International Journal of Computer (IJC)
ISSN 2307-4523 (Print & Online)

http://ijcjournal.org/

Monitoring an Experimental Field through Web Mapping Technology

Abel Wadoufey[a], Paul Dayang[b*], Albert Ngakou[c]

[a,b,c]*The University of Ngaoundere, Faculty of Science, Cameroon*
[a]*Email: wadouf@gmail.com*
[b]*Email: pdayang@univ-ndere.cm*
[c]*Email:alngakou@yahoo.fr*

Abstract

In order to efficiently combat soil degradation and desertification in Ngaoundere-Cameroon, an ecological approach called ReviTec® was established through an experimental demonstration site. In the light of the management of spatial data within the site, ReviTec® researchers have been encountering difficulties related to data collection, analysis and display on plant growth processes. For sustainable management of ReviTec® activities, we propose in this research, a Geographic Information System coupled with WebMapping, that makes it easier to directly disseminate and manipulate objects on a map. This system has enabled the viewing of items such as trees, islands, half-moons and bunds on the map where they are represented by points. For each structure, the system offers a possible visualization by a simple click on "More Information" on plant species, treatment applied on plants, plant growth, plant images, and tree biovolumes. Such an adapted and innovative technology is suggested to be implemented in other existing ReviTec® sites in Cameroon for a better visualization of results obtained.

Keywords: ReviTec®, WebMapping, GIS, spatial objets, soil degradation, desertification, information system.

1. Introduction

Worldwide, the exploitation of natural resources by humans is putting stress on ecosystems. This leads obviously to soil degradation and desertification [1].

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* Corresponding author.

To help combatting soil degradation and desertification, soil and vegetation environmentalists partners KeKo (Kesel, Koehler and Associates biologists) and the Centre for research on the environment and sustainable technology (UFT) at the University of Bremen developed an ecological approach of revitalization technology called ReviTec® [1].

The use of the ReviTec® Technology aims at combatting soil degradation and desertification by facilitating acquisition of knowledge to help restoration and rehabilitation of soil through planting of trees in a specific way. For activities to be carried out, ReviTec® will display information on growth and exact spatial distribution of plants on the experimental site in real-time. Therefore, in order to efficiently manage the data on plants, such data needs to be geo-referenced in advance. To successfully achieve this, a geographic information system (GIS) is integrated in a web environment via the concept of WebMapping which then serves as a tool for spatial analysis. This tool enables online monitoring of ReviTec® activities over many years. Prior to incorporation into ReviTec® data are pre-analyzed using Microsoft EXCEL Spread sheets.

The development and use of geographic information systems has become more wide spread with the increasing use of Internet and Web-based technologies. Since the 1990s, the emergence of WebMapping has reinforced the existence of spatial information systems. The technique of disseminating maps (WebMapping) via a computer network continues to be useful especially in the exploration and the manipulation of objects with a spatial component. With the growth of Internet, WebMapping, and Location Based Services (LBS) are providing today a new environment for consultation, management, and creation of geographic information where the user is s to searching to manipulate information with a spatial component as opposed to others without [2]. The mapping process and the geo-location of objects, services, activities or even ideas, are becoming considerably more important in the daily practices of Internet users [3]. Online Mapping, offers too many user groups, ways to overlay traditional geographical information layers on services, thereby substantially improving the added value of maps. In addition the development of online mapping platforms such as Google Maps and Open Street Maps, allows the geo-location of places and their interaction with other geo-referenced objects on a map. However, many of such platforms of Internet mapping do not enable third party manipulation of the data because the original data are stored in their owner servers.

2. Opportunities offered by an Online Mapping

Online GIS can be of great importance especially when facing challenges in structuring and manipulating spatial data. The approach of GIS allows the understanding of the surrounding space, the implementation of GIS platforms requires skills both in computer science and geography [4]. Based on services offered through online GIS, Green and Bossomaier [5] divide such platforms into two categories:

The first category offers one of the most prevalent features of online GIS, such as the spatial location-based queries. It involves the selection of spatial objects such as regions or points. An example would be a system offering a suitable interface to the users, including several options such as layers, colours, textures, so that the users can easily create their own maps by selecting layers. Users do not perform modifications on data and it remains limited by options offered by the system.

The second category allows the design and the dissemination of online maps. Contrary to the first category, the user can add his/her own data in the database which involves controlled access. An example of such an approach is proposed by the Charles Sturt University in Australia [6].

The implementation of a WebMapping solution uses a map server runs a program such as the Common Gateway Interface (CGI) application, servlet Java or other forms. A map server is designed to create maps at the request of the remote client and, depending on the chosen settings [7]. Located on the server, it works with the Web server and is an interface between the client through the Internet and the cartographic data server. It can also play the role of a Web server [8]. There are two categories of map servers: open source and proprietary software. Open source servers have the advantage of being inexpensive. Very malleable, and can be easily adjusted to local or user needs. However they require sound knowledge and regular updates and good programming skills. There are multiple open source mapping servers, among which is the Geoserver.

GeoServer operates under a 3-tier architecture: a client for the display, a Web server and a database server. It is also possible to integrate a spatial Database Management System (DBMS) such as PostGlS. GeoServer has diverse advantages. It can be run on various operating systems. A user via a simple Web browser can access the Geoserver application. An owner such as ArcIMS solution offers its application development tools; the formats used are very specific even if other formats are sometimes tolerated [9]. The acquisition of the license cost is quite high and depends on the chosen user set-up (number of posts, volume of data, etc.).

The features offered in this type of solution are numerous and varied. GeoServer allows the display of a large number of formats of raster and vector images. It is easy to get through the configuration file. The zoom, the displacement map and advanced options are available (transparency for example is available) and depend on the configuration files [10]. Advanced options are also available. It should be noticed that for both solutions, i.e raster and vector images, performing a zoom will automatically load a new image.

3. The as-is Analysis of the Management of ReviTec® Field

1.1. *The ReviTec® experimental site*

ReviTec® which means Revitalization Technology, is an ecological approah implemented within the partnership between the University of Ngaoundere (Cameroon) and the University of Bremen (Germany). This revitalization technology (bringing back the life on a degraded area) was initially developed by KeKo (Kesel, Koehler and Associate Biologists in co-operation with the Center for Environmental Research and Technology (UFT) of the University of Bremen [11]. It aims at developing knowledge required to combat degradation and desertification by the re-establishment of site-specific land uses with peculiar ecosystem services. This is achieved through erosion control, substrate management and fostering of site specific biodiversity. The measures include soil and water conservation, restoration of degraded and polluted soil and ecological afforestation [11].

The ReviTec® approach focuses on initiation and acceleration of a mosaic-type ecological succession (conservation in a dynamic sense) with exposure of a special substrate mixture which may be filled into biodegradable bags to prevent erosion control [11]. The flexible ReviTec® bags can be exposed to the topography and modularly arranged into structures, such as small islands, bunds, half-moons, etc. [11].

Demonstration and pilot studies have been conducted in Germany (Bremen), Spain (Mallorca), China (Ordos Desert in Inner Mongolia) and in Cameroon (Ngaoundéré and Maroua). The Cameroon sites are: Ngaoundéré, implemented in April 2012 on the premises of the University (0.25 ha); Maroua Salak and Maroua Boula-Mokong, implemented in June 2012 (0.25 ha each); Maroua Gawel I and II (32.6 ha in total) established in June 2014 [12].

The main results are:

- The ReviTec® structures provide an efficient erosion control and retain surface runoff for infiltration.
- Hard soil surfaces are softened in the range of the structures.
- High productivity of vegetation is activated and the greening period is extended.
- Organisms are attracted (e.g.,earthworms, ants, termites, rodents, , plants)
- Biodiversity is increased and associated ecosystem services are rehabilitated.
- Ecological succession is accelerated.
- Afforestation is supported through erosion control, water retention and enhanced growth of trees

These results indicate the success of the Revitec® approach in restoring degraded soil [12]. It is therefore recommended for adoption by local affected communities.

1.2. *Data collection and processing*

To follow plant growth, data collections from ReviTec® sites took place three times per year. The first collection was carried out in April, that is, at the beginning of the rainy season; the second in July at the middle of rainy season, and the third in September-October at end of the rainy season. Data collection took into account the monitoring of vegetation within the site, including herbaceous and woody plants which exist on bunds and half-moons exclusively; and on the other hand measurements of the microclimate and soil characteristics.

These three periods of data collection at the ReviTec® sites of Ngaoundéré generated huge amounts of data that were processed using excel software and stored as EXCEL spread sheets files.

However, the storage of data in EXCEL files represents a limitation in the dynamic viewing of the data regularly collected. Therefore treatments applied on the data are carried out manually. In addition, information is not centralized to facilitate simultaneous consultation which makes access to and manipulation of data extremely difficult, leading therefore to enormous loss of time. Moreover this approach of data collection and manipulation is not suitable for decision-making. On the other hand the data that ReviTec® manipulates comprises spatially localized information. Hence, the current monitoring of ReviTec® does not allow viewing space of the elements manipulated nor does it facilitate automatic processing of data.

4. System Integration in the Web Mapping Technology

1.1. Web Mapping as main Technology

Several platforms of online GIS exist for the geo-localization of places. However, these platforms do not allow personal use of data; neither are they suitable for follow-up of activities using a specific pre-determined structure. That is why we propose a system of monitoring for the ReviTec® site integrated and adapted to the concept of WebMapping for the management of activities.

Our approach consists at the first place of time to implement the mapping solution cited above, namely; achievement of a spatial database that contains the spatial data, the deployment of a map server that uses these data to produce map layers according to the requests of the web application. Secondary, development of a web application which interacts with the data. The web application provides two main functions, such as the management of dynamic aspects of the system and the redirection of requests from the client to the map server in order to retrieve map images requested by the client. The integration of a cartographic client in the web application will allow the display of the map [13].

The main idea is to create a new item on the map by adding the geographical coordinates through an interface of the Web application. Once added on the map, the element becomes interactive using the JavaScript API of the cartographic client allowing the update of data on the element newly added.

A zoom feature was proposed as well as the module of interaction enabling the interaction with the elements of the map. We have proposed several other layers displayed on the map. These additional features can be displayed or hidden according to the user’s need.

The introduced features are directly linked to the structure of the site of our study i.e. viewing the different elements of the ReviTec® experimental site (half-moons, islands, bunds, etc.). The display is done by clicking of the mouse on the item in question. It is also possible to perform a search, for this we rely on the spatial indexes.

Another feature is the possibility to update data at any time for each item located on the map with the help of a web application interface dedicated to this effect.

1.2. System Architecture

Figure 1 presents the overall architecture, including the main existing open source systems based on which the model of integrating WebMapping technology was developed in the monitoring field site.

In order to get geo-referenced information displayed, the user of the system begins the process, which goes through diverse steps as outlined below:

1. The request of the client to ask a resource on server.
2. The Web server assures the treatment of the HTTP request.
3. If the HTTP request received is for the applications server, then the web server passes it to application server. The two servers are connected via a channel called connector.
4. The application server receives the request. It therefore performs instruction of the corresponding service, known as java servlet, to which the query in intended, according to the URL. This call may require a map image from the server mapping (GeoServer directory) or data from the DBMS (PostgreSQL).
5. If the processing of the query needs a map image, the Application server will make it available from the geographical server.
6. To produce a map image, the cartographic server needs geographic data requested from the DBMS (PostgreSQL/PostGIS) via a query.
7. Once its response is generated, the server applications returns it by the connector to the Web server.
8. The answer is now embedded into a simple HTML code, understandable by a browser. The HTTP server returns the response to the client.

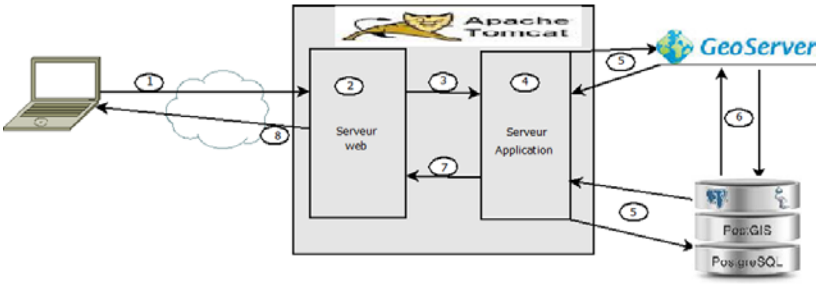

Figure 1: The overall architecture

5. The implemented System

The implementation of the solution was carried out with the vector map of the ReviTec® site of Ngaoundéré. This map was designed with the help of geographic coordinates identified on the ground (Figure 2).

The home page of the monitoring application contains the client map which allows the view of the geographical map of the ReviTec® site of Ngaoundéré.

This client map is based on the JavaScript library OpenLayers which allows the display of the maps from several geographic servers. We have implemented for it supports such a map vector, a map raster, zoom features and interaction modules.

Considering our system, the main technical constraint such as the use of a specific library or framework (JavaScript library OpenLayers), or limitations are often linked to technical design decisions.

1.1. Updating the Information in the System

First step: The application processes data visualization of a point on the map starts by clicking on a bag on the map. When the user moves the mouse pointer on a bag or click on it a tooltip appear. The result is displayed in Figure 3.

Figure 2: The geo-referenced ReviTec site

Figure 3: Main view of a structure such as demi-lune and bund

1.2. Visualization of Information

The visualization of the data on the map has two phases:

First step: The application process for data visualization of a point on the map begins by a click on the point on the map. When the user chooses to click on more information, the output is as displayed on Figure 4.

Second step: The second step of viewing information points of the card passes by the click of the button “More Information To” view all of the information concerning the element in question. The result is in Figure 4.

1.3. Description of the results

The system that we propose describes the functioning of the ReviTec® experimental site in Ngaoundéré.

The system allows viewing of items such as trees, islands, half-moons, bunds on the map of the ReviTec® site in Ngaoundéré. These items are represented by points on the map and are identified by their identifiers and coordinates. Islands, half-moons and bunds contain bags. Each bag contains a treatment which can be: compost, biochar, loamy sand, mycorrhizae. For each structure, the system offers the possibility to visualize the following information (by a click on "More Information" in Figure 3).

- plant species;
- treatment applied on the plant;
- plant growth;
- image of the plant;
- biovolume of tree

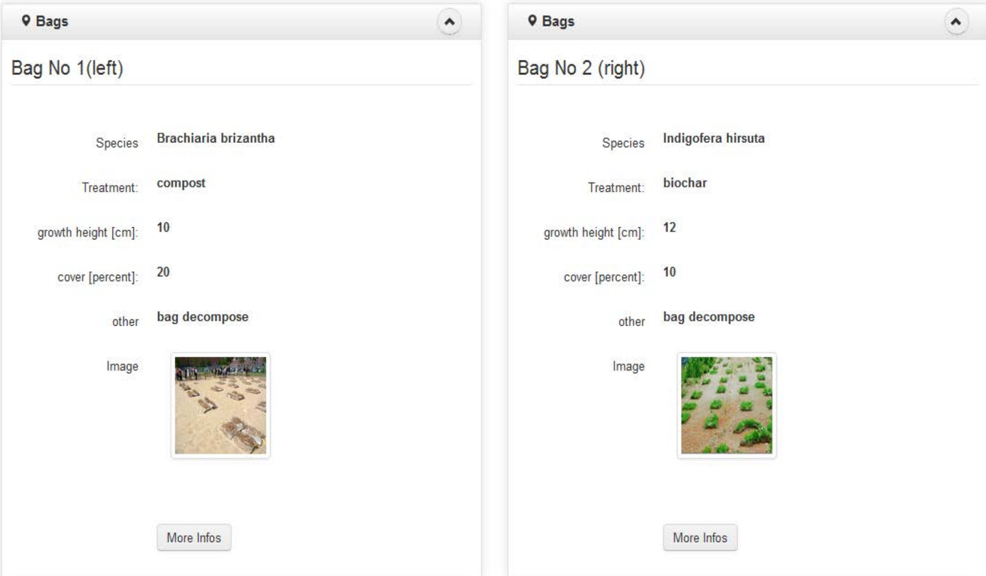

Figure 4: Entry forms for a series of two bags

6. Conclusion and Perspectives

GIS is important for spatial analyses and in recent years integration of WebMapping in a geographic information system environment has been possible. Systems such as GIS which deal with spatial information are of great utility. The evolution of GIS has led to the birth of the concept of WebMapping that provides a multitude of solutions, each having its own specific philosophy. The integration of WebMapping techniques has opened up new windows for exploring and manipulating spatial objects on maps.

In this work, we have integrated and adapted GIS technology in the dynamic monitoring of plants in order to observe and visualize their growth processes and contribute towards revitalization of degraded soils in Cameroon. We have focused on a ReviTec® site as an experimental site. Since there are other ReviTec® sites existing in Cameroon, our suggested solution could be extended and re-used for a better visualization of results obtained on other sites.

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