset below was initially considered but not included in the quality assessment following the analysis of their data source. Documents provided by the data holders show in fact that all data excluded from the evaluation are an elaboration or integration of raster with other type of source, but the overall accuracy can't be considered better than DEMs above.

- SRTM30 (Shuttle Radar Topography Mission);
- CGIAR-CSI SRTM (Consortium for Spatial Information of the Consultative Group for International Agricultural Research Shuttle Radar Topography Mission data);
- SRTM30 PLUS (Shuttle Radar Topography Mission Plus);
- HYDRO1k;
- HydroSHEDS (Hydrological data and maps based on Shuttle Elevation Derivatives at multiple scales);

- GLOBE (Global Land One-km Base Elevation Project);
- ETOPO 1;
- Global Map;

Finally, point layers include in the data inventory phase are not considered in the assessment that is aimed at comparing raster ones.

### 6.7.2.1 INDICATOR EVALUATION

#### GEOGRAPHIC EXTENT

The analysis has been done through the reading of the metadata and of the information published by the respective data holders and an activity of visual control of the data with desktop GIS software (in the present case ESRI ArcGIS Desktop).

All dataset are part of a global project but only GTOPO30 has a real global extent, in the sense that it cover the earth's surface from -180 to 180 degrees in longitude and from -90 to 90 degrees in latitude, so it gains the maximum score (see Table 66).

Dataset	Requirements	Score
ASTER	Continental	4
SRTM3	Continental	4
GTOPO30	Global	5

Table 66: Summary of scores given the datasets for the indicator Geographic Extent

#### LICENSING AND CONSTRAINTS

All the dataset listed for the present subtopic are free and available through the internet. Some of them are constraints related to specific use. In particular, for ASTER constraints are related to distribution and commercial use.

The score of this indicator is listed in Table 67.

Dataset	Requirements	Score
ASTER	Free data with limitations	4
SRTM3	Public Domain Data	5
GTOPO30	Public Domain Data	5

Table 67: Scores for the indicator Licensing and Constraints

#### SCALE DENOMINATOR

Rarely the metadata related to raster data indicate a value of the reference scale because of the nature of the data itself: the indication of the pixel size is more direct and clear.

A procedure for assigning a score to the datasets specific for this case has been used. The pixel size values and the scores assigned are showed in Table 68.

Dataset	Pixel Size	Score
ASTER	1''	5

Dataset	Pixel Size	Score
SRTM3	3''	4
GTOPO30	30''	3

Table 68: Summary of scores given for the indicator Scale Denominator

## UPDATE

The evaluation regarding this indicator has been carried out on the basis of the metadata<sup>1</sup> and the information published by data holders. The ranking refers to the latest edition released for each dataset. The results are resumed in Table 69.

Dataset	Requirements	Score
ASTER	In the past 2 years	3
SRTM3	More than 5 years ago	1
GTOPO30	More than 5 years ago	1

Table 69: Summary of scores given for the indicator Update

## TEMPORAL EXTENT

Temporal extent indicator is not significant for terrestrial elevation sub-topic.

## FITNET FOR USE

The evaluation has been carried out in a GIS environment with operations of display and analysis of sample areas. Raster data are available directly, so operations of pre-processing are not necessary.

All dataset gains the maximum score (Table 70)

Dataset	Requirements	Score
ASTER	No need of pre-processing	5
SRTM3	No need of pre-processing	5
GTOPO30	No need of pre-processing	5

Table 70: Summary of scores for the indicator Fitness for Use

## THEMATIC RICHNESS

*Thematic Richness* cannot be considered for digital elevation model because the only important information in the attribute table is the altitude value associated with each pixel.

## INTEGRATION

The information collected on the data holding is enough to face the evaluation for this indicator: the results are reported in Table 71.

<sup>1</sup> <http://www.ersdac.or.jp/GDEM/E/index.html> for ASTER

<http://srtm.csi.cgiar.org/> for SRTM3

<http://www1.gsi.go.jp/geowww/globalmap-gsi/gtopo30/README.html> for GTOPO30

Dataset	Requirements	Score
ASTER	Stand-alone dataset	1
SRTM3	Stand-alone dataset	1
GTOPO30	Stand-alone dataset	1

Table 71: Scores for the indicator *Integration*

## DATA INTEGRITY

The evaluation process as it was defined in previous chapter cannot be applied to raster data. In the present case, only the machine-readability of the data can be evaluated: all the datasets are perfectly machine-readable.

## POSITIONAL ACCURACY

For the evaluation of the present quality parameter, it was decided to compare data sets with a higher resolution, the USGS National Elevation Dataset (NED). This raster data are available throughout the United States at a spatial resolution of 1-arc-second and second 1/3-arc in certain areas. For NED more accurate tiles and our raster dataset to validate, a planimetric information consists of the watershed was obtained through the use of a GIS software



Figure 22: The figure shows the hydrographic grid obtained using GIS software for the NED in a sample area (ESRI ArcGIS Desktop) The evaluation has been performed by means of the procedure described below:

- For each candidate, a sample of raster in the USA territory has been extracted (Figure 22) and the hydrographic grid has been obtained with the use of a GIS software, in this case ESRI Arcatalog. The set of vertices of the obtained line feature has been extracted and each point has been buffered, setting as distance the accuracy estimated from the reference scale of the candidate layers.
- The positional accuracy of each sampled point has been estimated by comparing the above buffer with the vertex obtained for the NED buffered setting a distance of 1/3 arc second (about 10 m).

In particular, the following counties have been analyzed: Wyoming, Colorado, and Texas. The results are presented in Table 72.

Dataset	Requirements	Score
ASTER	High	4
SRTM3	Fine	5
GTOPO30	Intermediate	3

Table 72: SCORES FOR THE INDICATOR POSITIONAL ACCURACY

### THEMATIC ACCURACY

Raster datasets are not provided with an attribute table. The information content is stored as pixel value expressing the average elevation of the area corresponding to each pixel itself. The evaluation has been carried out by reading the data available in literature and comparing with the values given by the holders on their websites. Results are reported in Table 73.

ASTER and SRTM3 have respectively a vertical accuracy declared of 20 m and 16 m. The absolute vertical accuracy of GTOPO30 varies by location<sup>1</sup> according to the source data. Generally, the areas derived from the raster source data have higher accuracy than those derived from the vector source data and varies from 18 to 300 meters in Peru. Globally, therefore, the accuracy is lower than the 2 previous set. The procedure for assigning scores in this case is an exception of the general protocol (see Table 73).

Dataset	Requirements: vertical accuracy	Score
ASTER	20 m	4
SRTM3	16 m	4
GTOPO30	variable	2

Table 73: Results of the thematic accuracy analysis

### 6.7.3 COMPLETENESS

For all data sets, a frequency histogram of pixel values has been calculated in order to detect the presence of No Data values. These areas could comprehend also seas and oceans: a visual comparison between the datasets in evaluation and a dataset representing the coastlines has permitted to extract only the real data gaps. In these cases, the ratio between the numbers of pixels of No Data over the raster size has been calculated in order to evaluate the current indicator. As shown in, all data are completely consistent (see Table 74).

Dataset	Requirements	Score
ASTER	0	5
SRTM3	0	5
GTOPO30	0	5

Table 74: Summary of scores for the indicator Completeness

<sup>1</sup> <http://www1.gsi.go.jp/geowww/globalmap-gsi/gtopo30/README.html>

### 6.7.3.1 OVERALL EVALUATION

The results of the analysis described in section 6.7.1.1 can be summarized all together in the single matrix reported in Table 75.

For the indicators of quality and consistency of datasets representing *Terrestrial Elevation*, the user needs assessment brought to the definition of weights contained in Table 76. The final scores are calculated as a result of the product between the quality matrix and the vector of weights; then the datasets are ordered according to the final score, in descending order (Table 77).

#### QUALITY MATRIX

Dataset	Geographic Extent	Licensing and constraints	Scale Denominator	Update	Temporal Extent	Fitness for Use	Thematic Richness	Integration	Data Integrity	Positional Accuracy	Thematic Accuracy	Completeness
ASTER	4	4	5	3	NA	5	NA	1	NA	4	4	5
SRTM3	4	5	4	1	NA	5	NA	1	NA	5	4	5
GTOPO30	5	5	3	1	NA	5	NA	1	NA	3	2	5

Table 75: Quality matrix for the data sub-topic Terrestrial Elevation

#### VECTOR OF WEIGHT

Indicator	Weight (0 to 1)
Geographic Extent	1
Licensing and Constraint	0.5
Scale Denominator	1
Update	0,5
Temporal Extent	0
Fitness For Use	0.5
Thematic Richness	0
Integration	0.5
Data Integrity	0
Positional Accuracy	1
Thematic Significance and Accuracy	1
Completeness	0,5

Table 76: Weights assigned to the indicators of quality and consistency for the sub-topic Terrestrial Elevation

#### FINAL SCORE AND RANKING

Dataset	Final Score
ASTER	26
SRTM3	25,5
GTOPO30	21,5

Table 77: Results of the quality assessment: total scores for each dataset ON SUBTOPIC TERRESTRIAL ELEVATION

## 6.8 GEOLOGY

### 6.8.1 GEOLOGY

In the sub-topic *Geology*, the following datasets have taken part in the assessment:

- OneGeology Portal;
- World Mineral Deposits (GSC World);
- World Geologic Maps (WGM);

Dataset	Final Score
WHYMAP	24
GGIS	25
WCR	24

Table 78: RESULTS OF THE QUALITY ASSESSMENT FOR THE SUB-TOPIC HYDROGEOLOGY ON SUB-TOPIC GEOLOGY

### 6.8.2 SOILS AND SOIL PROPERTIES

In the sub-topic *Soils and Soil Properties*, only the datasets containing mainly soil type information have taken part of the assessment:

- Harmonized World Soil Database (HWSD);
- WRB Map of World Soil Resources (WSR);
- Digital Soil Map of the World (DSMW);
- Stwab\_Rosen\_GISS (GISS).

Dataset	Final Score
HWSD	30
DSMW	28
GISS	23
WSR	20

Table 79 RESULTS OF THE QUALITY ASSESSMENT FOR THE SUB-TOPIC HYDROGEOLOGY ON SUB-TOPIC soils and soil properties

## 6.9 SATELLITE IMAGERY: LAND COVER/USE, FORESTS AND VEGETATION

### 6.9.1 SATELLITE IMAGERY

With reference to the requirements defined in paragraph 3.1.2.2 of the deliverable of Task 10, the following data sources have been taken into account in the SubTopic *Satellite Imagery* and considered during the assessment:

- ASTER
- MOD 02
- MOD 09
- GLS
- Landsat Legacy Collections
- Landsat Archive Collections
- EO-1
- AVHRR

Dataset	Final score
ASTER	33
MOD 02	30
MOD 09	28
GLS	29
Landsat Legacy Collections	28
Landsat Archive Collections	32
EO-1	32
AVHRR	28

*Table 80: RESULTS OF THE QUALITY ASSESSMENT FOR THE SUB-TOPIC HYDROGEOLOGY ON SUB-TOPICs satellite imagery*

### 6.9.2 LAND COVER/USE, FORESTS AND VEGETATION

With reference to the requirements defined in paragraph 3.1.2.2 of the deliverable M21 of Task 10, the following data sources have been taken into account in the SubTopic *Land Cover/Use, Forests and Vegetation* and considered during the assessment:

- GLC 2000
- GLCC
- AVHRR Global Land Cover Classification
- MOD 12
- ESA Glob cover
- FGGD
- Global Map
- Land Use System database
- Global Land Use Database (SAGE)

Dataset	Final score
---------	-------------

GLC 2000	26
GLCC	28
AVHRR	25
MOD 12	29
ESA Glob cover	29
FGGD	25
Global Map	31
Land Use System db	24
Global Land Use db (SAGE)	19
Global Land Use Data Sets (NASA)	23

Table 81: RESULTS OF THE QUALITY ASSESSMENT FOR THE SUB-TOPIC HYDROGEOLOGY ON SUB-TOPIC land cover/use, FORESTS, and vegetation

## 6.10 METEO-CLIMATIC

### 6.10.1 RAINFALL

Due to the irrelevance of the sub-topic to the project goal in this thesis, only the list of the available datasets is mentioned here and the quality assessments are omitted.

## 6.11 SOCIO-ECONOMIC

The following databases were evaluated:

- Global Administrative Areas;
- Food insecurity, poverty and environmental Global Gis Database;
- Geographic Information Systems in Sustainable Development;
- GEO Data Portal;
- Atlas of the biosphere - Human Impact;
- World Data Center for Biodiversity and Ecology;
- Global distribution of poverty;
- Food for education global atlas initiative;

Dataset	Final Score
Global Administrative Areas	26
Food insecurity, poverty and environmental Global GIS Database	21
Geographic Information Systems in Sustainable Development	24
GEO Data Portal	27
Atlas of the biosphere - Human Impact	20
World Data Center for Biodiversity and Ecology	20
Global distribution of poverty	21
Food for education global atlas initiative	23

Table 82: Results of the quality assessment: total scores for each dataset FOR SUB-TOPIC SOCIO-ECONOMIC

## 6.12 NATURAL DISASTERS

### 6.12.1 VOLCANIC ERUPTIONS DATA

In the Sub-Topic *Volcanic Eruptions Data*, the following datasets have taken part of the assessment:

- CHRR Centre for hazards and risk research - Columbia University
- Global Hazards Information Network (GHIN) - Pacific Disaster Centre
- The collapse caldera database - Grupo de vulcanologia de Barcelona

Dataset	Final Score
CHRR	30
GHIN	29
CCDB	27

Table 83: Results of the quality assessment: total scores for each dataset FOR SUB-TOPIC VOLCANIC ERUPTION DATA

### 6.12.2 FLOOD DATA

In the SUB-topic *Flood Data* the following datasets have taken part of the assessment:

- CHRR Centre for hazards and risk research - Columbia University
- UNEP/GRID - Global Risk Data Platform
- Dartmouth Flood Observation - Global Active Archive of Large Flood Events
- Centre for Research on the Epidemiology of Disasters (CRED) - Emergency Events Database (EM-DAT)

Dataset	Final Score
CHRR	30
UNEP/GRID	30
Dartmouth Flood Observation	27
EM-DAT/CRED	24

Table 84: RESULTS OF THE QUALITY ASSESSMENT: TOTAL SCORES FOR EACH DATASET ON SUB-TOPIC FLOOD DATA.

### 6.12.3 FIRES DATA

In the topic, *Fires Data* the following datasets have taken part of the assessment:

- UNEP/GRID - Global Risk Data Platform
- Centre for Research on the Epidemiology of Disasters (CRED) - Emergency Events Database (EM-DAT)
- The Fire Locating and Modelling of Burning Emissions (FLAMBE')
- MOD 14 - Thermal Anomalies - Fires and Biomass Burning
- EUMETSat
- The Fire Information for Resource Management System (FIRMS)
- AATSR World Fire Atlas (WFAA) ESA

Dataset	Final Score
UNEP/GRID	25
EM-DAT/CRED	22
FLAMBE <sup>1</sup>	25
MOD 14	30
EUMET Land Products	24
FIRMS	25
WFAA	22

Table 85: Results of the quality assessment: total scores for each dataset ON SUB-TOPIC FIRE DATA

#### 6.12.4 EARTHQUAKE DATA

In the topic *Earthquake Data* the following datasets have taken part of the assessment:

- CHRR Centre for hazards and risk research - Columbia University
- UNEP/GRID - Global Risk Data Platform
- IRIS - Incorporated Research Institutions for Seismology
- CSEM-EMSC Centre Sismologique Euro-méditerranéens

Dataset	Final Score
CHRR	30
UNEP/GRID	30
IRIS	24
CSEM-EMSC	23

Table 86: RESULTS OF THE QUALITY ASSESSMENT: TOTAL SCORES FOR EACH DATASET ON SUB-TOPIC EARTHQUAKE DATA

### 6.13 DATA SETS UTILIZATION IN VARIOUS PROJECTS

#### 6.13.1 EARLY IMPACT ANALYSIS

The main aim of the Early Impact activities is to rapidly produce geo-referenced information on the impact of disasters, especially data on affected areas and population. The rapid mapping activities aimed at supporting the first stage of disaster management are generally based on satellite remote sensing data. Different types of satellite data can be used, mainly according to the type of disaster and the approximate extent of the affected areas:

- Low/medium resolution multispectral optical imagery (e.g.: MODIS, ALOS AVNIR, DMC, Landsat),
- High resolution optical data (e.g.: Spot, Formosat, Ikonos, WorldView-1 and 2; Quickbird, GeoEye),
- Medium resolution radar data e.g.: Envisat, Radar sat, ALOS Palsar);
- High-resolution radar data (e.g. Cosmo-SkyMed, TerraSAR-X);

The aforementioned data belong to two main families: public-domain data (generally accessible through the web (e.g. MODIS, Landsat); or commercial imagery that should be purchased through reseller companies (e.g.: Eurimage, Spotimage, DigitalGlobe). Sometimes it is possible to freely access



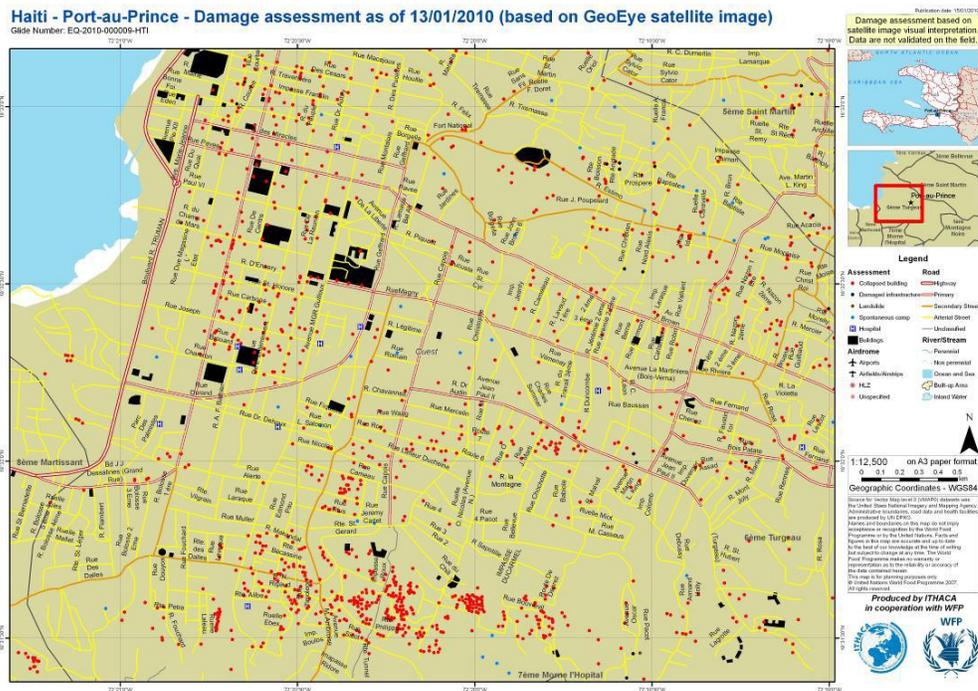


Figure 24: Example of cartographic representation of post-earthquake damage assessment

### 6.13.2 EXTREME RAINFALL DETECTION SYSTEM (ERDS) – VERSION 2

The Extreme Rainfall Detection System (ERDS, <http://erds2.ithacaweb.org/>), developed and implemented by ITHACA, is a service for the monitoring and forecasting of exceptional rainfall events, with a nearly global geographic coverage.

This system is conceived to be a strategic tool, providing complete, immediate and intuitive information about potential flood events, to be used during the preparedness and response phases of the emergency cycle. Information are accessible through a WebGIS application, developed in a complete Open Source environment, that processes and disseminates warnings in an understandable way also for non-specialized users. Available capabilities include the analysis of near real-time rainfall amount and of forecasted rainfall for different lead times, with the aim to deliver extreme rainfall alerts. The combination of such information with reference data allows the system to generate value-added and event-specific information, such as the list of the affected countries and an estimation of the affected population. Currently the system is one of the tools used by UN World Food Program (WFP) Emergency Preparedness Unit.

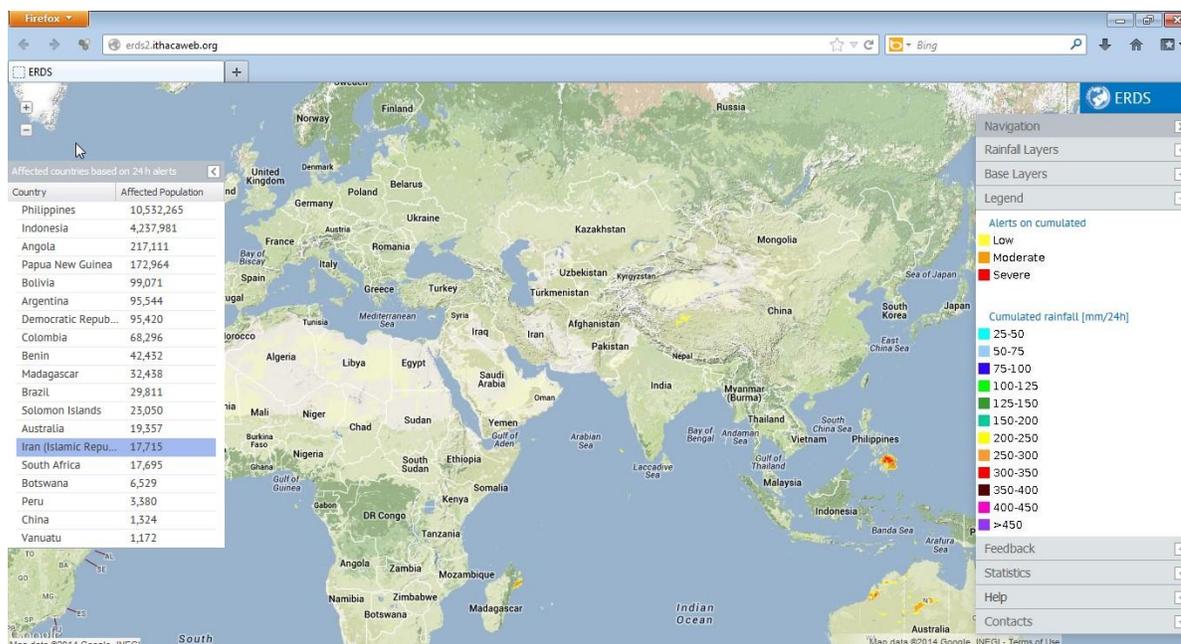


FIGURE 25: INTERFACE VIEW

The data used for the near-real time detection of extreme events are mainly based on the Tropical Rainfall Measuring Mission (TRMM) Multisatellite Precipitation Analysis (TMPA) data, updating on a 3-hour basis. Spatial resolution of TRMM data is 0.25x0.25 Lat/Lon degrees, between 50° latitude N and 50° latitude S.

This system is also able to provide a longer lead-time alerts (up to 6 days) for heavy rain and floods, using forecast rainfall data, coming from NOAA-GFS (Global Forecast System) deterministic weather prediction models, with 1.0x1.0 Lat/Lon degrees resolution and worldwide coverage, updated on a 6-hour basis.

Three different alert levels can be visualized (low, moderate and severe), based on specific rainfall intensity threshold, defined as the amount of precipitation for a given duration over a specific climatologically area. Concerning real-time rainfall data, two kinds of events are considered: short-term events, up to 24 hours cumulated rainfall, and medium terms events, up to 1 week cumulated rainfall. In case of forecasted rainfall data, three kind of events are considered: short term events (24 hours), and medium term events both on 72 hours basis and 6 days basis.

In order to facilitate the users in interpreting the alerts, specific information about the impact of heavy rainfall, such as the visualization of the affected countries and the calculation of the potentially affected population, are displayed in a table. Countries currently under alert are listed, ordered from the potentially most affected to the less affected in terms of population; the header of the table allows the sorting of the content. Clicking on a row triggers the maps to zoom over the envelope extent of the active pixels in the chosen country.

# Data Quality Assessment Processing And Results

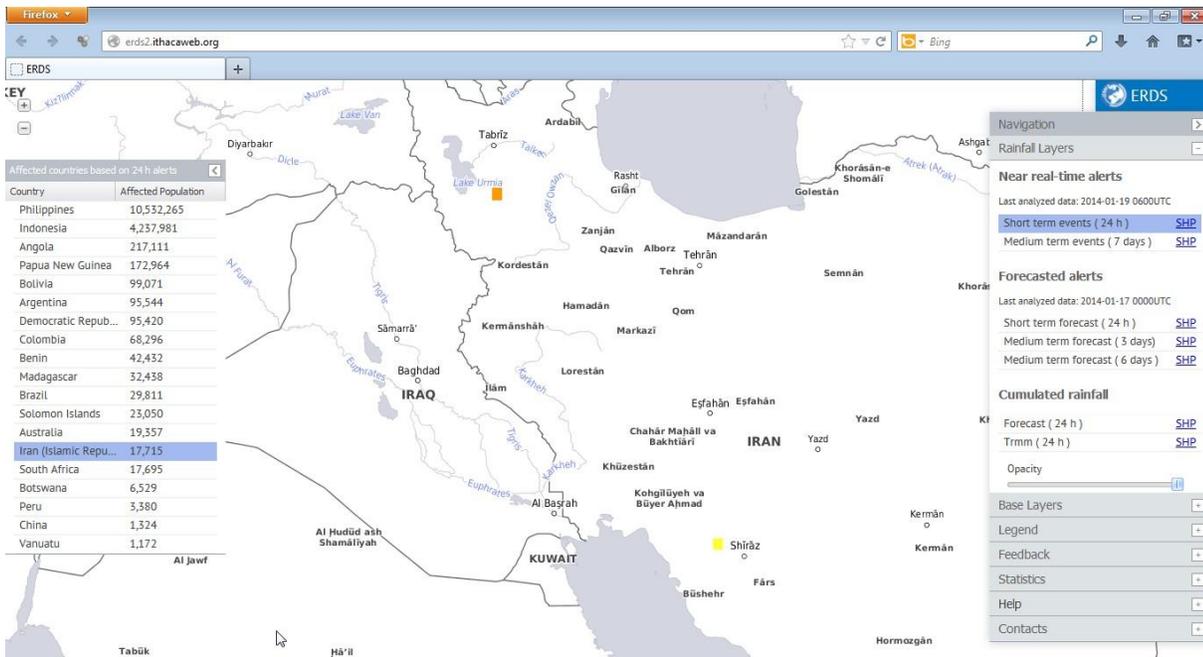


FIGURE 26: EXAMPLE OF ALERTS

## 7. CONCLUSION

GIS software is not only provided by companies but increasingly also by free and open source software projects. While commercial vendors usually offer products for all of software categories, open Source Software projects often concentrate on a single category, e.g. desktop GIS or WebMap server.

The key players in the GIS software market today are Autodesk, Bentley, ESRI Inc., GE (Smallworld), Pitney Bowes (MapInfo), and Intergraph. GIS software companies tend to target specific application domains. For instance, ESRI's ArcGIS product tends to be mainly used for business analysis, planning, and environmental applications, while Autodesk, GE and Bentley products are rather used in utility and facility management. Competitive GIS software that is developed by free software projects exists as well - especially with respect to server applications (MapServer, GeoServer) and spatial DBMS (PostGIS). Free desktop GIS projects, such as Quantum GIS and gvSIG, currently experience growing user communities. Such free GIS software rather complements the set of proprietary software instead of competing with it.

There are well-known benefits of open source software, such as cost savings, vendor independence, and open standards. However, there are also a number of barriers, such as knowledge barriers, legacy integration, forking, sunk costs, and technology immaturity. (Nagy, D., Yassin, A. M., & Bhattacharjee, A. 2010)

Knowledge barriers often exist because potential users are not aware of the availability or relevance of FOSS4G<sup>1</sup>, nor of the technical requirements necessary to make effective use of FOSS4G.

Legacy integration has been problematic when using FOSS4G, but in recent years there have been numerous middleware solutions developed that have minimized this barrier.

Forking of a project occurs when different groups develop software, and the resulting components no longer interoperate with each other because the original project failed to impose adequate standards. This can result in the failure of smaller open source projects that fail to maintain a large enough developer base. This particular barrier can be addressed through the development of self-managed standard groups within a project.

Sunk costs arise due to prior investment in proprietary software. The simplest way to address this barrier is to compare future cost streams of maintaining proprietary software versus open source software.

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<sup>1</sup> FOSS4G stands for Free and Open Source Software for Geospatial.

With regard to technical maturity, it is essential that software be evaluated independently against case studies derived from an organization's core functionality. As an organization, it would be folly to adopt FOSS4G just because other organizations do, or based solely on claims in the literature.

Instead, the decision to adopt FOSS4G should be based upon careful considered rationale (Ven, K., Verelst, J., & Mannaert, H. 2008). The selection process, if it is for business, research, or teaching, should be based on a rigorous software evaluation process.

Among the criteria that should be applied during the evaluation process are for instance: software functionality, software stability, platform support, market share, credibility (and branding) of the software manufacturer, as well as the size of the support and distribution network. While these criteria are common to the selection of proprietary software - with respect to free and open source software other criteria are also important. In particular, consideration should also be given to the software project that created the FOSS4G software, since the status of the project will influence software support, software evolution (in terms of functionality and domain of use), and prolonged existence see also (Cruz, D., et al. 2006).

However, in each case in particular there could be different questions to be asked and answered. These questions can be originated from national or international as well as business and commercial points of view. Some of them are concerned by Managers that has to take care of politics, hi level long-term economic trend and some of them are technical issues that deals with technological nature of GIS software. Nevertheless, it is getting clear that the future belongs to Open Source Software for Geospatial FOSS4G, and the lack of maturity in this field is being vanished during the ages. The more experiences that GIS community gains throughout the development of FOSS4G push them closer into the core design of the software which in past was a black box controlled and dominated by giant GIS software companies. The increasing number of papers, reports as well as the sheer number of downloaded FOSS4G, prove the fact that the future belongs to those who establish it through the breaking all the barriers and bridge towards solving GIS related subjects.

According to (Steinige, S., Hunter, A. 2012) we see three characteristics features for future FOSS4G development, besides a growth in users:

Emergence of new projects;

Consolidation, due to projects that stop their developments (e.g. MapBender and MonoGIS);

Collaboration among projects.

Apart from the necessity for transition showed by GIS community toward Free and Open Source Software that caused considerable multi Software exchange and collaborations; establishment of OSGeo foundation can play an important role as a focal point in this way and has been useful and very efficient.

## 8. ANNEX I

### 8.1 ITHACA

ITHACA is the acronym for Information Technology for Humanitarian Assistance, Cooperation, and Action; it is a non-profit association, founded in November 2006 by the Politecnico di Torino and SiTI.

The different competences characterizing ITHACA are related to the acquisition, management, and elaboration of geographic and cartographic data. The operational team has deep experience in several of the domains concerning Geomatics, such as remote sensing, photogrammetry and Geographic Information Systems (GIS). Therefore, ITHACA is able to produce basic and thematic cartography, through both consolidated and innovative procedures.

With a view to cooperate with the World Food Program, the food aid arm of the United Nations and the world's largest operational humanitarian agency, the Association proposes itself as a centre of applied research and for the distribution of products and services related to Information Technology in support of humanitarian operations. It aims to serve as a bridge between advanced research science and humanitarian practitioners, delivering scientific methodologies, analytical services and technical tools to improve the capacity of the WFP and the broader humanitarian community in Early Warning and Early Impact phases.

ITHACA's activities are realized with the cooperation of Politecnico di Torino, specifically with the Land, Environment, and Geo-Engineering Department and of other technology partners such as public and private research centres, companies operating in the aerospace and telecommunications fields and other suppliers of territorial data. ITHACA is governed by a Board of Directors and assisted by a Technical Committee<sup>1</sup>.

### 8.2 GMES IN BRIEF

The well-being and security of future generations are more than ever dependent on everyone's actions and on the decisions being made today on environmental policies. To take the right actions, decision makers, businesses and citizens must be provided with reliable and up-to-date information on how our planet and its climate are changing. The European Earth monitoring programme GMES provides this information.

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<sup>1</sup> <http://www.ithacaweb.org>

Policymakers and public authorities, the major users of GMES, will use the information to prepare environmental legislation and policies with a particular focus on climate change, monitor their implementation, and assess their effects. GMES also supports the critical decisions that need to be made quickly during emergencies, such as when natural or man-made catastrophes and humanitarian crises occur<sup>1</sup>.

The program envisages the users to be provided with information through services dedicated to a systematic monitoring and forecasting of the state of the Earth's subsystems. Six thematic areas are developed: marine, land, atmosphere, emergency, security, and climate change. A land monitoring service, a marine monitoring service and an atmosphere monitoring service contribute directly to the monitoring of climate change and to the assessment of mitigation and adaptation policies. Two additional GMES services address respectively emergency response related to floods, fires, technological accidents, humanitarian aid and security-related aspects such as maritime surveillance and border control. GMES services are all designed to meet common data and information requirements and have global dimension.

In practice, GMES consists in a complex set of systems, which collects data from multiple sources like earth observation satellites and in situ sensors such as ground stations, airborne and sea-borne sensor; then it processes these data and provides users with reliable and up-to-date information through the services mentioned above. Some of these systems and data sources already exist today, as well as prototype services but many developments are still required in all domains.

The GMES initiative is led by the European Union: the program coordination and management is ensured by the European Commission. The setting up of initial versions of the GMES services have been assigned to several projects partly financed through the seventh Research and Development Framework Program of the European Union. While the developments related to the observation infrastructure are performed under the aegis of the European Space Agency for the space component, such as the Sentinel missions, and of the European Environment Agency and the Member States for the in situ component. The sustainability of the GMES operational services are going to be ensured through public funding from EU, intergovernmental agencies, and Member States. These services should be accessible to any organization or citizen, because they are considered as “public goods”.

Based on the GMES services, many other value-added services tailored to more public or commercial needs are envisaged to be developed: for instance, forecasting services with a local scope and others include socio-economic data. This is going to stimulate the downstream sector.

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<sup>1</sup> [www.gmes.info](http://www.gmes.info)

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