Design of Web-GIS of the Major Risks in Algeria and Implementation with Two Cartographic Servers

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Abstract
The objective of this work is to propose, at first, a conceptual data model of a Geodatabase dedicated to the disaster management in Algeria. This model highlights the two main components of disasters management: the risk prevention and the response to the disaster, while respecting the 04.20 law (an Algerian law on the prevention of major risks and disaster management in the context of sustainable development). The second part aims to create a WEB-GIS for publishing spatial data corresponding to major risks in Algeria. This solution has been implemented on two cartographic servers (GeoServer and MapServer), a Web server and a spatial database server, all from open source tools.

1. Introduction

Natural disasters such as earthquakes, hurricanes, floods, avalanches, forest fires, landslides, etc.., cause considerable damages every year all over the world, with serious consequences for the life and health of people, the economy, urban structures and landscapes. During the last decade, the disasters are becoming stronger and more frequent. The number of people that have been impacted is increasing as well. In the Mediterranean, Algeria is exposed to a set of natural and industrial disasters risks. It has experienced earthquakes (El Asnam in 1980 Boumerdes in 2003), floods (Bab El Oued in 2001, in 2008 Ghadaïa ...), industrial accidents (the accident at the gas liquefaction complex "GL-1K" Skikda in June 2004 etc.). From warning the population to the monitoring of the post-disaster event, Geoinformation systems combined with other segments of information and communication technologies can provide the necessary elements for decision making and crisis management. Real-time cartographic data tools show the capacity to provide solutions for rational management of the crisis.

National governments, international organizations and research institutions worldwide have set to work to improve disaster management in all its phases. In this aspect, the awareness of new geospatial technologies and their successful utilization in disaster management is becoming crucial. These technologies are emerging very fast contributing in turn to reduce losses of life and property (Orhan et al., 2010). Rapid mapping process is one of the potential tools, which helps to generate all possible cartographic products of the affected area in very short delays in order to reduce disaster risks and losses. And consequently, action programs and rescue plans are developed accordingly in order to protect people, property and the environment. This information can easily be shared with people who respond to the news of the disaster as well as orchestrate aid operations in efficient way. Extensive role of media covering recent major crises highlights new practices in managing and processing information of this type of event. Internet has become a crossroads where victims and their families, governments, civil security services gather to share and manage the crisis. Adapting to this massive information flow, new geoinformation technologies are supporting a wide range of data provided by different databases especially those called open sources.

In this article, following a need expressed by the departments involved in disaster management of the Algerian ministry of the Interior and Local government, the design and application of a disaster management concept based exclusively on open sources will be introduced in order to collect, process, analyse and distribute the necessary data during the crisis. In the end, a local geodatabase is created and updated permanently from the database source. During the crisis, different levels of users can access to the local database in order to retrieve, visualize, customize and disseminate the data using web-based disaster management application. This article is organized as following: an introduction and reviewing the literature about principal disaster management laws in Algeria, then a presentation of a conceptual model of our database. The second part will be dedicated to achieving our Web GIS solution. Finally, a conclusion with some perspectives.

2. The Disaster Management System in Algeria

The need to develop a strategy for reducing disaster risk pressed the Algerian governments to adopt a "National Plan for Disaster Reduction and Response and Relief Organization" in May 29, 1985, accompanied by a short, medium and long terms program. This immediately translated after the promulgation of 85-232 and 85-231 decrees of August 25, 1985, respectively surrounding the two (2) aspects of prevention, on one hand, and intervention and aid on the other. In 2004 the 04-20 law of 25 December 2004 on the prevention of major risks and disaster management in the context of sustainable development has strengthened the legislative system that existed and was governed by two decrees of 1985. This law (04-20) provides two devices: one for risk prevention and the other for disaster management which aim to protect territories and populations against the risks associated with natural hazards (Various P, 1985).

3. Disaster Management Cycle

Natural disasters often occur as a function of vulnerability (fragility factor) and risks (probability); which leads analysts to often use the equation:

$$\text{Risk} = \text{Vulnerability} * \text{Impact}.$$

Therefore, development in all countries should not just consist of unstoppable growth but also a reduction of "vulnerabilities" and risks zone by zone. By developing this approach, we should introduce a parameter of "prevention" in development policies. Nowadays, many countries have adopted disaster management plan as a primary ongoing process in their annual agenda; using administrative directives, organizations and operational skills and capacities to implement strategies, policies and improved coping capacities in order to reduce the adverse impacts of hazards and the possibility of disaster. A new emerged idea has been highlighting a question of whether we can reduce the disaster risks before the impact through systematic efforts by analyzing and managing the causal factors of disasters, including through reduced exposure to hazards, lessened vulnerability of people and property, wise management of land and environment, and improved preparedness for adverse events (UNISDR, 2009).

As the amplitude of natural disasters in the world is increasing dramatically, the prevention to reduce their impact without discontinuity is a continuing challenge. It is therefore necessary to deploy and improve concepts for forecasting, monitoring tools and develop regulatory measures and contingency plans for disasters. In this context, different models for disaster management are developed based on the four phases of the disaster management life cycle aiming to avoid or reduce as much as possible potential losses from hazards (Figure 1). The critical step in the cycle appears to be the respond phase by its impact on limiting losses of human life on one hand; and how fast to assure prompt and appropriate assistance to victims on the other hand. Often, the disaster impact is followed by an emergency situation calling for a series of immediate and rapid responses. These include initial rapid assessment, search and res-cue, and emergency relief to stabilize the situation, followed swiftly by more detailed damage, needs and capacities assessment, leading to short-term interventions to safeguard life, health and livelihoods in the medium term (Wisner and Adam, 2002).

Figure 1: Disaster management life cycle (Kada, 2012)

4. Potential of Geoinformation Systems

Reducing the impact of disasters requires a complex mix of technical and social activities, and no single prescription or discipline can provide all the answers. Information Technology represents an important point of leverage for enhancing disaster management by providing the necessary elements to the decision makers (Ramesh et al., 2007). In the last ten years, experts learned from facing different and strong disasters, that availability, processing and dissemination of geoinformation data play a critical role in disaster management especially in the outcome of the event and saving lives. Considering geoinformation system one of the most important components of IT which has been involved in all stages of disaster management life cycle; it is widely used to provide accurate data for location, mapping and preliminary estimates of damage in the affected areas. From prevention to immediate reaction, GIS can provide additional complex tools and make the phase more efficient and intuitive. Also, the interoperability aspect of the geoinformation technology makes the data sharing easier and avoids wasting a precious time in exchanging from/to different formats.

5. Database Design

Modelling our database for the management of major risks highlights the risk prevention component as well as the modalities of intervention in disaster, provided in the texts of laws and regulations. This model is represented by the DCM below (Figure 2). The description of the tables of this model is presented in the Table 1

6. Completion of the Application

In this second part, we present the application developed to fulfil the needs expressed before which are summed up in the implementation of a Web-GIS mapping tool that enables the creation and integration of geographic data related to major risks in Algeria. In order to do this, it is necessary to consider; at first, the audience. Next consideration will be made on the features that should be incorporated into the application and the geographic data to publish.

6.1 Users of the Application

This application is dedicated for two types of users, the first is the risk management department of the Algerian Ministry of the Interior and Local government which has the ability to create, change and consult the database. While the second is represented by the general public that will have the possibility to consult the database.

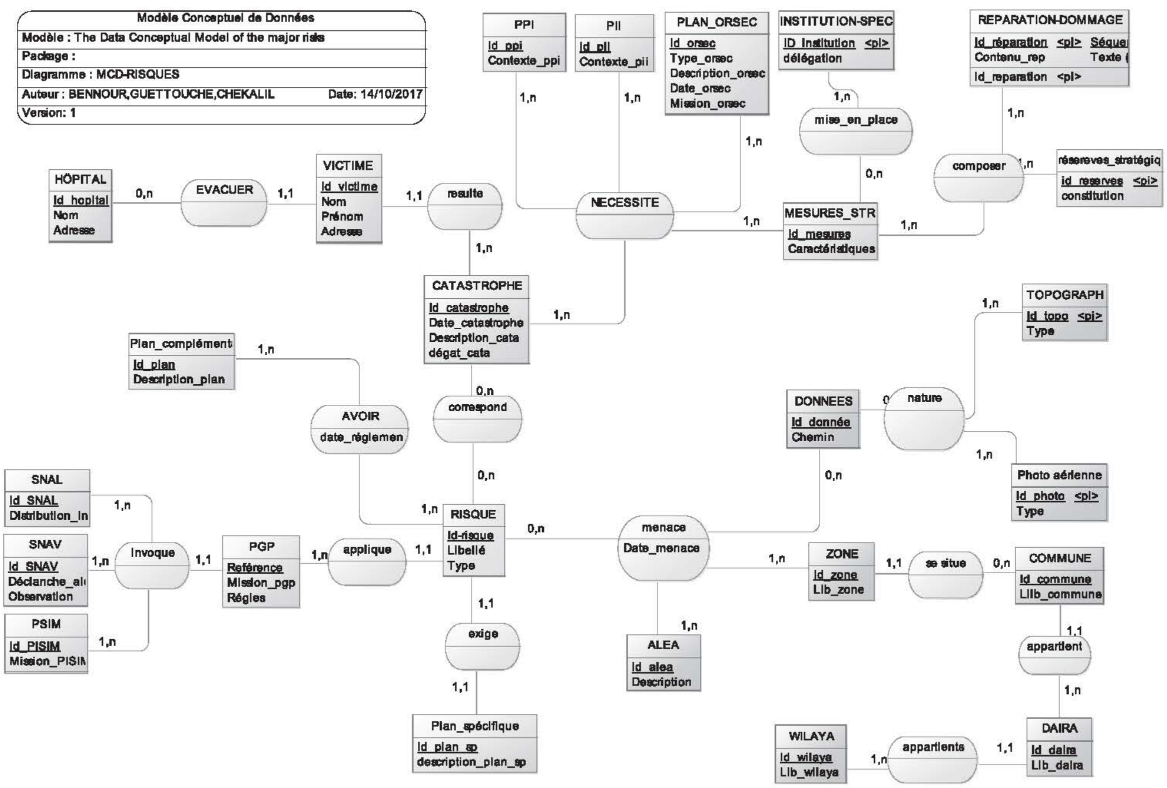

Figure 2: The Data Conceptual Model of the major risks

Table 1: Description of used tables

Table	Description
Risque	Risks
Données	Geographic data concerning the risks, disasters
Typologie	Type of data : point, line, polygon, raster
Alea	Different hazards that can cause a risk
Zone	Sensitive areas
Commune	List of towns
Daira	List of sub-prefecture
Wilaya	List of prefecture
PGP	General plan for the prevention of major risks
SNAV	National vigil system
SNAL	National Alert System
PSIM	National simulation programs of major risks used to check and improve prevention
Plan_Spécifique	Specific plans required for each type of risks
plan_complementaire	Complementary plans which guarantees the widest protection of persons and
Catastrophe	Disaster
Plan_ORSEC	Succor organization plans
Victime	Victims of disasters (dead and injured).
Hoptial	Hospitals to evacuate victims.
PPI	Special Plans of Intervention
mesures_structurelles	Structural measures to be taken following the occurrence of the disaster
Institution_spécialisée	Institutions responsible for putting the structural measures.
Reserves_stratégiques	Strategic reserves made in the disaster by the institutions.
Réparation_dommage	Damage caused by disasters and repaired by the institutions.

6.2 Components and Technologies

The selected components for the implementation of the application will allow us to develop navigation tools more or less accessible in a customizable Web interface. The technologies used in the different components are:

6.2.1 Web server (Apache)

Nearly 400 million Websites powered worldwide (nearly 70 percent) are now running on the legendary Apache HTTP server (Report, 2009). In addition to the open and industry-friendly licensing aspect, Apache has been chosen based to other crucial factors such as stability, security, flexibility, modular and reliability. The new release (v2.4) delivers a host of evolutionary enhancements throughout the server that users, administrators, and developers will welcome. Many new modules has been added in this release, as well as broadened the capability and flexibility of existing features (Blog Apache, 2014).

6.2.2 Web map server

The Web Map Server is the automated portal used by different users to display maps on their own computers. By using Internet communication protocol, TCP / IP, networked computers can share information through a Web browser, software or transfer files through FTP. The architecture is client/server, meaning that a computer called server responds to requests from a series of computers called clients. (Kada, 2012). In this project, we used two servers interact between.

6.2.2.1 GeoServer (2.4.3)

GeoServer is an open source software server written in Java that allows users to share and edit geospatial data. Designed for interoperability, it publishes data from any major spatial data source using open standards. Powered by community-driven project, GeoServer is developed, tested, and supported by a diverse group of individuals and organizations from around the world. Regarding standards, GeoServer is the reference implementation of the Open Geospatial Consortium (OGC) Web Feature Service (WFS) and Web Coverage Service (WCS) standards, as well as a high performance certified compliant Web Map Service (WMS) (GeoServer, 2014).

6.2.2.2 Mapserver (6.4.1)

MapServer is an Open Source platform for publishing spatial data and interactive mapping applications to the web. MapServer is released under an MIT-style license, and runs on all major platforms (Windows, Linux, Mac OS X).

MapServer is not a full-featured GIS system, nor does it aspire to be. MapServer support of numerous Open Geospatial Consortium (OGC) standards: WMS (client/server), non-transactional WFS (client/server), WMC, WCS, Filter Encoding, SLD, GML, SOS, OM. (Mapserver, 2014)

6.2.3 Database management system

PostgreSQL is an open source object-relational database management system (ORDBMS) supporting the standards of SQL technology. It has an excellent performance, high record of reliability, it is rich in features; easy to use, learn and manage. PostgreSQL is designed for large and small applications. Whether it will be transaction processing or data warehousing, PostgreSQL is the most suitable solution even in some cases competing the commercial ones. PostgreSQL has an extensive support from technical community, experts and users over the world (John and Joshua, 2011). SQL is considered as a strongly typed language. This means that any piece of data represented by PostgreSQL has an associated data type, even if it is not plainly obvious. Officially supported by PostgreSQL, geometric types have offered, with combination of PostGIS plugin, to GIS experts to build up a real geoinformation platform with high flexibility and ease management of the database. Open source PostGIS, adds support for geographic objects to the PostgreSQL object-relational database. In effect, PostGIS "spatially enables" the PostgreSQL server, allowing it to be used as a backend spatial database for geographic information systems (GIS), much like ESRI's SDE or Oracle's Spatial extension (PostGIS, 2014).

6.2.4 Client Side

Born from the fusion of OpenLayers and Ext, GeoExt is an open source JavaScript library to build rich mapping interface easily. Much more than a simple combination of the two mother libraries, GeoExt has completely redesigned the initial cluster models to offer the final completely custom new objects. Inheriting the powerful modules from OpenLayers library, GeoExt can create a very complex GIS mapping tools allowing a high interactivity and conviviality while manipulating geospatial data (Kada, 2012). We opted for the GeoExt API in its 0.7 version. To sum up, GeoExt corresponds to the intersection of the mapping

6.2.5 Free packages

6.2.5.1 QGIS

QGIS is a user-friendly Open Source Geographic Information System (GIS) licensed under the GNU General Public License. QGIS is an official project of the Open Source Geospatial Foundation (OSGeo). It runs on Linux, Unix, Mac OSX, and Windows and supports numerous vector, raster, and database formats and functionalities (QGIS, 2014).

6.2.5.2 UDIG

uDig is an open source desktop application framework, built with Eclipse Rich Client (RCP) technology. uDig can be used as a stand-alone application. It can be extended with RCP "plug-ins". uDig can be used as a plug-in in an existing RCP application.

6.3 System design and implementation

After discussing the necessary open source technology required to build-up a GIS working platform, comes the overall architecture of this software platform. It is subdivided into two main groups: server side and client side. We opted for an architecture client/server whose GeoServer and MapServer are a Web Map Servers and are GeoExt as API to achieve the client side interface and PostGIS as DBMS. Different protocols are supported in this architecture allowing interaction and manipulating data. HTTP query are sent from an internet browser to Apache web server, then receive HTML pages as a response of the initial query. OGC web services are used to exchange the data with PostgreSQL database using QGIS aiming to retrieve the data on one hand, and push back update sets on the other hand; depending on the privileges set earlier on the Geoserver level. uDig is used to create data style in order to display it in Web Map server.

Geoserver as a GIS server works without any problem with vector data available in postgis2 database. The innovation introduced to the version 02 of PostGIS facilitates integration and processing of vector data. Many changes were added. For example, it is possible to load a large amount of vector data at the same time. The scanned maps loaded to PostGIS are displayed in Mapserver using GeoExt. Mapserver was used to manipulate PostGIS raster database. The Mapserver product was selected due to some JDBC connectivity issues faced in Geoserver for Pgraster data type. The WMS published using Mapserver for Pgraster data was accessed in Geoserver as a WMS store and a final WMS/WMTS for public access is provided using Geoserver. Also, existing scanned maps are presented in one band. QGIG was used to convert it into three bands (Red, Green, and Blue). After that, it can be displayed with colors and not in grey scale. During this project, it is demonstrated that the above architecture is workable and is a stable solution.

Compatibility issues of different software products are solved.

6.3.1 Publisher

The publisher tier collects all possible queries sent from different users; whether coming from Apache server, then forwarded to Geoserver; or coming directly from GIS client to Geoserver. Queries are processed and the publisher sends back to the answer to the correct original user so that data logic flow is completed. Using GeoServer, all vector layers and raster layers are published respectively through WFS and WMS services. A set of client parameters can be set to define the access rule for each user like read only, write, etc. Styling map layers in GeoServer can be done using Styled Layer Descriptor (SLD) code, in order to define every style which will be printed on the map for example: color, feature dimensions, using specific symbology, zoom level criteria, etc. Within the framework of disaster management, styling file can play a significant role for customizing thematic maps, by using specific symbology for related disaster features like shelters, hospital, school, critical facilities, etc. The administrator describes, earlier before the disaster, this file with all expected symbology, so any user during the crisis management will use it directly without wasting time.

6.3.2 Administrator

Administrator tier, as its name indicates, consists of the full system administration, including collecting data, loading the data, managing the database, publishing data, and styling the data (SLD file). PgAdmin is a graphical user interface tool for administration and management of the database. The administrator generates the necessary tiles to be served as WMS requests and set up the automated tiles generation process after each database update. These tasks have to be done earlier before the crisis in the preparedness phase of the disaster management life cycle. Also, for crisis mapping, the administrator has full access to use, UDig tool to generate maps in very short delay, or QGIS software for further GIS analysis tasks. Finally, different thematic maps are generated to support relief activities.

6.3.3 User

User tier is composed of all potential clients that connect to the back-end PostgreSQL database. Usually, users don't have the right to manipulate the vector data, except for allowed one by the administrator. In general, users retrieve the data through WMS or WFS protocols using QGIS or web mapping application (GeoExt), and depending on the right given by the administrator, users can only view and print maps, or manipulate, push-back the update and print maps (Figure 3).

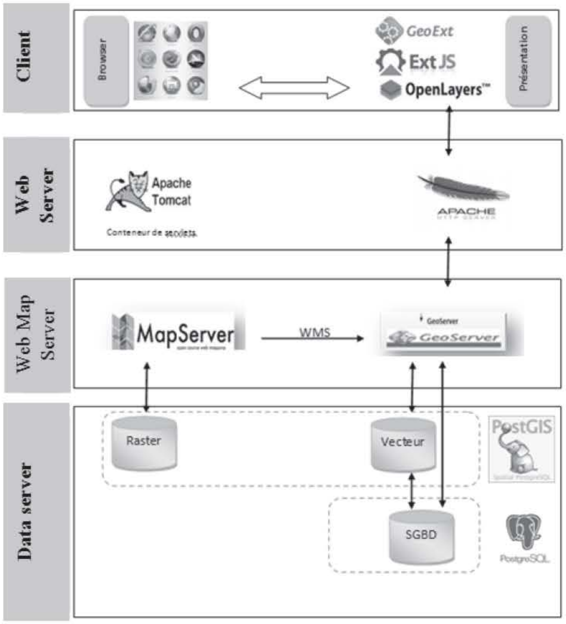

Figure 3: Architecture software of the solution

6.4 Data Sources

In addition to the free data (Google and OpenStreetMap), the data used in this project are from different state institutions in Algeria namely:

- The National Agency of Water Resources (NAWR) : water resource and flows maps ;
- The data produced by the National Institute of Cartography and Remote Sensing (NICRS) : topographical database, satellite images;
- The Centre for Research in Astronomy, Astrophysics and Geophysics (CRAAG): the seismological data.
- National Metrology Agency (NMA): the precipitation data.
- The maps produced using ArcGIS software: flood risk layers, forest fires and earthquakes layers.
- The National Statistics Office (NSO): tabular data.
- The Algerian Ministry of the Interior: tabular data.

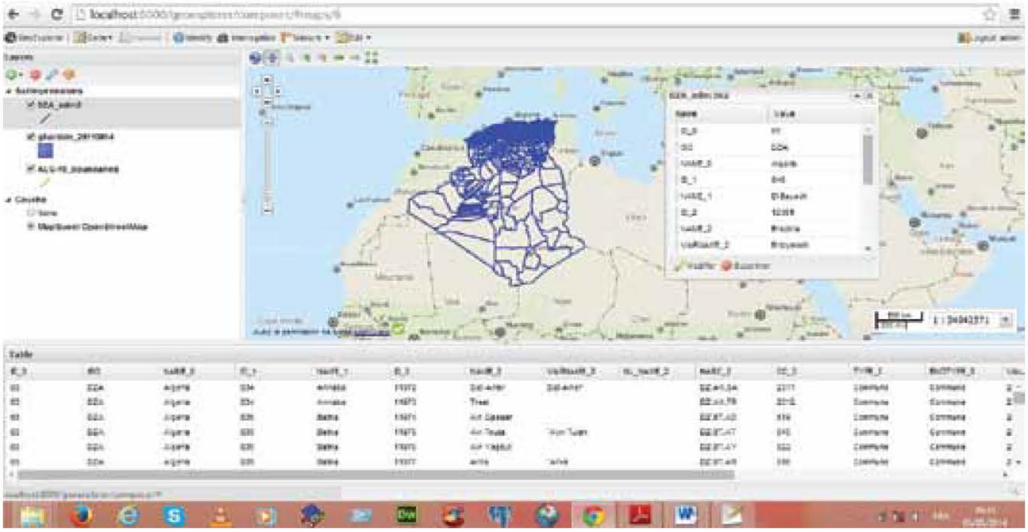

Figure 4: Map interface of Web-GIS of the major risks in Algeria

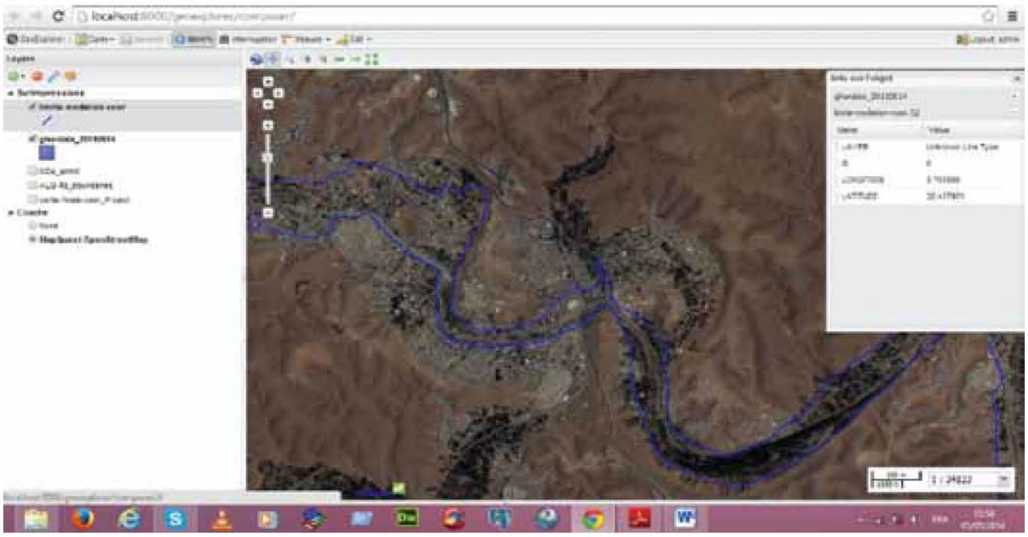

Figure 5: Identification of flood Risk

Figure 6: Forest fires distribution map in 2014

6.5 Data Characteristics

Two maps were produced in Algeria, the NGI (National Geographic Institute) maps (before 1962) and NICRS (National Institute of Cartography and Remote Sensing) maps (after 1962). The study area is the country of ALGERIA, which is limited in four UTM zones (29, 30, 31, and 32). The Coordinate Reference Systems (CRS) used in NICRS are:

- Nord Sahara 1959: UTM Zone 29N, UTM Zone 30N, UTM Zone 31N, UTM Zone 32N.
- WGS84: UTM Zone 29N, UTM Zone 30N, UTM Zone 31N, UTM Zone 32N.

In this project, the coordinate reference system used is WGS84 (Projection: UTM, Spheroid: WGS84, Datum: WGS84, Map units: meters).

7. The Interface of the Application

Respecting the general schema of any GIS software, the Web-GIS developed application is subdivided into five sections (see Figure 4):

A - Map Object: It is a map panel window to display spatial data (vector or raster).

B - WMS browser: It a "GetCapabilities" request sent to GeoServer and the response is intercepted and arranged within a grid displaying all published layers

C - Layer Tree It is a "DescribeFeatureType" request sent to GeoServer and the response is intercepted and arranged within a layer container tree allowing users to control the visible layers on the map panel

D - WMS browser: It is a "GetFeature" request sent to GeoServer and the response is intercepted and arranged within a feature grid displaying all attributes of the vector layer

E - Dynamic Legend: Shows a legend image for a WMS layer. The image can be read from the styles field of a layer record (if the record comes from "WMSCapabilitiesReader").

8. Use Cases

A use case of our WEB-GIS is to define the mapping of the flooded areas, with indication of the flooding heights of the affected areas. This mapping is based on the analysis of medium-resolution images taken before and after floods to assess the damage caused by these floods and their impact on local activity (Figure 5). Another natural risk in Algeria is the forest fires, the system's database contains a layer of this risk (Figure 6). Forest fire mapping is essentially based on the remote sensing of different fireplaces using satellites, and maps that define the type of land use (forests, maquis, agricultural land, etc...).

9. Conclusion

The objective of this work was to propose approaches that meet our problem: designing a geodatabase of major risks and implementation of WEB-GIS. A system design based on open source technologies to support crisis management has been successfully achieved. Free and Open Source Software for Geospatial (FOSS4G) can be efficiently used for spatial applications, and providing spatial data. For example, thematic maps in very short delay, using free data or data of different producers of geographic information in Algeria. The administrator clients, accessing directly to the back-end geodatabase, start generating maps. By changing the bounding box, zoom level and disaster related styling file, high scale and well-designed maps are generated. With Quantum GIS, further thematic analysis is performed for crisis mapping, where a specific symbology is suitably used. General users, with low privileges, can use WMS or WFS communication protocol to retrieve, view, manipulate and print the data.

In parallel, decision makers are receiving permanently every new version of updated map, in order to coordinate and focus the first activities on the most vulnerable people and save lives. Indeed, for the implementation of our WEB-GIS the Geoserver was employed as vector data server. A good performance was proved during the project. Concerning raster database, the Mapserver was used as raster data server. A tentative to use Geoserver by adding ImagemosaicJDB was not successful. It should be noted that the relevance of this system is the ability to quickly dispose of the latest updates, assumes an active partnership with key participants in the topic of the risk in Algeria which ensures both the knowledge of hazards, and an effective disaster management. Finally, further work can be done to improve this project. Integration into Spatial Data Infrastructure (SDI) framework is highly recommended, in order to take benefit from the sharing data policies that support the SDI.

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