Web-based GIS Approach to Enhance Public Participation in Development Planning: Developing The Emuhaya Constituency WebGIS Portal

Fanon T. Ananda[a], Moses M. Ngigi[b] and David N. Kuria[c]

[a] Department of Geomatic Engineering and Geospatial Information Systems,
Jomo Kenyatta University of Agriculture and Technology, P.O. Box 62000,00200, Nairobi, Kenya
Email: Fananda@jkuat.ac.ke

[b] Institute of Geomatics, GIS and Remote Sensing (IGGReS), Dedan Kimathi University of Technology,
P.O Box 657 - 10100 - Nyeri, Kenya
Email: murimi99@gmail.com

[c] Institute of Geomatics, GIS and Remote Sensing (IGGReS), Dedan Kimathi University of Technology,
P.O Box 657 - 10100 - Nyeri, Kenya
Email: dn.kuria@gmail.com

Abstract

This paper presents an approach taken in the implementation of a community webGIS portal. Local community empowerment and inclusion in resources planning and management were the key objectives of the project. A hybrid Y-Model methodology for webGIS development was adopted. The methodology splits up the development activities into two clear lines; the GIS development and Web development lines before integrating the two into a single product. The findings of the project indicate that disseminating information about the presence of a community webGIS will greatly influence its effectiveness. Community literacy levels also directly influence usability of the platform. Most users at the community level lack the expert technical competence it is therefore important to maintain simplicity in design and content presentation on the webGIS. The developed system leverages on web technologies to integrate data from disparate sources and make the same seamlessly available during the planning process.

Keywords: Public Participation GIS; WebGIS; FOSS; FLOSS; Desktop GIS; Methodology;

1. Introduction

A key principle in development planning is participation. All stakeholders are ultimately affected by these plans and therefore it is necessary to provide opportunities for wider participation beyond the normal democratic process. This presents a unique involvement challenge at the community level that can only be addressed through incorporating modern information and communications technologies. Distributed Internet Services technology and the WebGIS are constantly improving. With this changes, participants are provided

a wide range of interactive communication channels, complex spatial analysis and multimedia capabilities to better understand the natural environment and to contribute to the planning process in the community (Dragic´evic´ and Balram, 2004).

GIS refers to a set of computer based tools used to collect, store, manipulate, analyze and display spatially referenced information (Burrough *et al.*, 1998). These tools are useful in planning, data analysis and decision making. The World Wide Web has made it possible to deliver distributed/decentralized GIS capabilities which can now be harnessed as instruments of inclusion and participation in development planning and environment management. WebGIS promotes a participatory forum mainly due to its limitless access to the Web and the presence of a large online community (Eisner *et. al*., 2012). In Kenya, widespread adoption of pocket friendly Smartphones has seen a tremendous growth in our local online community.

It is however important to note that attributing technology to empowerment and inclusion is not new. According to Sieber (2006), GIS has sparked interest for the following three reasons; most information used in policymaking has a spatial component (e.g. address, zip code, latitude/longitude); secondly extending the use of spatial information to all relevant stakeholders presumably leads to better policymaking; thirdly the policy information can be visualized and analyzed spatially and the resulting maps can convey ideas and convince people of their importance.

The study area is Emuhaya constituency which is located in the western province of Kenya. The province is bordered by Rift valley province to the east and Nyanza province to the south (Figure 1). A Constituency is a geo-political area that is represented in Parliament by an elected representative: a Member of Parliament (MP). According to the Ministry of National Planning and Development (2005), the constituency had a total estimated population of 158,876 with the estimated number of poor people at 95,196. This is more than half of the total population. The percentage of people living below the poverty line was put at 60% (poverty incidence), with a national poverty rank of 132 (out of 210 with 1=richest and 210=poorest). Western province contributed 13.9% to national poverty with Emuhaya contributing 0.7% to this figure. Within the province Emuhaya contributed 4.8% to provincial poverty. This data was based on the 1999 population census.

This research develops a Web-based GIS portal for Emuhaya Constituency that integrates planners and the community by transparently providing spatial data about the environment. Open access to the data provides the much needed information for proper planning and decision making. The paper outlines the development process and the results achieved. The remaining sections of this paper are organized under the following subtopics; Literature review, Methodology, Results, Discussion, Conclusion and Recommendations.

The specific objective of this study was to design, implement and optimize a WebGIS for Emuhaya constituency that will disseminate geospatial information at all community levels.

2. Literature Review

The core component of any web-based GIS is the mapping and visualization technology. Some of the features to be visualized include imagery, routes/directions etc. So then what is the difference between WebGIS and Desktop GIS? Well, WebGIS provides ease of access through web compatible interface that allows for data sharing and the integration of different data (Adnan *et.al*., 2010). Rapid evolution of web mapping technologies has resulted in a number of benefits/advantages; provision for rich mapping and imagery, increased scalability, improved map services designed for the web, reduced learning times for non-technical users, and improved data management. Most web mapping solutions take advantage of hybrid raster/vector approaches. Vector data consists of 3 primitives; lines, points and polygons while raster data consists of raster imagery like aerial imagery and satellite imagery.

2.1. Factors to consider when choosing a web mapping technology

Currently there are several WebGIS technologies in the market both commercial and open. For a developer your desired choice should be greatly driven by the objectives of the WebGIS e.g. for flexibility and code improvement once would opt for an open technology. Miler et. al. (2010) note that most developers are adopting FLOSS(Free/Libre/Open Source Software) as their preferred choice. As opposed to the closed model, FLOSS allows users to directly influence and drive software development. Software under the FLOSS model has no restrictions. The users are free to use, study, change and redistribute software in new forms. The underlying motive in this model is to promote software improvement through reuse and user driven development.

The Open GIS Consortium(OGC) develops spatial web policies with an emphasis on the spatial web being built as a community resource accessible to all through publicly available interface standards. This advances have brought open WebGIS of age with systems exhibiting maturity, robustness, stability and user friendliness that rivals proprietary GIS products.

WebGIS is gaining more popularity as a result of the increasing demand for inclusion and participation. however it is important to note that the dissemination of large amounts of heterogeneous data is a growing challenge that is further worsening with the limits placed on internet bandwidth. We need to consider the following 2 factors if we are to address this challenge; Yang et. al. (2005)

> i.) *How do we share and interoperate the heterogeneous data among different systems, communities and users?*
>
> ii.) *how do we improve system performance so that the data is delivered to the users within reasonable time span?*

Different scholars share similar concerns on this matter. Rao and Vinay (2009) identify the following items as a checklist to be used by designers when determining their technology choice; server performance, maintenance and backward compatibility, scalability, interoperability, Total Cost of Ownership, customization options and network bandwidth capacities.

2.2. WebGIS architecture

Figure 2 outlines the standard/typical architecture of a WebGIS showing the main components; client, web server, map server, GIS Database and application.

Client -This represents the user's point of interaction with spatial data and analysis tools accessible to the user, usually the web browser. Most modern browsers have the capability to render and manipulate the complex spatial data served from the servers.

Servers- Various servers are present in this model each playing a distinct role; *Web server* responds to requests sent from the web browser via HTTP. All websites published on the Internet must be accessed through a web server e.g. Apache, a multiplatform web server; *Map Server* which is the software used to render maps from the database or shapefiles. It provides traditional GIS functions that include: spatial analysis, spatial and attribute queries, geo-coding, geoprocessing and generates and delivers dynamic maps to the client based on user requests; *Application server* acts as a middleware that establishes, maintains and terminates the connection between the web server and the map server. It also manages the concurrent requests and balances the load amongst map servers. The main objective of an application server is to separate business logic from presentation logic and database logic. An example of an application server is GeoServer; *Database server* manages both spatial and non-spatial data, in a relational or non-relational DBMS. Databases feature spatial data which represents some of the geometric shapes. Spatial functions are also performed here e.g. area calculation, length of roads and relations between geometry data etc. An example of a Database is postGIS.

The overall application still maintains the 3-tiers of the client/server architecture; presentation, business and database logics. The business logic is the part of the web application containing all the functional parts. Figure 2 also shows this generic multi-tier architecture of the client/server components of the WebGIS.

2.3. Technology used to Develop WebGIS

After careful examination of several webGIS solutions and their approaches, the research focused on FOSS (Free and Open Source Software). Several factors informed this choice but key among them was the huge prohibitive costs of proprietary software and secondly in support of the massive push towards the adoption of FOSS in GIS. Donnelly (2009) shows that there has been a significant focus shift and support towards FOSS GIS projects through increased support by government entities, increased downloads of FOSS GIS software and a growth in case studies involving FOSS GIS projects. This serves as evidence that open source GIS software systems have reached a stage of maturity, sophistication, robustness, stability and user friendliness rivaling that of commercial, proprietary GIS and WebGIS products (Boulos et.al., 2008). OpenGeo suite was used for this project. The suite consists of the following components;

    i.) **PostGIS** - Spatial database
    ii.) **GeoServer** - Web map / application server
    iii.) **GeoWebCache** - Tile cache server
    iv.) **OpenLayers** - Browser-based map display library
    v.) **GeoExt** - Mapping application library

Most of the webGIS reviewed was designed for the non-technical user. This necessitated limited functionalities and quick self-learning resources about the platform. This has been achieved through provision of online tutorials/manuals and reducing the features on the WebGIS (MacEachren et.al.,2008). This view was taken into account and the prototype Emuhaya webGIS has limited itself to visualization of features without any classification, statistical and graphical options.

Principles of information systems security also had to be considered when developing the webGIS. In particular it is important for the non-technical users of the system to trust the system as this directly affects how they will use the system. People generally tend to engage systems that they trust and shun those they mistrust (Sillence *et al*. 2006).Some of the trust concerns here include accuracy of data sources, map quality/relevance and analysis and results accuracy (Artemis, 2010). Though not equipped with the technical competency to assess this elements, non-expert users can still rely on primitives like aesthetics, usability and reputation of the source to develop trust perceptions accordingly. Newman et. al. (2010) advice developers to focus on simplicity when developing web map applications with emphasis on visual accuracy, precision and eliminating uncertainty while integrating usability and user feedback into the application. Usability engineering principles are at the core of the prototype Emuhaya webGIS, with the system relying on a simple but aesthetically pleasing interface to win user confidence.

3. Methodology

The methodology used for the development is based on the proposed hybrid Y-Model methodology for webGIS development. Figure 3 illustrates the main phases of the methodology. The methodology has three distinct sections; GIS development, Web application development and Integration. The methodology appreciates that a webGIS project produces a hybrid product that has qualities of both traditional GIS and web applications. Hence it is important to fuse their different approaches for better results. The following section highlights the main steps of the methodology;

3.1. GIS Development Line

i.) Problem Definition

ii.) Data Collection

iii.) Data Processing

iv.) Database design and development

The original data was collected between 2011 and 2012 using transcent walks, GPS, photos and unstructured talks and interviews. High resolution Satellite images and maps were also used. Figures 4-5 show the data collection team during technical consultation and field sessions. The data was then cleaned and mapped. PostGIS database was used to represent the data as spatial entities. The GIS data created were point, line, and area features such as; Administration Centers, Churches and Mosques, Markets, Health Centers, Primary Schools, Rivers, Bridges and Wetlands, Secondary and Tertiary Institutions, Nursery Schools, Socio-economic Information, Transformer Distribution, Polling Stations, Major Roads and Railway and Roads(footpaths). Initial thematic maps were generated using the open QGIS software. These visualizations enabled analysis to discover trends, relationships and patterns including further refinement. Figure 8 shows a sample page of the Spatial Data on Administrative centers.

3.2. Web Development Line

i.) Needs assessment and discovery

ii.) Business Requirements Analysis (functional and non-functional requirements)

iii.) Conceptual and Navigational Model Design

iv.) Construction and Unit tests

It was useful to establish the rationale for the web based version of the GIS. This was done through a number of informal discussions with the constituency planners and potential users. Through our discussions it emerged that a majority of stakeholders in the constituency are non-technical users and were more interested in simplicity and comprehensibility of the final data. Some of the functional requirements for the webGIS are; It was to accept user query requests, enable user visualize various thematic maps, enable the user perform primitive analysis, allow user mapping of new uncollected data and allow printing of maps. The main non-functional requirements were usability and security of data.

3.3. Integration Line

i.) WebGIS Integration(web server configuration, map server configuration, visualization & integration tests).

ii.) Optimization

iii.) System testing and User Acceptance Tests (UAT)

iv.) Deployment and Configuration/Installation

v.) WebGIS Maintenance and Updating

This final phase is very important in that it consolidates the two different aspects of the system. It involved configuration of the relevant servers and optimization of the same to increase throughput. The system was tested by a handful of stakeholders initially but detailed user testing is still ongoing. A domain has been paid for and the system can be accessed on www.emuhayawebgis.info. Optimization is still ongoing with the aim of increasing system performance. An overall administrator is in-charge of updating the system with volunteered geographic information.

4. Results and Discussion

This research project resulted in the development of a geospatially enabled website for Emuhaya constituency. Figure 6 shows a high resolution satellite image of Emuhaya (now split into Emuhaya and

Luanda Constituencies). All geographic files were projected in the WGS_1984_UTM_Zone_36N coordinate system.

4.1. System Design

The system has a relatively easy to follow navigation structure because most of the potential users are non-technical stakeholders. Challenges of internet access and bandwidth also forced the developer to consider a simple implementation design with a simple user interface. Figure 7 shows the basic user interactions with the system on a use case diagram. Based on the functional requirements, the initial version of the webGIS implements only the core minimum functionality suitable for non-technical users as is the case in this study area.

The outline of the map contains; main links to thematic maps and the map viewer. The functionalities of the Basic Toolbar include a slide zoom bar, zoom-in, zoom-out, identify, pan, world extent, back and forward, remove all, and get coordinates. Figure 8 shows a screenshot of the main system.

4.2. Community Outreach and Feedback

Disseminating information about the presence of the webGIS was going to directly influence its effectiveness. From the onset of the project a lot of emphasis was put on stakeholder involvement at all levels. A number of modern technologically driven approaches have been used to publicize the webGIS. Firstly a web portal for the community has been created. It consists of a number of pages introducing the webGIS and most importantly it provides online assistance/help to the users. The portal address has been widely disseminated at the community level in schools, market places and through public meetings where possible. Secondly the project intends to develop a facebook page to attract the more technology savvy community users already on social networks however this appears to be only a small fraction. Outreach will also be in the form of demonstration camps in schools. Students form a significant majority of the population and if they are nurtured and encouraged to use these platform they can be useful in testing its capabilities. Constituency office staff in the various departments will also be trained on how to use the platform and a support person will be stationed in their office for this purpose. There are currently talks to set up a GIS office within the Constituency Offices Building to support this initiative. To create awareness the project will also look for sponsors/partners who can enable us offer free promotional material to encourage use of the platform e.g. airtime rewards for top ten highest contributors on the platform every week. A lot of search engine optimization has also been performed by focusing the content on easy to use keywords. The platform is also in the process of sharing links with other GIS initiatives in the country with the aim of interlinking and benefiting from any existing user base to increase awareness on a national level. As a long term strategy, constant improvement of the webGIS experience will be undertaken regularly to retain and attract community users who desire simplicity.

The webGIS went live on *www.emuhayawebgis.info* in the beginning of June 2014. This was after development and testing locally which ended in the end of October 2013. Despite the efforts to create awareness about the platform, the level of community participation is very low. In fact most of the accesses to the site are not from locals but from other scholars pursuing interests in GIS. As part of the project a survey will be designed and administered to the community. The main aim of using this technique is to elicit useful feedback from the potential community users on their challenges and suggestions about the webGIS. It is anticipated that this feedback will provide the desired information necessary to raise the community participation levels on this platform.

A section has also been added to enable the users to add spatial information to the system. However the data will only go live after scrutiny and cleaning by a moderator on the platform. The idea of users volunteering information is anticipated to foster a sense of ownership of the platform. Informed by the experience during

data collection, community users are excited to see and know that their volunteered data is being used widely provided that some form of recognition/reward is attached to it.

Community literacy levels has also been a key factor affecting the use of this platform. It has been observed that a majority of the local community is uncomfortable with internet technology. In fact most of the contributors of indigenous and traditional knowledge have no idea what the internet is all about. It is mostly the young and youth (ages 10 to 35) that are technology savvy. It is hoped that this group can be targeted to popularize the platform and initiate discussions. Access to internet connections at the community level is also a challenge. However a number of community digitization initiatives by service providers like Wananchi online are expected to introduce internet to the community through digital kiosks. The Constituency office is also in the process of getting connected. It is anticipated that this will increase the access to the webGIS by constituency office staff.

4.3. Lessons Learnt

While successful in its initial technical implementation, this project has disclosed a number of revelations that have shaped this and future initiatives

i.) Intensive local community lobbying and participation have to be part of the process from the beginning. Do not attempt to develop a solution without all stakeholders being on board. Communities care less for products that seem distant as they will be labeled "foreign affairs".

ii.) Most community users are not technology literate and thus introducing this technology may be a challenge. It will be useful to create a throw-away prototype that can be used for creating awareness, further data collection and end user training.

iii.) Data collected from the community may be incomplete, inconsistent or altogether incorrect. There is a need for continued reliance on scientific approaches to rely on scientific approaches to verify the data. This project relied on existing aerial photos and both low and high resolution satellite imagery to verify volunteered data.

iv.) End users at the community level are excited when introduces to the system for the first time. However sustaining the interest through continued use of the system is difficult. Most users require a personal identity on the platform. It helps to build into the platform a social network that allows users to interconnect and share information and alerts on various issues e.g. an alert if a place close to you has been mapped or modified.

v.) The system requires continued monetary support from the county government. When the research funds run out, it is difficult to keep it running. GIS initiatives are yet to take root in Kenyan county governments and they are thus reluctant to make a budgetary allocation to the project. Outside support by donors can still sustain the project but for true success to be achieved, a lion's share of the budget should originate from the county government. This will make the system more accountable when audited for benefits versus costs.

vi.) A GIS office with staff and other resources should be created at the community level. Members of the community should be recruited and trained to support all aspects of the system. This will create a local identity for the system. They can further create a community version in the local language to accommodate the wider community. Supporting the system through the current project structure will not be sustainable in the long run.

5. Conclusion

This paper presents a community GIS initiative in a Kenyan context. The developed system has the ability to deliver various spatial responses to users queries. With a simple to use interface, it is anticipated to be easy to learn and be productive on the system in a very short time. This project covers a new area in the Kenyan

context even though that may not be the case globally. The project heavily borrows on the documented experiences of other similar projects in different countries. This experiences are tweaked to fit the Kenyan context albeit with challenges because of various situations unique to current Kenya.

The system leverages on web technologies to integrate data from disparate sources and make the same available for the planning process. This webGIS approach supports the push by Kenyan county governments to use ICT to modernize planning operations. It is anticipated that in the long run there will be increased access to emuhaya resource information which will foster participation and equity in planning activities at the community level.

6. Recommendations

Subsequent versions of the webGIS will target devices that are easily accessible to the local community for example mobile phones. In the Kenyan market mobile phone subscriptions increased by 2.5% in the last quarter of 2013 to reach 31.3 subscribers (Communications Commission of Kenya,2013). Though having slightly dropped, the number of estimated internet users stands at 19.1 million. This is a significant number that creates opportunities to exploit the mobile internet as a service/product delivery channel. The mobile phone market in the country has also seen an increase in cheap smart phones. These phones are popular as they give users an opportunity to participate in social networks and other internet dependent services. When properly optimized, the webGIS can also be delivered/rendered on this smart phones thus increasing coverage by relying on the numerous smart phones already in use. However this is still a discussion in progress with implementation not yet started.

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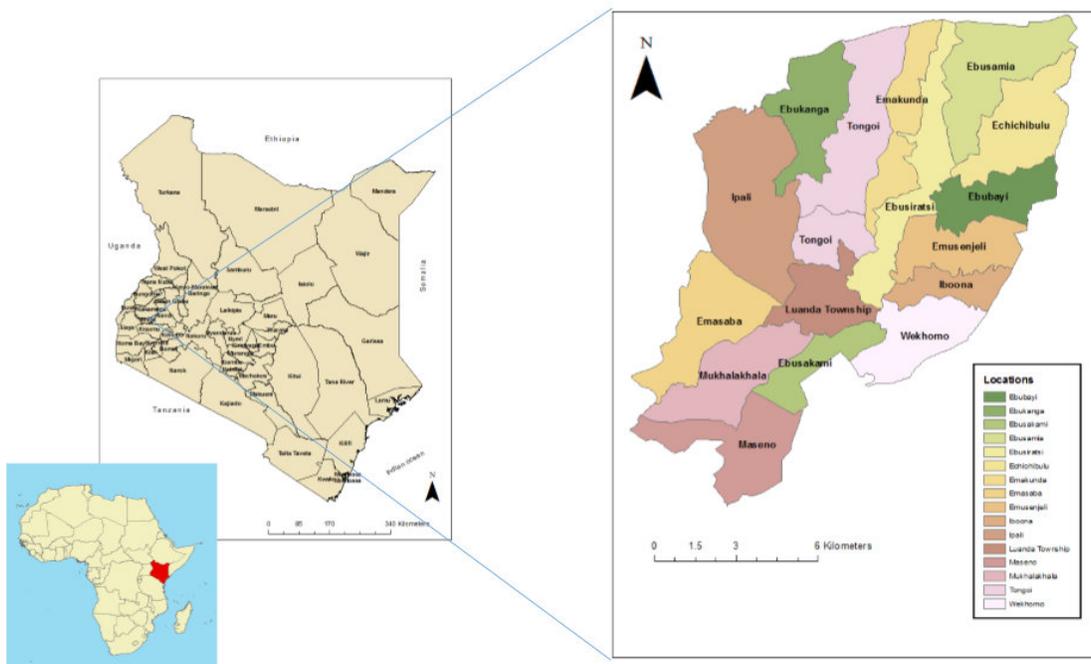
8. Appendix

Figure 1: Location of Emuhaya showing location administrative boundaries. Inset on the right is Vihiga County, the administrative county of Emuhaya.
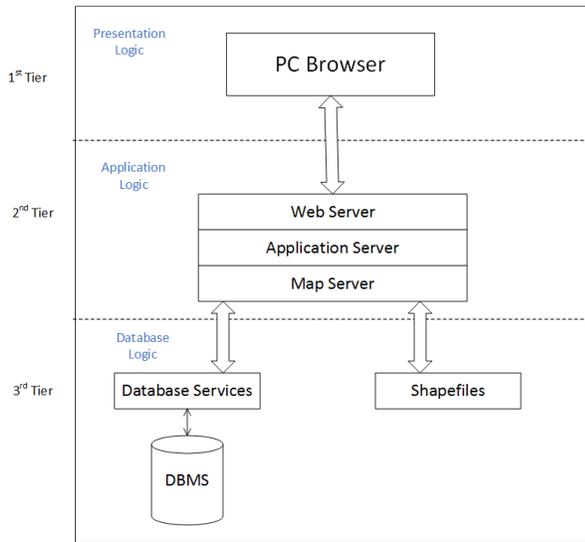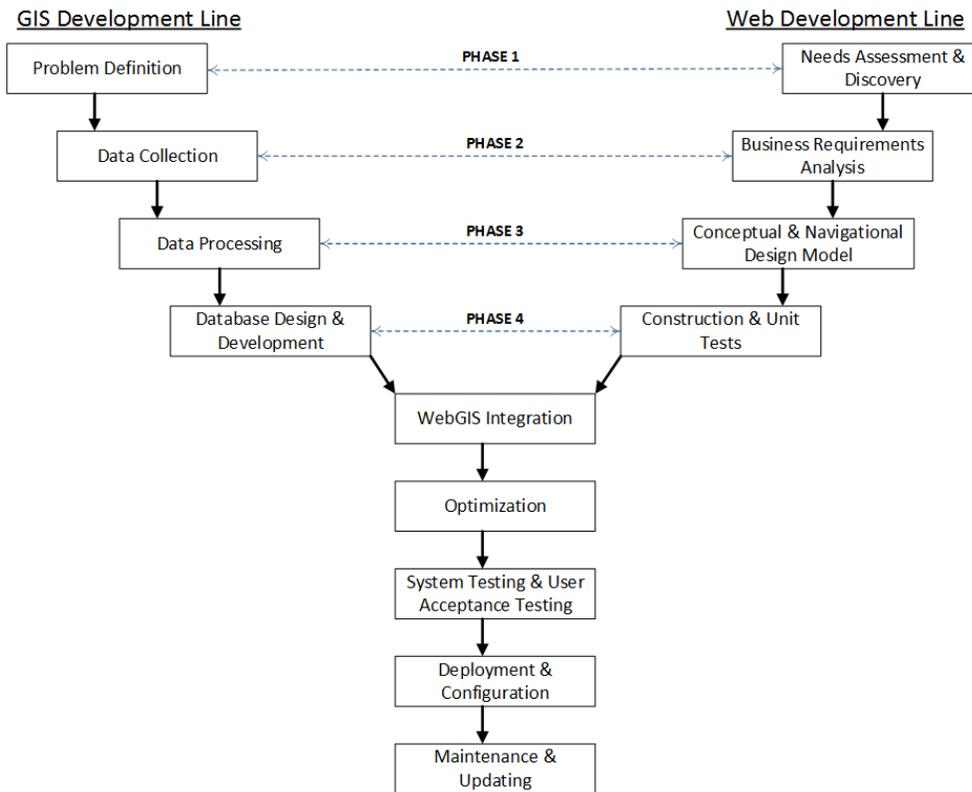
Figure 2: WebGIS Architecture

Figure 3: Development Methodology

Figure 4: Technical Office Consultations

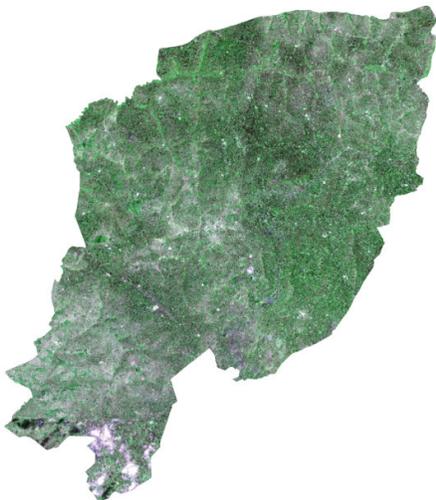**Figure 5: Field Sessions**

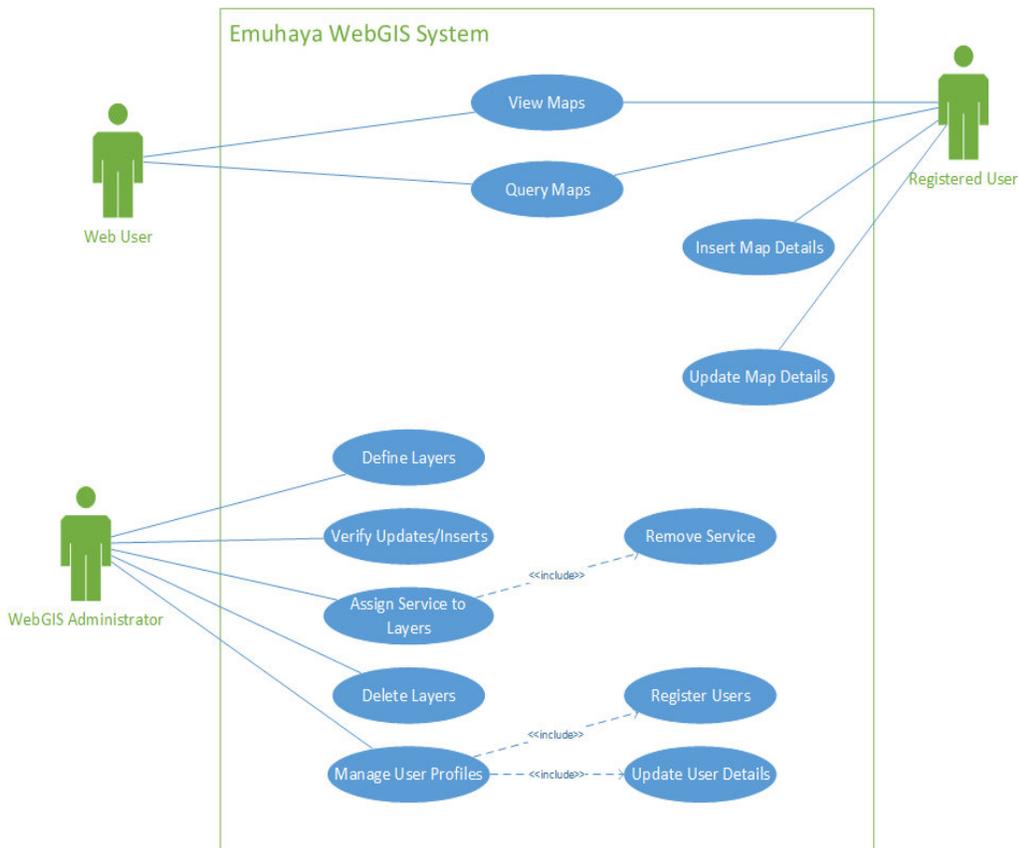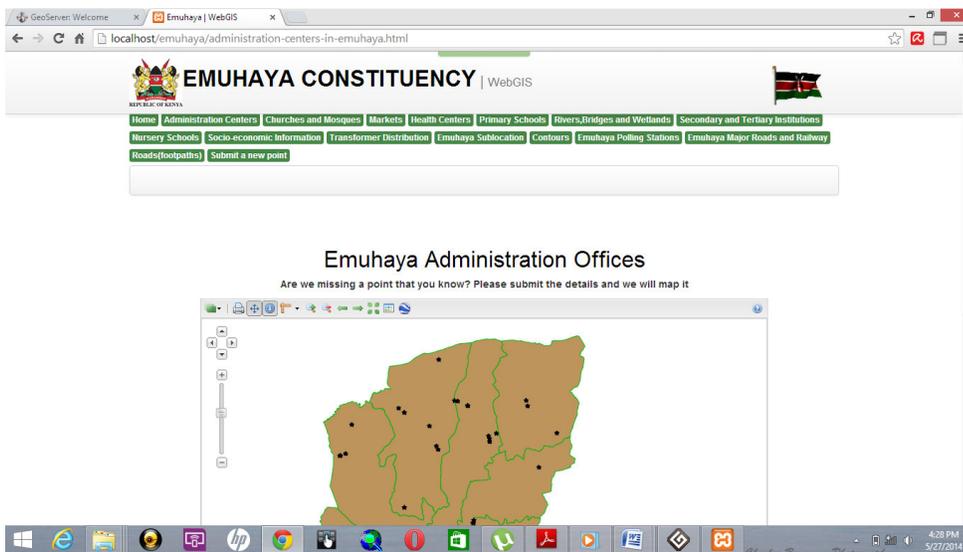**Figure 6: High Resolution Satellite Image of Emuhaya**

Figure 7: System UseCase Model

Figure 8: Sample Screen Shot