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A WEBGIS FOR DATA COLLECTION AND DECISION SUPPORT IN NATURAL DISASTER MANAGEMENT: A CASE OF BAMENDA, CAMEROON

Akam, B*, Zhang .F* and Laari, P.B**
**Faculty of Information Engineering, China University of Geosciences*
***Department of Environment and Resource Studies, University for Development Studies-Wa*

Abstract
WebGIS is increasingly becoming a useful spatial tool for effective interventions and decision-making in disaster and natural resource management. This paper presents the techniques used for the development of a prototype Web based GIS tool for risk analysis of natural hazards like floods and landslides. The scheme designed uses open source as well as proprietary geospatial software and technology. It aims at being a prototype or a tool to assist officials and risk managers in analyzing the vulnerability of communities to identify risk. Moreover, it also serves as a useful data collection mechanism, place of identification and interactive visualization tool. This is a vital input into the decision-making process to enable risk managers make informed decisions in the selection of natural hazard management strategies. The platform developed enables users to upload information about recent hazard occurrences, do flood plain delineation, and interactively visualize datasets of the area of study. This system basically combines hazard history, recent hazard occurrence, hydrological and landscape information for natural hazard monitoring. It is expected that this would serve as a base tool to spatially monitor, highlight and tailor interventions at areas prone to natural disaster occurrence.

Keywords: **WebGIS, Risk Assessment, Flood and Natural Disaster**

Introduction

Natural disasters are reportedly increasing worldwide; partially due to population increase and increasing concentration of populations in hazard prone environments (Awuor, 2008; Doocy et al., 2013).The natural events like hurricanes, floods, earthquakes or tornadoes are, in fact, hazards that have the potential to harm people and damage property. They become hazards and cause disasters when they interact with vulnerable communities in a way that overwhelms their ability to cope (Ragheb and Tzu, 2008; Stobil 2012: Hannigan, 2013).

Hazardous processes in mountainous environments such as landslides, debris flows and floods have also increased in terms of frequency, magnitude and impact, as a result of climate change combined with continuously growing settlement areas (Sterlacchini et al., 2014).

Natural hazards have been recurrent in Cameroon in recent years; they have become usual occurrence with very little to halt this situation. More of these have occurred in areas within Bamenda. Several urban slum have suffered from such hazards such as the Limbe floods in 2001, Floods and a landslide at Abangoh Bamenda in 2004 (Lambi, 2004) and similar floods in Sisia neighborhood (Ndi, 2010).

Annual flooding in the Bamenda flood plains have caused enormous damage to property, life and the socio-economic development of the area. These disasters if neglected, have the potential of plunging the area into an abyss of environmental chaos (Nyambod, 2010). The impact of these natural hazards or disasters is normally very intense at local communities even though resources and mobilization from the local Government is often in adequate and most often lack immediate strategies to mitigate these effects (Bang, 2013). There is therefore need for a multidisciplinary and holistic range of approaches to solving present day environmental hazards in Bamenda, which is rapidly developing amidst such hazards.

The aftermaths of these natural disasters are always dilapidating to the economy (Kalinaki, 2012) and the affected areas become more vulnerable to the coming disasters. GIS is an essential tool in addressing natural disaster management. Its capability lies in the fact that it is designed to provide succinct, up-to-date information particularly to managers and first responders in their assessment of the natural disaster, at any stage and time (Peggion et al., 2008; Giri et al., 2011).

It is however not widely used in disaster scenarios due to lack of disaster data to feed them and if it exists, getting ones hands on it is very costly. This technique have raised great expectations as potential means of coping with natural disasters, including floods and landslides. Although GIS and spatial data play an important role in disaster management, data formats and data standards can also prove a limiting factor in the deployment of GIS infrastructure.

Risk assessment and management therefore includes the estimation of the level of risk, followed by an evaluation of whether this level of risk is acceptable or not thereby exploring the adaptation of appropriate measures to mitigate this risk (Fell et al., 2008). Nowadays, with the support of advanced internet developments, open-source data, software and technologies, it has become much more easier to exchange and analyse spatial information on the web through webGIS based applications. WebGIS originates from a combination of web technology and GIS, which is a recognized technology that is mainly composed of data handling tools for storage, recovery, management and analysis of spatial data (Pessina et al, 2009).This webGIS based application of disaster monitoring has been used in few instances to explore, predict and identify areas where support must be tailored though an emerging trend in Cameroon. (Yao, 2000: Prakash, 2013; Ayer 2016)

This paper aims at contributing to the practice of the open source research community through the development of an interactive, open-source WebGIS-based risk analysis tool for natural hazards management such as floods and landslides.

Methodology/System Design

Database Conceptual Model

This database conceptual model is used as a method for designing the spatial database according to its own design activity, model and purpose (Yannuar et al, 2003). It is designed as a bridge between the urban reality and its spatial representation as far as information on urban realties of flooding and landslides in a spatial database is concerned.

Tools for conceptual modeling

Several tools to support the conceptual database modeling activity has been developed. One widely accepted and used technique is the entity –relationship (E-R) modeling technique developed by Chen and Shen (Chen, 1976; Shen et, al., 2004). Assertions are placed on the detailed E-R between the entity and the relationships using the following conventions, optionality: cardinality, where

Optionality '0' - can
Optionality '1' - Must
Cardinality '1' - Only one
Cardinality 'N'- Many or At least one.

The list of possible outcomes of optionality and cardinality that can appear on the E-R diagram is stated below.

0:1 - [Entity] **can** [relationship] only one [Entity]

0:N- [Entity]can [relationship] many [Entity] or [Entity] can [relationship] at least one [Entity]

1:1-[Entity] Must [relationship] only one [Entity]

1: N [Entity] Must [relationship] many [entity] or [entity] must [relationship] at least one [entity]

Data Flow Model

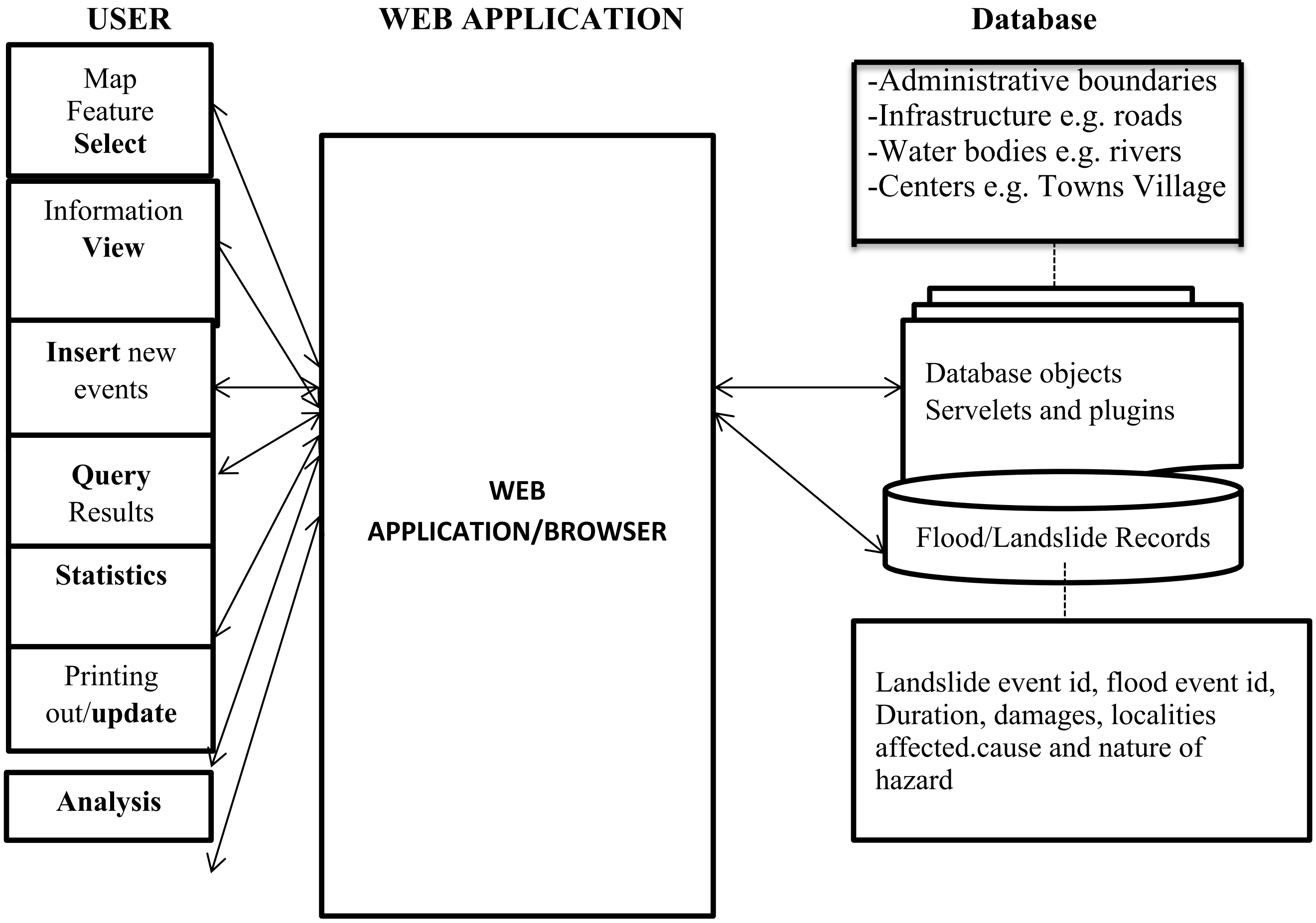


Figure 1: Data flow Model of the Platform.

Landslide and flood events as records in the database are stored and retrieved by the web application. The use of a database is an ideal choice for this data model because databases offer reduced data entry, storage, and retrieval cost (Beynon 2004; Cattell, 2011).

In this model communication between the data files and the web application is possible; Using this application requires the user to perform some task which include being able to view, insert and select/query some items on the application. The arrows represent directional flow through the system in a two way communication.

System Implementation and Discussion

Risk Modelling

As a tool for decision support the risk model used five factors to illustrate the causes and influence of each hazard occurrence. The factors included, wetland, river, slope, locality, and road network, using a pair wise comparison and an Eigen vector of weights. For flood calibrations, *wetlands* had highest value of *0.557,* while for landslide calibrations *Habitat* and *Roads* highest values 0.45 each. Though other human factors might trigger the occurrence of hazards, these factors are considered to be the predominant triggers of hazard in Bamenda, as such all vulnerability maps are built around them.

Data

Primary data in the form of shape file was gotten from CAMGIS and other online resources, Secondary data, that is hazard event history and occurrences was mostly gotten from reports, past research journals and online resources since 2004

Data Transformation

Secondary data, combined with information from Contour, Localities, Wetlands and stream data layers were used in ArcGIS 10.2 to produce new shape file layers*, Landslide extend.shp, Escarpment.shp, Floods.shp and flood extend.shp* respectively. An Attribute table was created for each of this new layers. This was done to make vulnerability analysis convenient.

Web Application Realization

Technology Choices

To accomplish an interoperable design these technologies using programming languages were selected and shown in Table 1

Web Application	Map Service	Data Management
Open Layers JavaScript API + JQuery JavaScript API + HTML + Servlets	Geoserver	Oracle Database

Table 1.Technological choices

Most of the technological choices are free and extendable open source GIS products, open layers JavaScript API and JQuery JavaScript API for the web application interface. A Geoserver as the Map service provider and the data management function by Oracle Spatial. Even though it is not free, it is a powerful relational database system, especially suitable for handling large data sets

System Architecture

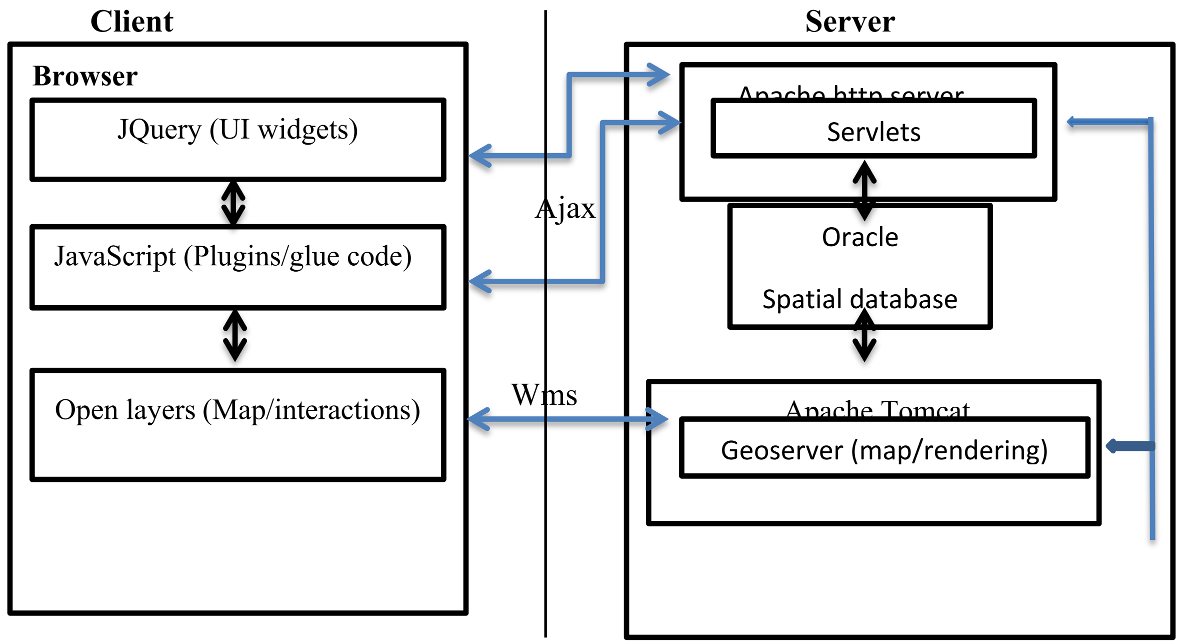


Figure 2: System Implementation Architecture

The client (browser) side is specialized in presenting a task. It consist of a web interface responsible for data entry .Visualization and manipulation task is powered by JavaScript libraries, JQuery and Open layers 3.

Spatial Database Implementation.

The database design is more of an object related database design in which entities have relationships with database objects which communicate with web service and web application by means of servlets. The tables (entities) in the database can be identified based on the following sub categories, *Decision support* (New events), *hazard information* (flood event, landslide event), *vulnerability factors* (escarpment, floodplains), *risk factors* (localities. roads), *spatial data management* (WMS, vector, layers, viewport), *objects* (plugins, services, function, entity). To implement the conceptual model we went further to create a Crows foot **(**R-M) diagram, which is an implementation model diagram as such represents the developer's view of the data and the physical structure of the database,

(Fidel, 2013) illustrates three main kinds of relationships, *One to Many*, *Many to Many*, and *One to One.* The database is at the center of the design and it serves the web application with all the useful information it needs pertaining to hazards and acts as a repository of new hazard events recorded in the *New Events* Table (Figure 3). All functionality of the web application is powered by the database objects, *Plugins and Services*, while hazard attribute data and vector data are stored differently as tables. The crow's foot diagram can be seen in Figure 3.

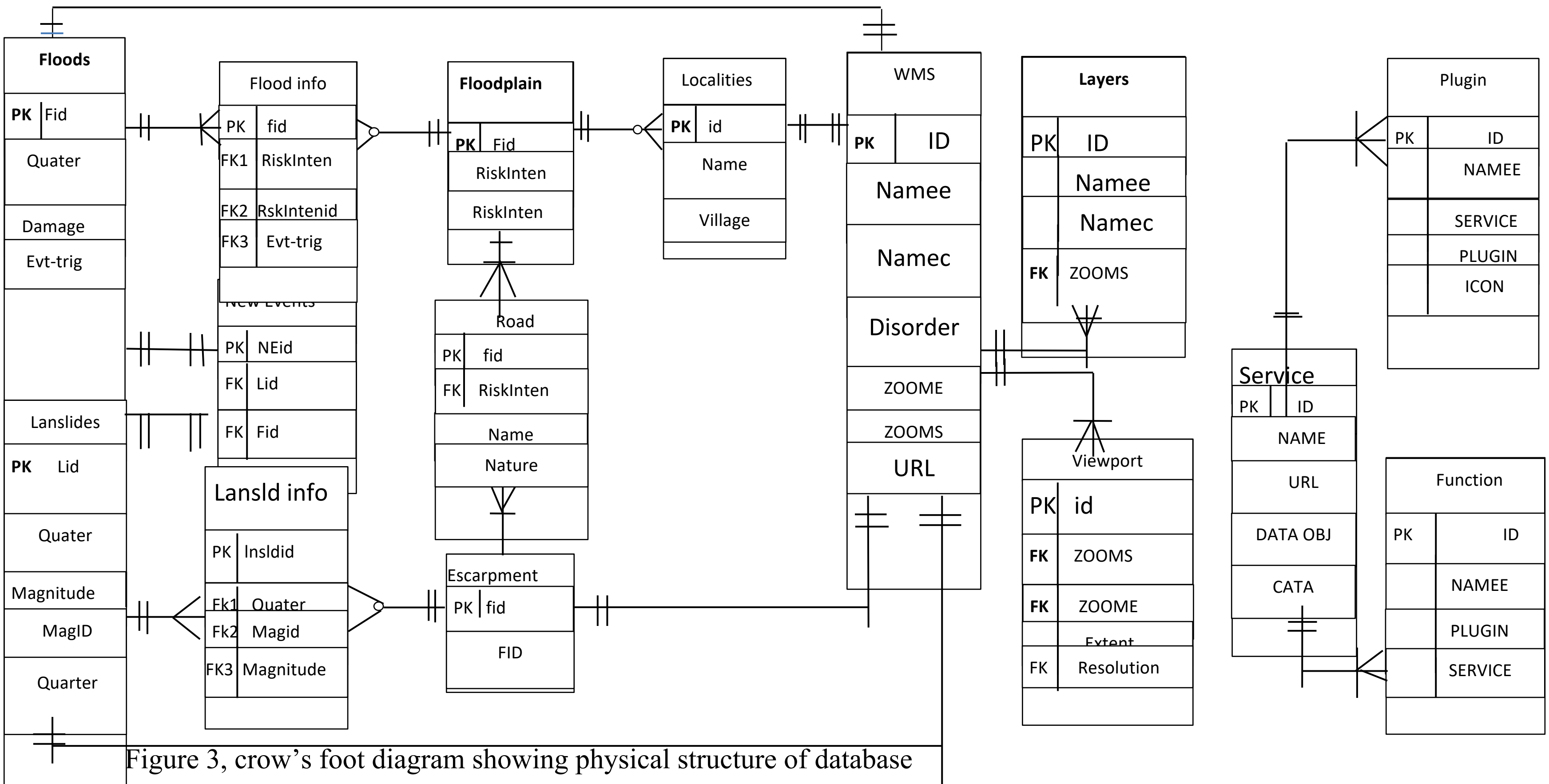
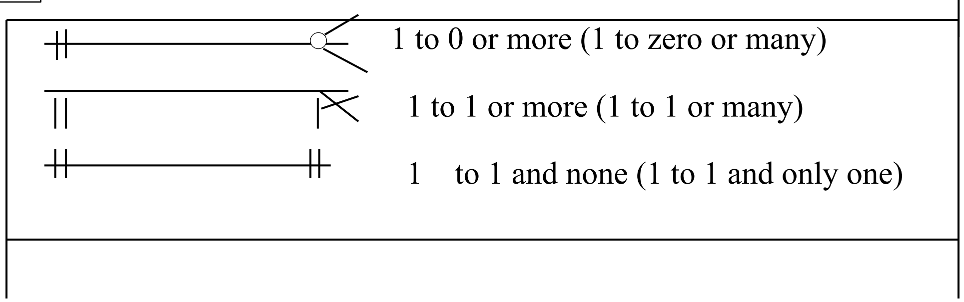


Figure 3, crow's foot diagram showing physical structure of database



Publishing Data
The spatial data transformed and upgraded in ArcGIS software was saved as a shapefile in C:\bdshp from where it was published in the server (Geoserver), which serves as a repository for spatial data from where the relational database gets its data. The method used to publish data on Geoserver is as seen in Figure 4.

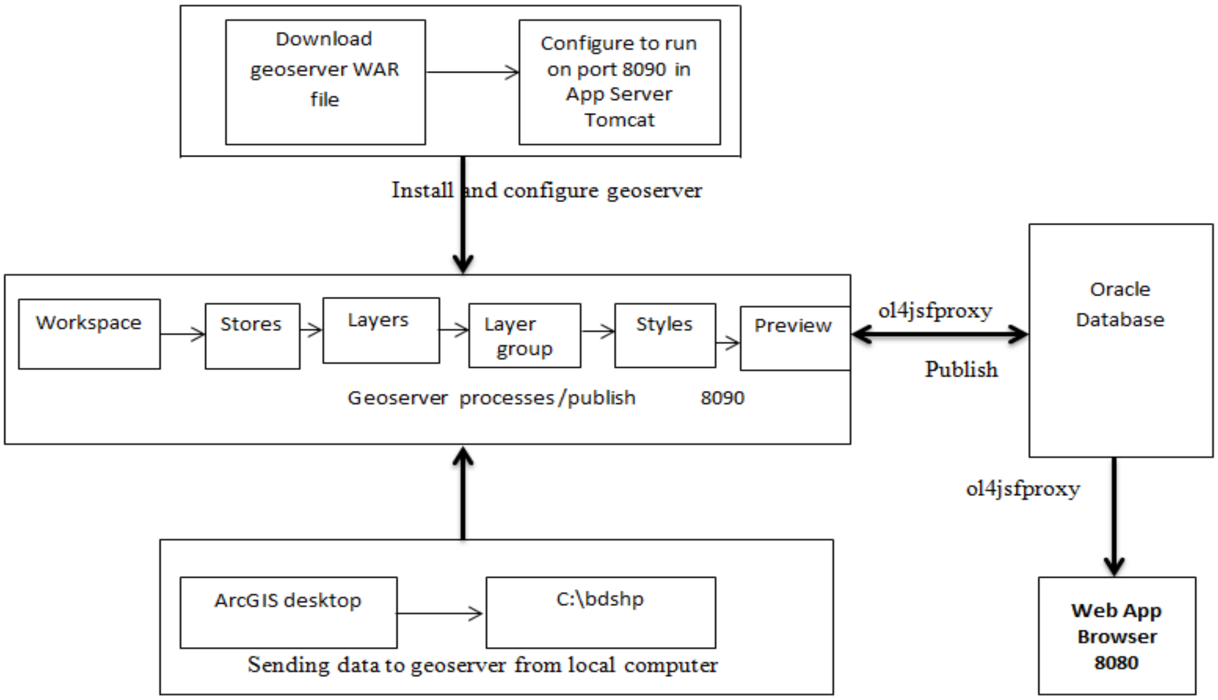


Figure 4: Publishing data.

The spatial reference has to be defined beforehand in order to be able to use it in the Geoserver. The reference system assigned is shown in Table 11. The EPSGS is defined as 2077.

Table 2: Geodetic Reference System for Cameroon

Country	**Datum**	**Geodesic System**	**Associated ellipsoid**	**Projection**	**Zone**
Cameroon	Adindan	WGS 84	Clarke 1880	UTM	32N

Web Application Loginpage/interface

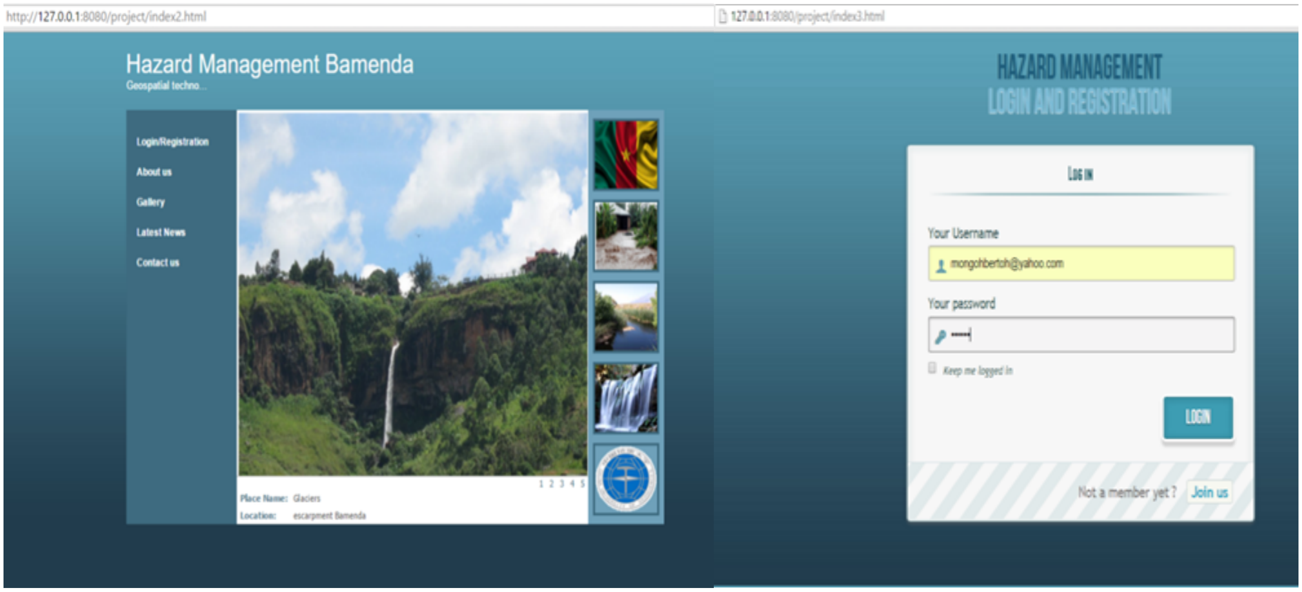


Figure 5: Web application login and registration form

The user interface of the application is a simple user friendly interface with most of it made up of Map at the center, query functions to the left **(A),** Map controls to the top right corner **(B)** and quick map interactions available by right clicking on the map **(C)**, this interface was developed using jQuery Easy UI, Open layers, maps are served from Geoserver to relational database (oracle) using OL4JSFProxy, figure 6.

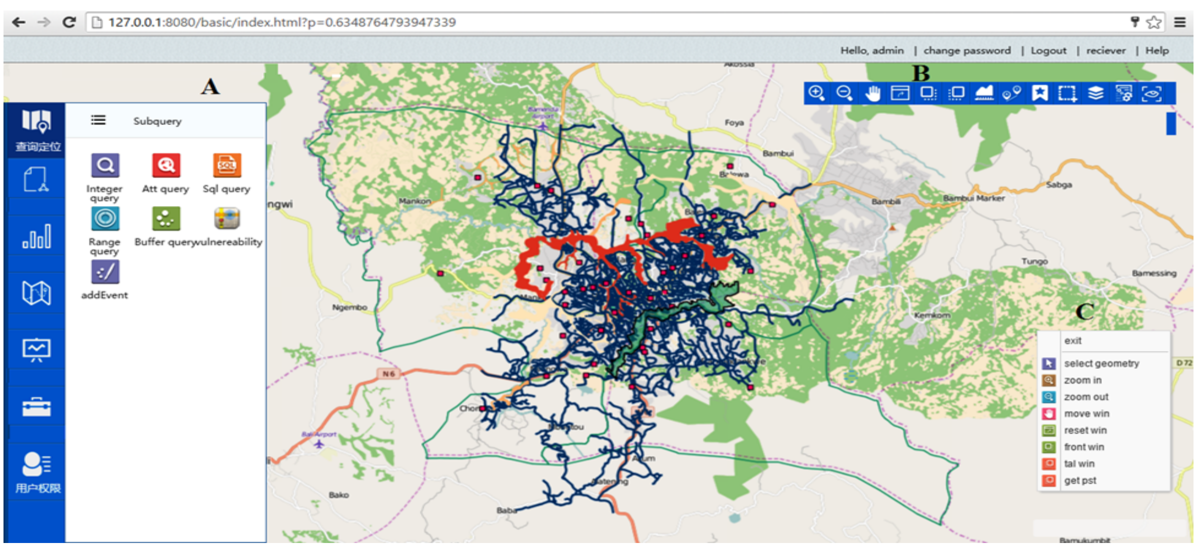


Figure 6: Web Application User Interface.

Application Functions

Visualization

Layer Switcher and select geometry, the latter involves selecting or highlighting features either to perform a query or get feature information, whereas the former is use to toggle layers on and off, overlaying them to get their spatial occurrence, and establish relations

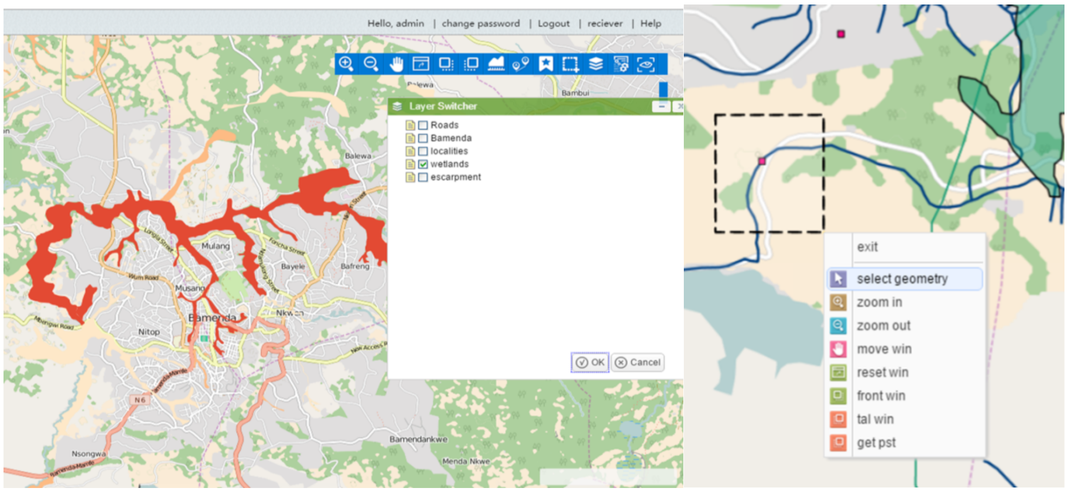


Figure 7: Layer switcher and select geometry

Fast query

This function allows user to select the fast query functionality from which they can import all map layers in a combo box, checking a layer will upload the names of all feature in that layer, selecting a name will highlight the feature on the map. This functionality has sub groups like query by coordinates, query by place, query by road, you type in a name based on the sub group it takes you to this location. The query by place is illustrated in Figure 8

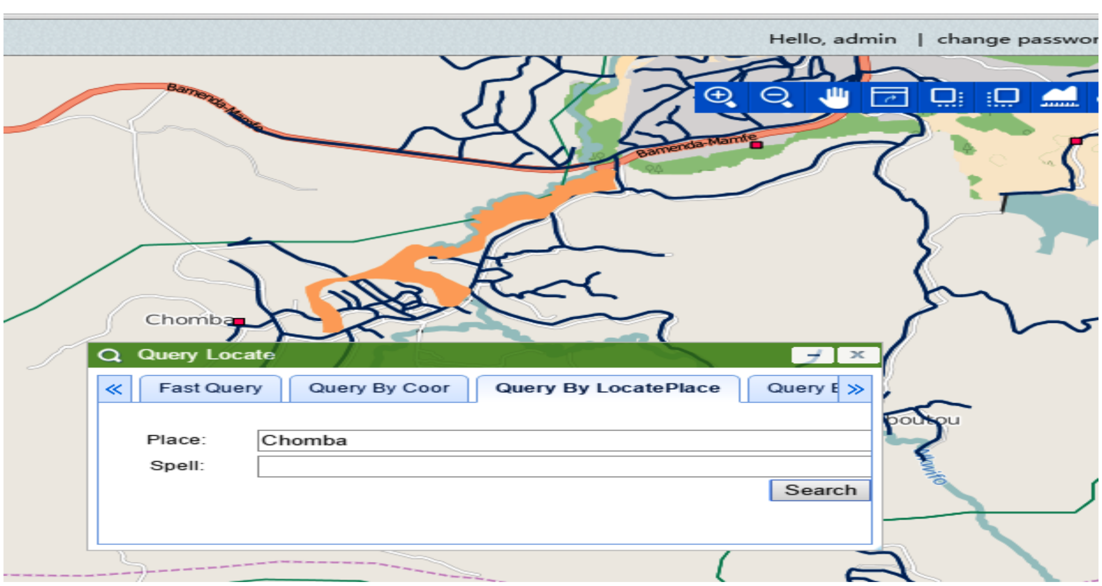


Figure 8: Query function

Map grade Symbol

This is a vulnerability calculator which classifies attribute Risk intensity, of the flood and landslide extent layers to a selected number of classes, with either Equal interval or equal amount classification methods. A color map of that layer is produced based on classification method selected to show the intensity of risk of a given community based on its proximity to the Bamenda flood plain or the Bamenda escarpment., It equally provides the option of exporting the map created.

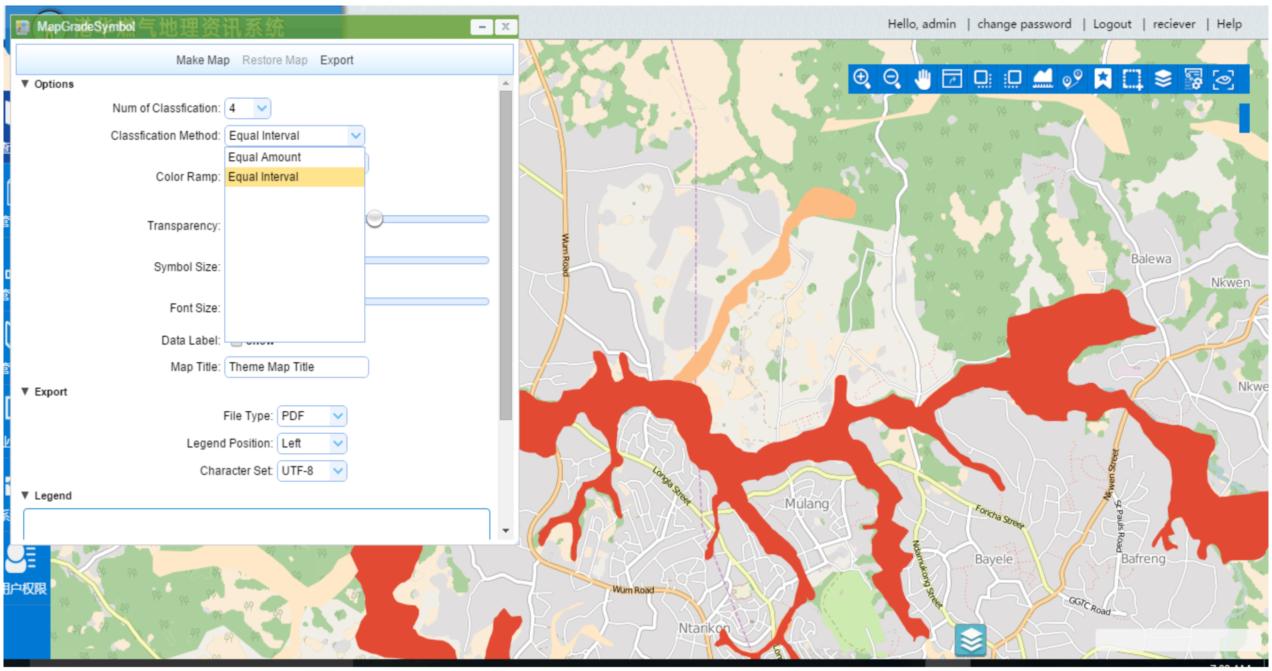


Figure 9: Mapgrade Symbol

Decision support Functionality, Insert and view features

In this aspect of the platform we illustrate how this functionality can assist public officials to generate data, by inserting recent occurrence of hazard in the platform. On the homepage page of the platform click on the map layer switcher, from the list select map layers which will help situate the flooded areas in this case Bamenda base map, localities, roads, and wetlands are most convenient .Unselect the layers and click insert an event'(Figure 10). Keep localities and Bamenda base map layers visible, zoom in to the map, and insert a point at the locality where the disaster has occurred, on the insert event dialogue box click OK button. On the form that appears, fill in details about the flood and its impacts. Click save and be redirected to the home page. The User wants to see the recent created event, he selects query events 'and clicks on the event he just created .These steps are illustrated respectively in Figure 10.

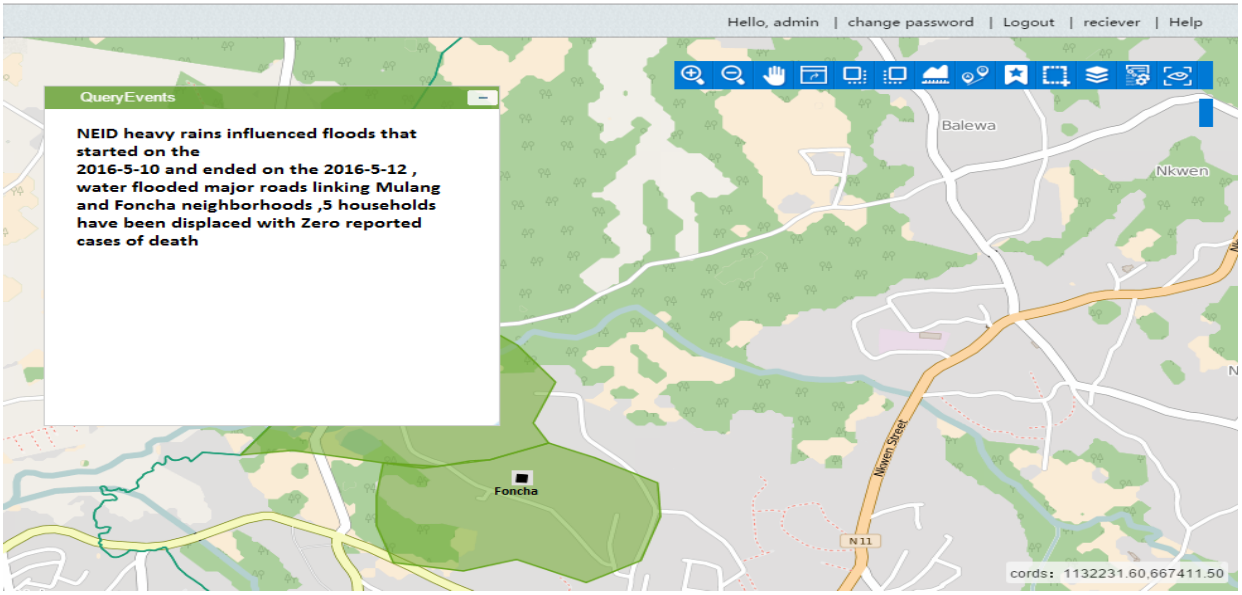


Figure 10, insert and view new hazard events.

Determine communities most affected by floods/ Hazard Management

The user wants to choose 3 localities most vulnerable to floods in the region to further investigate the allocation of a developmental project. On layer switcher, click on landslide events, flood events, and vulnerability factors 'wetlands and escarpment'. You are presented with a map with all events that have occurred in the region since 2006 .Granted that all the events on the platform are real events with these three layers on display the user can at a glance see the communities which are located in vulnerable areas. To determine the three most vulnerable communities, he can use the select geometry function of the platform to see more attributes of individual features, attributes to consider here will include, frequency of flooding, Damages, Risk intensity.

He is now left to choose the three areas which have suffered the most damages from flood, with information on localities' hazard frequency, and risk intensity gotten from the platform; he will need to add more information with data gathered elsewhere like the population of each zone and the development ratios of the identified zones to choose the 3 communities.

Using Mapgradesymbol the user selects wetland layer, puts Number of classifications to three, classification method to equal interval, color of display black and click on make map, the feature ID (fid) or risk identity, with highest value (3) stands for areas with highest risk to flooding on the selected layer, the classification and the results are shown in the legend as seen in Figure 11.

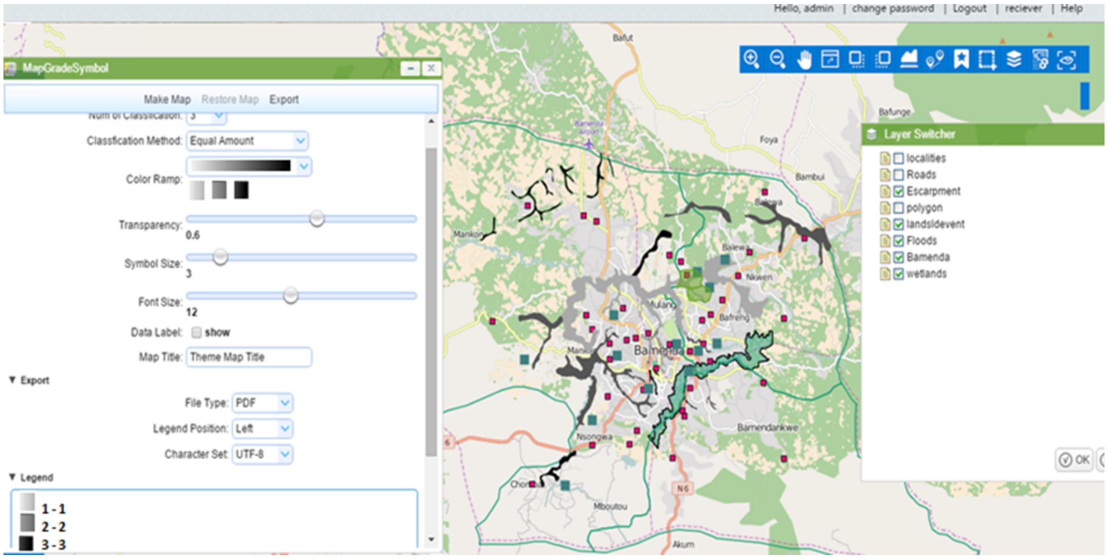


Figure 11 Vulnerability Mapping

Conclusion

A strategic implementation plan is required for effective disaster management, for this to be successful, creation of natural disaster data and information management system should be given prime importance among policy initiators. This work was motivated by the need for data affecting disaster management, with the aim to encourage use of geospatial technologies and creation of data. A prototype WebGis was developed, to collect flood events and create spatial data for these disasters in a two dimensional scale. It also presented a simple but useful application design based on interoperable and modular components of a design which facilitates re-use of components since each component can operate independently to serve a unique purpose. The application can be used to determine areas in need of urgent aid alongside other useful disaster information. It can also be used by experts to report floods and also by citizens to validate or update data to highlight vulnerable areas online or in real time. More functions can be added to the platform like statistical analysis to do graphs and other visualization or shortest route analysis among others.

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