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School of Engineering

DEPARTMENT OF GEOSPATIAL AND SPACE TECHNOLOGY

DEVELOPING A WEB MAPPING APPLICATION FOR MANAGING AND VISUALIZATION OF THE LOCATION OF KENYA PORTS AUTHORITY LAND PARCELS IN MOMBASA

BY

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A Project submitted in partial fulfillment for the Degree of Master of Science in Geographic Information Systems in the Department of geospatial science and space technology of the University of Nairobi

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Dr. COLLINS M MWANGE Date

Dedication

I would like dedicate my research to my parents Mr and Mrs Omido for their support in my academic life, thank you and my wife Farida Namelok, thank you.

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This research project would not have been possible were it not for support and guidance from various institutions and people. Firstly I would like to thank God for the gift of life; secondly I pass my gratitude to my supervisor Dr. Collins M Mwange for the close guidance and immense contributions to the whole research process. Thirdly I would like to thank Mr Bernard Munyao of Survey of Kenya for the valuable assistance in data collection.

Lastly I would like to thank all the supportive people from KPA Mombasa offices and Ministry of lands land registry and valuation department.

Abstract

In the year 2017 Kenya Ports Authority land audit, it was reported that Mombasa County has 90% of the land parcels used by the agency for its operations. The number of parcels allocated and owned by KPA in Mombasa is 171, based on land ownership documents provided by KPA land survey division; the land documents includes certificate of leases and land titles. From the 171 parcel ownership documents, only 65 of the land documents indicated the parcel acreage while 106 documents did not indicate land parcel acreage or were not legible. This research project aimed at filling the gaps in information from the audit report that is important for use and is not readily available on land ownership documents. The web application was developed using Free and Open Source Software (FOSS) web development tools. Tools such as QuantumGIS (QGIS), HyperText Mark-up Language (HTML), Cascading Style Sheets (CSS), GeoJSON, LeafletJS, Apache Tomcat, JavaScript and Open layers, notepad++ were selected for the web application development. These FOSS tools were used to create and deploy a web application that will provide a better option for KPA stakeholders to quickly access information about parcels in the office or in the field without referring to paper survey plans.

In creating this web application, survey plans for land parcels available paper formats were collected from Survey of Kenya (SOK), digitized and resultant Geographic Information Systems (GIS) vector data overlaid online on interchangeable Google Maps and OpenStreetMaps (OSM) base maps to provide contextualization of parcel location. Furthermore, the web application provides a scalable, portable and efficient online platform that can be used to retrieve timely and useful information about parcel size, location and additional information about parcels not available on survey plans i.e. ownership/lessee of land.

This web mapping application provides a web-based land information system that can be utilized by all stakeholders involved in parcels related activities for Kenya Ports Authority (KPA). The stakeholders include; high level managers, mid-level managers and technicians in constructions within the port The web application provides a user friendly interface that provides quick answers about the physical location, size, perimeter and current use of land. More so the web application allows the user to view additional information such as the current owner of parcels/lessee and market value of the parcels. In conclusion, this research project can be scaled up to integrate all land in Kenya belonging to KPA to ease parcel management activities. This research project conclusively achieved all its objectives since all users of the web platform

developed can accurately measure areas of parcels, view the location of parcels on an earth model such as Google maps and be able to view additional information regarding a parcel via a pop up window The project can also be adopted by government and non-government agencies that own large number of parcels for ease of land information management.

Key words: CSS, FOSS, GIS, HTML, KPA, QGIS, OSM, SOK

Contents

Declaration of Originality ii

Declaration iii

Dedication iv

Acknowledgements v

Abstract vi

Contents viii

List of Figures xi

List of Tables xii

List of abbreviations xiii

CHAPTER 1 : INTRODUCTION 1

1.1 Background 1

1.2 Problem Statement 2

1.3 Objectives 3

1.4 Justification for the Study 4

1.5 Scope of Work 5

1.6 Organization of the Report 6

CHAPTER 2 : LITERATURE REVIEW 7

2.1 About the Kenya Ports Authority 7

2.2 Geographic Information Systems (GIS) 7

2.3 Land Information System 8

2.4 Evolution of GIS from Desktop to WebGIS and Web Mapping 10

2.5 Web-based Land Information System 12

2.6 Effort of the National Land Commission in Public land Management 14

2.7 Web technologies and current trends in Land information 14

2.8 Google Maps and OpenStreet Maps (OSM) 16

CHAPTER 3 MATERIALS AND METHODS 17
3.1 The research project objectives 19
3.2 Data collection 19
3.3 Scanning, Georeferencing and Digitization of Survey Plans 20
3.4 Data Entry into Attribute Tables of the Parcels Shapefiles 22
3.5 Developing a Web Mapping Application Interface 23
3.6 Creating GeoJSON from the Shapefile 23
3.7 Web Mapping Code with HTML and LeafletJS 25
3.8 Developing of Search Tools 25
3.9 Development of Measuring Tools 26
3.10 Developing a tool to Provide Additional Information about a Parcel 27
CHAPTER 4 RESULTS AND DISCUSSIONS 29
4.1 Website for Managing KPA parcels 29
4.2 Overlay of Parcels on Online Imagery 30
4.3 Verification of Accuracy of Areas of Parcels 31
4.4 Querying of Additional Parcel Information about Specific Parcels 44
CHAPTER 5 CONCLUSIONS AND RECOMMENDATIONS 47
5.1 Introduction 47
5.2 Conclusion 47
5.3 Recommandations 48
5.4 Areas of further research 49
REFERENCES 50
APPENDICES 52
APPENDIX 1: KPA Parcels List 52
APPENDIX 2: Web Application Source Code 61

APPENDIX 3: Web Application Interface.. 75

List of Figures

Figure 1-1 Mombasa County 5

Figure 2-1 A Simple Web Mapping Architecture 11

Figure 2-2 A digital Cadastre of Lagos Nigeria Overlaid on a VHR Geo-eye Image 13

Figure 2-3 Web-Based LIS for a Municipal Region in Spain 13

Figure 2-4 A conceptual framework for developing web map 15

Figure 3-1 Methodology Flowchart 18

Figure 3-2 Scanned Survey Plan for a parcel in Mombasa 19

Figure 3-3 Survey plan for parcels in a block 20

Figure 3-4 Plot number 662 digitized from Survey Plan 21

Figure 3-5 Some of the parcels digitized in GIS environment 21

Figure 3-6 Data Entry into shapefiles attribute tables 22

Figure 3-7 A mock design of User interface for web application 23

Figure 3-8 Creating a GeoJSON file from parcels shapefile 24

Figure 3-9 GeoJSON file viewed in Notepad++ 24

Figure 3-10 Created JavaScript Map Overlay Code 25

Figure 3-11 A code created in JavaScript to Initialize the Parcel Search Tool 26

Figure 3-12 A code written in JavaScript to initialize and Launch Search Tool 26

Figure 3-13 A code in JavaScript to initialize the Measurement Tool 27

Figure 3-14 JavaScript code for display of attribute information 28

Figure 4-1 User Interface Developed for Web Application 29

Figure 4-2 Web Application that displays the location of parcels on Google Maps 30

Figure 4-3 Parcel I/358 with Additional Information about the Parcel 45

Figure 4-4 Parcel I/439 with Additional Parcel Information Displayed for the Users 46

Figure 4-5 Parcel I/254 Leased by KPA and Attached are Additional details About Parcel 46

Figure 7-1 Web page for KPA parcels of land in Mombasa 75

List of Tables

Table 4-1 Reported Areas Vs. Areas from Survey plans digitized 31

Table 4-2 106 Parcels Whose Size was Unknown, Measured Online and all Areas Determined 33

Table 4-3 All Parcels List Complete With Actual Areas Measured From Web Application 38

List of abbreviations

FOSS Fee and Open Source Software

GIS Geographic Information Systems

HTML Hypertext Markup Language

KPA Kenya Ports Authority

LIS Land Information Systems

OSM OpenStreetMaps

PLIS Public Land Information System

QGIS Quantum GIS software

SOK Survey of Kenya

CHAPTER 1 : INTRODUCTION

1.1 Background

An Act of Parliament in 1978 led to the establishment of Kenya Ports Authority (KPA). The main obligation of KPA is to manage the port of Mombasa and other smaller ports along the Kenyan coastline including Lamu, Malindi, Kilifi, Mtwapa, Kiunga, Vanga, Funzi and Shimoni. In addition, KPA is tasked with the management of Kenya inland waterways and container depots in Embakasi located in Nairobi and Eldoret and the Port of Kisumu and recently a new container depot in Taveta.

The port of Mombasa is not only the headquarters of KPA but also the main gateway of imports delivered by Sea to East and Central Africa. This makes it one of the busiest ports along the Indian Ocean coastline in East Africa. Mombasa port links to over 80 other ports worldwide and provides direct link to other countries such as Rwanda, Uganda, Burundi, Eastern Democratic Republic of Congo, Southern Sudan, Northern Tanzania, Ethiopia and Somalia

With a large clientele for KPA, the government of Kenya has allocated the Agency a lot of lands, which varies in size, shape, use and are located in different counties and towns. The main aim of allocating more parcels to the agency is to allow for container holding and clearance to different destinations inside and outside Africa, specifically Kenya.

With the allocation of more parcels of land in various counties, there are a high number of parcel records that need to be managed by KPA. Since the start of land transactions at the beginning of the last century, the storage of land records has been in manual paper format. The agency owns more than 170 parcels in Kenya and this has resulted in the handling of a lot of paper records. KPA has also leased some of its land parcels to other organisations, private individuals and businesses. Therefore the management of this vast amount of data and regular retrieval of some important parcel information is a daunting task since all the land records are stored in paper format and kept in storage that are in different locations within the agency or separate offices in different towns for example parcel information stored by one section and lease information stored by a different section within the organization.

Some of the parcel information stored in paper formats by KPA include: the sizes for all parcels, leaseholder information in case the parcels were leased, and the market values of the parcels.

This represents a lot of information in paper format that provide paper storage challenges to the organisation and may result in information loss.

This project focuses on the digitization of land parcel geometrical information from survey plans collected from Survey of Kenya (SOK) and addition of attribute information then utilizing a Geographic Information System (GIS) environment to integrate these two types of information. After integration in a GIS, land parcels information resource was developed and shared on the web for use in Land Information System Management and visualization. The application was created using Free and Open Source Software (FOSS) and tools.

The worldwide availability of Internet and the rapid development of web 2.0 have made sharing information from remote sources via the web very simple, efficient and desirable to the information society around the world. Sharing of information on the web provides ease of access as the only requirement is a device that can connect to internet; this in effect saves time it takes to retrieve important information about any subject including land parcels whether in the office or on field assignments. This study outlines the development of web-based LIS that can not only be used for management of land parcels but also visualisation of parcels physical locations by overlaying accurate parcel information on available free base maps online such as Google satellite imagery and OpenStreetMaps.

In this project, FOSS tools were used to develop a web mapping application for managing KPA land parcels, software to be used will include: QuantumGIS, Notepad++, JavaScript, GeoJSON, HTML, Apache Tomcat Server, CSS, LeafletJS, Google and OSM imagery

1.2 Problem Statement

Kenya Ports Authority (KPA) has been allocated many land parcels in Kenya; the total number of parcels allocated for the authority activities according to KPA audit report in 2017 is estimated to be well over 200 parcels in the country. The 2017 KPA parcels audit report estimated that a total of 171 parcels are located in Mombasa County.

In Kenya since the colonial era, all land records are stored in paper format and additional parcel information such as land-use, are stored in paper format but in separate sections within the organisation, all this information has to be retrieved separately during a land query activity.

Therefore with a large number of parcels to operate and manage, handling of manual paper files for storing parcel data has proven to be inefficient and ineffective in the agencies' operations.

Paper records have proven to provide several challenges when poorly stored and mishandled. Paper records also are affected by age. To avoid the challenges associated with the paper formats, creation of digital databases to store spatial parcel information that is then using GIS technology integrate with other non-spatial attribute information will provide an efficient way of storing land information and the paper files will be archived for future references.

GIS and web mapping will provide an integrated platform that can provide an online interface for filtering specific land parcels through tailored selection queries, visualisation of parcel physical location through overlaying of parcel spatial extents on base map tiles such as Google satellite and OpenStreetMaps, this will provide a useful land management approach as paper files are archived. Attached to appendix number 7.1 is a list all plots located in Mombasa County from 2017 KPA Audit Report

1.3 Objectives

The main objective of this project is to develop a web application that will be used to manage all land parcels owned by Kenya Ports Authority located in Mombasa County using Free and Open Source software (FOSS).

The specific objective of the study was to:

i. To develop a website and overlay the land parcels over online base tile layers such as Google satellite and OpenStreetMaps for contextualization

ii. To query specific information about individual land parcels in a web environment accessible anywhere on a device with internet connection

iii. To verify the actual parcel areas and perimeter that are digitized from Survey Plans compared to reported areas from land registration documents as per the 2017 parcel audit

1.4 Justification for the Study

The process of recording the land parcels and transactions in land parcels in Kenya began in 1890s and the records has been stored in analogue paper based forms which are always poorly handled and stored. The land records in most cases are poorly managed and the analogue paper records as time goes by get affected by wear and tear and they become unusable. For larger organisations that have many parcels of land under their management, managing paper records quickly become ineffective and inefficient.

When the information about the parcels is lost, the land parcel is not utilized economically by organisations. The process of collecting parcel information from the ministry of land in Kenya maybe tedious and strenuous to the done more than once, if the land parcel records get torn or worn out due to poor storage.

To eliminate these challenges of poor land records management, many government agencies are adopting the process of transforming all their land related records from analogue paper based record to electronic digital records stored in digital databases. By creating of digital databases, it ensures ease of access of records and improves record security for the organisations. Having digital records allow the manual paper record to be properly stored in stores and can only be rarely retrieved to confirm and verify certain information.

Once a digital database has been developed, there is a need to share the information on a platform that can be accessed by all stakeholders who are GIS professionals and other different professions and careers involved in the organisations operations, hence the requirement to create a web based land records information system for the management of KPA parcels. Some of the information that will be captured in the web mapping application includes; the shape of the parcels, physical location of parcels displayed over a base tile layer, size of the parcels, current ownership of the parcels, status of leased parcels and finally the current land value of the parcels.

The availability Free and Open Sources software provides a cost effective way of making and developing web mapping applications that can be used to manage land resources.

Therefore this study focuses on how to use FOSS to create, and deploy a web mapping application to provide a tool for managing and visualization of physical location of land parcels belonging to the KPA in Mombasa County.

According to the 2017 Audit Report, the KPA senior management had three specific interests that necessitated the audit of land belonging to the agency, one of the needs was to know the

physical location of the parcels, and the second need was to know the shape of the parcels and ownership status of parcels. The agency had also decided to erect perimeter walls and fences on all its properties and land. Therefore by implementing this project, the final website developed can easily and conveniently provide answers to all this queries that had necessitated the activities that led to the agency requiring retrieval of all its land records to get parcel information.

1.5 Scope of Work

Kenya Ports Authority has land parcels in 9 counties in Kenya as indicated in the Figure 1.1 from the 200 parcels owned by KPA all over Kenya, 171 parcels are located in Mombasa County. It's on this basis that the study will focus on Mombasa County. Mombasa County is one of the forty seven counties in Kenya and it's the capital and administrative city of Mombasa county. Mombasa County lays between latitudes 3°56' and 4°10' south of the equator and longitudes 39°34' and 39°46' east. The county covers an area of 229.7 km^2 excluding 65 km^2 of water mass.

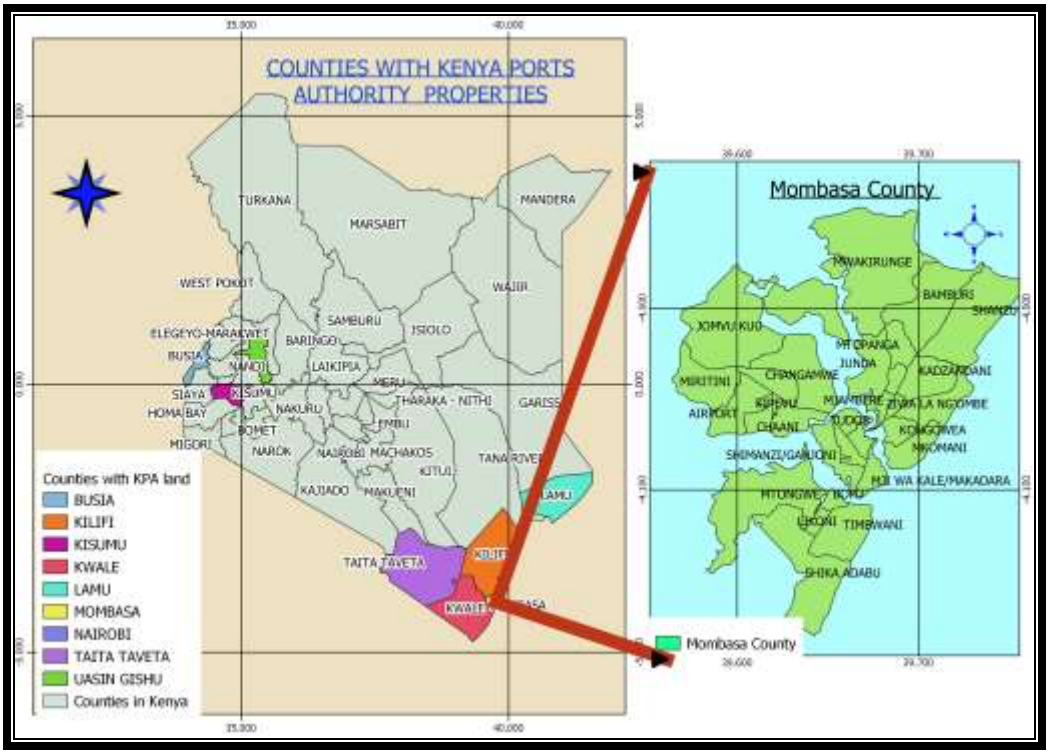


Figure 1-1 Mombasa County

The scope of work for this research project is to create a web mapping application that can help users to locate physical location of parcels using an online platform ,and access other related information including confirm the area from digitized data, perimeter, leaseholder, use and the market value of the parcels.

1.6 Organization of the Report

This project report is divided into seven chapters, Chapter One details the background information about the port and its functions as a gateway to East Africa mainland, detailed explanation of the research problem and how objectives of the research. Chapter Two provides literature review related research, while Chapter Three contains the materials and methods used for the research. Chapter Four contains the results of the research which is the web application and how it can be used to fulfil its purpose, while Chapter Five has the conclusions and recommendations of the research.

CHAPTER 2 : LITERATURE REVIEW

2.1 About the Kenya Ports Authority

Kenya Ports Authority was established by an act of parliament in 1978, it is mandated to operate, maintain and regulate all sea and inland ports in Kenya. The Headquarters of KPA is at Mombasa where the main port is also located; other smaller ports include Malindi, Lamu, and Kilifi, Mtwapa, Kiunga, Shimoni, Funzi and Vanga. Kenya Ports Authority also manages inland container depots in Nairobi Embakasi, Kisumu port, Eldoret, Busia and Taita Taveta.

Mombasa port is the main gateway to the East Africa hinterland; some of the countries that use Mombasa port for import and export include Kenya, Uganda, Burundi, Eastern Democratic Republic of Congo, Northern Tanzania, South Sudan, Somalia and Ethiopia. (Winnie, 2018)

Kenya ports Authority has been allocated over 200 parcels of land that are supposed to be used in the ports operations, this land parcels vary in size and are located in very different locations within the country. The Port has the capability to lease some of the land to other competing agencies and private individuals, hence there is a documentation system for the management of this records that store information about the parcels belonging to the port. All the land records and land related information available is currently stored in paper format and stored in separate offices within the organisation.

2.2 Geographic Information Systems (GIS)

A Geographic Information System (GIS) is a type of information system that utilizes the spatial data and attributes data (non-spatial data) in the sense that it allows capture, storage, manipulation, analysis, management and provision of actionable spatial data to the end users.

The GIS application is made of tools that allow users to make interactive queries, perform spatial analyses, edit maps data and finally generate reports from operations.

Modern GIS technologies consist of computer hardware and software, users, procedures and data. A fully functional GIS uses digital spatial and non-spatial information to produce results.

Data that is used in a GIS environment is created by either cadastral surveys, field data collection or by a process of transforming of analogue paper files and maps to digital formats through a process called digitization. GIS tools have the capability to store digitized data in spatial of geographic formats with their associated non spatial information (attributes), this make GIS an

important tool in creation of a Land Information System (LIS). In this research; GIS technology will be used to map and store information on the physical location of land parcels and also through queries provide information about the associated land parcels and what a unit parcel is used for.

2.3 Land Information System

The basic definition of a Land Information System (LIS) is that it consists of a GIS that stores cadastral information and land use –mapping records that are created from spatially accurate, up to date and reliable land records cadastre and associated non spatial parcel attribute stored together for use by users.

From Wiegand N (2002), definition a cadastre is a description of legal rights and financial interests in land or a cadastre can also be described as records that stores land ownership information. ·According to Ventura, (1997), a LIS functions as a way to collect, store, manage, retrieve, and perform analysis and display of land records. The LIS has several components which include a primary component known as the cadastre, a cadastre is normally managed and updated by a government agency, and a LIS is parcel oriented and uses hard copy maps or GIS to represent spatial shapes of parcels. LIS is used to manage parcels in large scale and provides a link between legal (titles) and the technical (maps) in land parcel management, LIS may also use technologies in data collection and data managements as well. LIS provide for a range of capabilities when storing and manipulation of spatial data such as spatial querying and graphical display of results on computer screens

Wiergard et al (2002) also notes that a parcel of land is the basic unit for access, control of land and land use decisions in a society and Portdar (2005) verifies that Land is an important asset in any country and any information regarding a land parcel is useful and important because it serves as a basis for land related decisions either for financial investments, commerce, industry and agriculture.

Since 1890 most land information in Kenya has been recorded and stored in files consisting of manual paper records. In most cases there are various independent agencies of the government managing specific information referencing to a specific land parcels i.e. shape and area is maintained by Survey of Kenya, value of land parcel is maintained by valuation department and lease information or information about ownership is maintained by other agencies i.e. the land

registry. In Kenya, some government agencies are mandated by law to own and completely manage their own parcels of land and with reference to the Kenyan law (RLA cap 300) land includes the surface covered by/in water, living things growing on land surface and anything fixed on the land surface.

Therefore, for any organisation to be able to effectively manage all natural resources including land it is important for the organisation involved to be able to acquire and manage information about the land resources. To be able to effectively manage the information acquired about land resources there is a requirement to create a dedicated information system for the land information, commonly known as land information system (LIS). Wiergard (2002) specifically states that a Land Information System(LIS), consist of information that refers to any physical, legal, economic, environmental information regarding land, water, groundwater, subsurface resources and also include air.

LIS properly functions by collection of land data, processing of collected data, storing of the data processed or collected and regular maintenance and updating of data and timely access and retrieval of associated information about land parcels. The LIS integrates spatial and non-spatial information about a land parcels, usually information is collected from different sources

As stated by Ventura(1997),the greatest challenge for storing data in a GIS is utilizing modern geographic information systems to store analogue paper based land records stored for many years since the agrarian revolution 200 years ago all over the world and in Kenya since the years 1898.

Some of the components of a GIS land records systems that are captured and stored in a GIS include the spatial reference framework where the datum and coordinate systems of the land parcel are linked to the national coordinate system. In Kenya, the coordinates systems used are Arc1960 and recently ITRF where the datum are Clarke 1880 and WGS84 respectively. To collect such data may involve intensive and costly field works and re-establishment of parcel boundaries for land parcels.

The other component required for GIS-based land records is the conversion of parcel data form analogue to digital formats through digitizing of existing paper based maps, and use of coordinates from parcel deeds descriptions and use of rectified orthophoto .The third component is the checking of data quality before its integrated in a GIS environment, this data quality check is important as it ensures that the collected data harmoniously mergers with existing parcel data

and also harmonises that parcel boundaries where there are discrepancies i.e. fixed survey boundaries and general survey boundaries. The data collected of the parcel boundaries must fit properly with other government based applications requirements such as planning, infrastructure and other agencies in government.

The GIS-based system for land parcels must also allow for regular update and maintenance to keep up with the dynamic nature of parcel layers which include parcel transaction updates such as transfer of ownership and subdivisions of parcels. This means that the GIS system for parcels should accommodate regular changes to the parcel unit and also store the historical records of all the parcel transactions on the parcel unit and the application should be portable, scalable and interoperable for different categories within the organization.

Furthermore, Khaleel et al (2016) clarifies that the GIS for parcel information should be assessable and usable throughout the organisations and also be available to satisfy the information needs for all users in the organisation. The public can have access to the data at the user terminals with limited privileges. This system is cost effective in terms of cost of data and information retrieval and information duplication; it's also an effective source of information for senior management and administrators and allows equal information distribution for all decision makers and stakeholders.

Khaleel also notes that some of the benefits of an LIS in being electronic and digital data storage provides for efficient and effective spatial data storage and spatial data management tool with multiple capabilities in data operations. Importantly a LIS also allows for ease of spatial data update and retrieval at the time of need within an organization.

2.4 Evolution of GIS from Desktop to WebGIS and Web Mapping

From Caitlin Dempsey, GIS lounge (1999) the definition of Geographic Information System (GIS) technology originate from the 1960s and it's was a necessity due to the increase in need for geographic or spatial information and the appearance of the first computers as well.

Most GIS are operated on a desktop computer and are called DesktopGIS, recently with the advancement and rapid development of the internet and the World Wide Web; more and dynamic GIS related applications are available online or on websites. The increase in computing capabilities and functions automation of GIS related analysis has led to up rise of web mapping and WebGIS. With advancement in technology, web GIS has rapidly developed as well and gained popularity with the advances made through web 2.0.

Web mapping in simple definition, is sharing maps on the web through the internet. The maps on the World Wide Web are a provided to users by webservers. The web mapping applications users interactively use web browsers to display maps as per the client request, the maps and geographic data and attribute data are stored in dedicated GIS databases. According to Mangondu et al (2014) a web mapping application normally has 3 components and these are a centralized spatial and attribute data storage, a web mapping component and a website to share the information to the users or clients. Figure 2.1 below shows a simple web mapping architecture

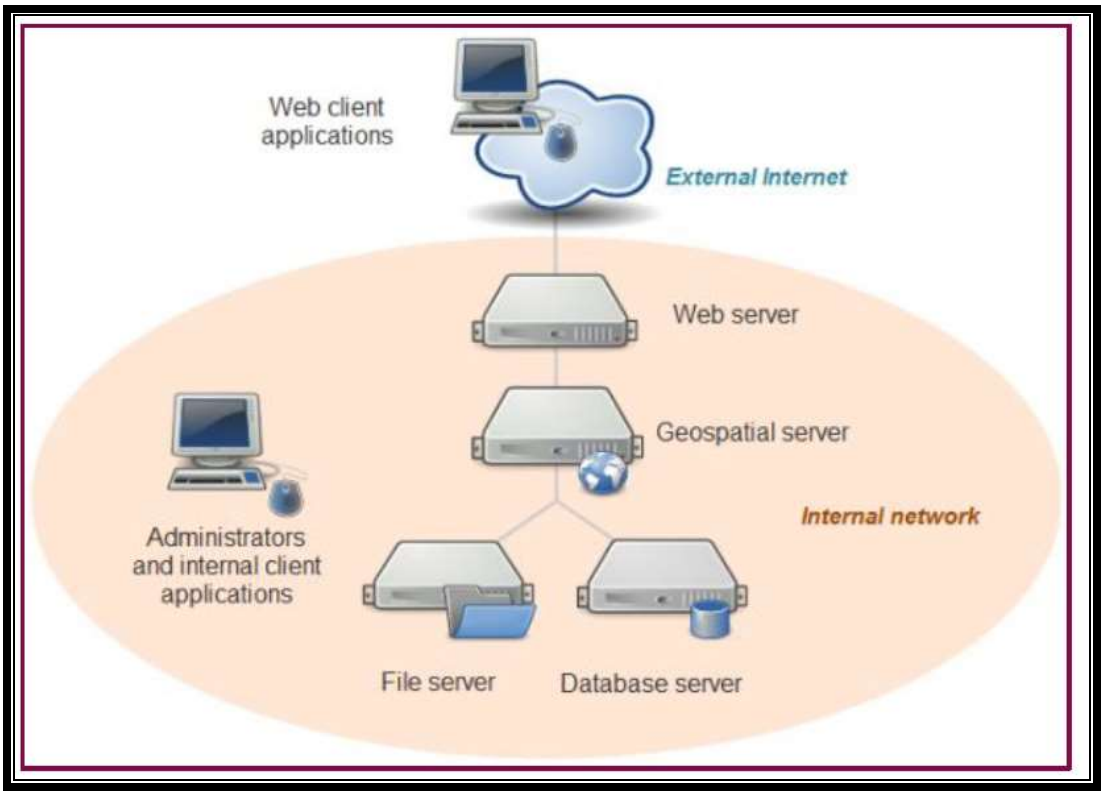


Figure 2-1 A Simple Web Mapping Architecture

Onyango (2014), identifies that simple web architecture consist of the 3 components such as database for spatial data, web servers and the clients who are the end users of the system.

In this architecture a user makes requests using the web browser referred to as web clients, the specific request is transmitted to the web servers using the Hyper Text transfer Protocols (HTTP) A web server is simply a computer that is capable of processing a web request. The web server acts upon the web request and sends the request to the geospatial server which is has the ability

to generate maps to be displayed on the web browser/ client based on the clients request received by the geographic server.

The geospatial map server fetches the request parameters form a geographic database, the geographic database is queried based on the application user's request. The final results received by the user will be a map drawn that is passed to the web server and displayed on the client's web browser based on the clients request parameters.

Before the geographic data is to be uploaded in databases, the geospatial data has to be prepared and processed by the system administrators using GIS software such as QGIS or ArcGIS. The data preparation and processing before upload to spatial databases may include coordinate transformations and generation of digital geographic data by way of digitizing paper maps and records.

2.5 Web-based Land Information System

A land Information System (LIS) can be effectively hosted on a website over the internet and this provide an efficient access to spatial and non-spatial data freely and quickly by geospatial professional and non-geospatial experts, this data can also be accessed by private companies and governments.

Khaleel et al (2016), states that a well designed and developed digital cadastre and the World Wide Web hosted over the internet provides an effective solution to the challenges that are systematically associated with the analogue and paper based cadastres in an organisation. LIS on a web platform provides a rare opportunity for widely sharing of information that can be assessed and accessed for a variety of uses and by a various users of the system.

A Survey of Kenya report (2013), indicates that a web LIS provides for an efficient way to share spatial and non-spatial data by providing an open and distributed web mapping architecture for sharing spatial data and online geospatial data processing tools over the internet. The users of the web LIS system can easily navigate on the displayed geospatial information on a user interface. The user interface when operational will display land parcel information as maps and the user interface will also enable for searching for specific land parcels using a pre-determined search criterion such a plot parcel number and also perform analysis such as measure area of parcel and print the parcel map.

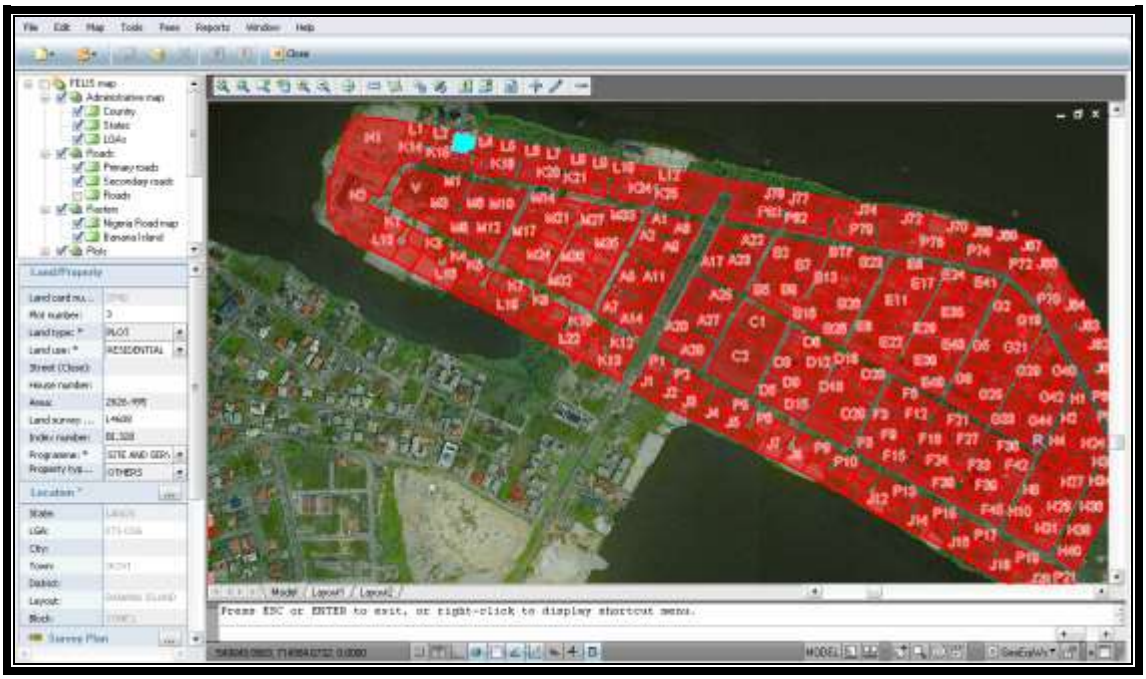


Figure 2-2 A digital Cadastre of Lagos Nigeria Overlaid on a VHR Geo-eye Image

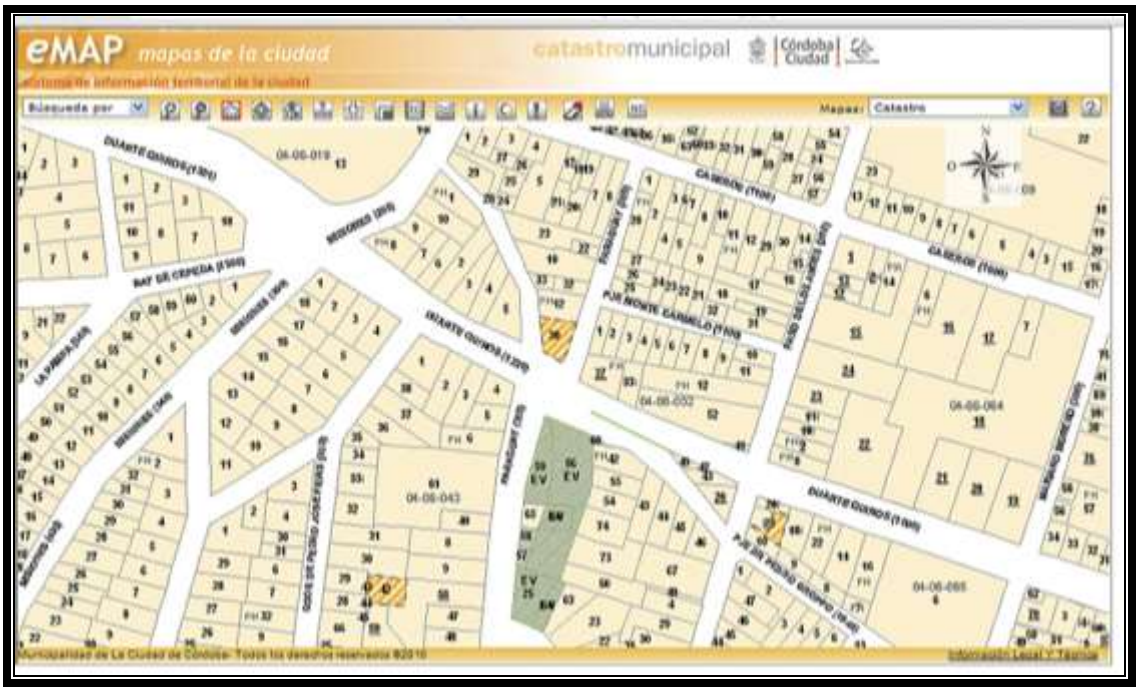


Figure 2-3 Web-Based LIS for a Municipal Region in Spain

2.6 Effort of the National Land Commission in Public land Management

The constitution of Kenya Promulgated in 2010 provides for the formation of the National Land Commission (NLC) under Article 67 of the Constitution, it also outlines the main functions of NLC which include managing of public land on behalf of national and county government Currently the NLC is developing an online platform for managing all public land for national and county governments, that will provide effective land information management system at national and county levels. The 2013-2019 commissioner end of term report by NLC indicated that the NLC directorate was tasked with developing and maintaining geographic spatial, legal, and environmental databases that are relevant to real property throughout the country. This Involves creation, analysis and publishing of land based data such as parcel information, zoning, land use, ownership and general property information. This task was prior to the Land (Amendment) Act of 2016 that broke down this role and shared it out with the Ministry of Lands, which NLC retained the role of creating a Public Land Information System (PLIS) while collaborating with the Ministry of lands on the project. This project is slight different since it manages public land for national and county government however KPA is an agency that has some autonomy in its operations. The PLIS has to be managed and operated by a directorate at NLC on behalf of national and county government.

2.7 Web technologies and current trends in Land information

Williamson (1999) noted that Global drivers such as sustainable development, globalization, micro-economic reform and technology are changing the way humankind relates to land. This has resulted into result existing land administration and cadastral systems are being re-engineered. There has been a revolution in the information society that consumes complex information about land. Brief history of changes in land information for mankind has evolved from the human settlement ages, to agrarian revolution, feudal systems, the industrial revolution age, the post-world war era and information society age. In each era specific information about land was required by the stakeholders. For the new age in information sharing the land related information presents a complex type of phenomena that many stakeholders need information about from engineers to environmentalists.

(Prof . Dr. Eng Tamenoujka Bardrova 2020) states that with the rapid growth and spread of internet connectivity there is a shift from paper maps to electronic and the emergence of web

map services impose new challenges in front of modern map makers that need to utilize ICT achievements and meet requirements of map users. Moreover Against the backdrop of massive and widespread information-gathering tools, modern cartography is becoming extremely attractive to both developers of maps and users. Web mapping products and services consumers includes cartographers, ICT professionals, developers and providers of GIS / Web geospatial data and software platforms, international standardization organizations, the private sector, politicians, governments and geo-communities

Cloud computing, in computer science, is a model for providing ubiquitous and convenient network access on-demand to a collective pool, configurable computing resources (for example, data networks, servers, storage devices, applications and services - both together and separately). Supported by the emerging needs and principles for interoperability of geospatial data, standardization and pragmatism in visualization, many open platforms for the development of WEB GIS-mapping products and services are emerging. The continuous technological progress and the development of modern science allow innovations and automation of cartographic processes. Cloud technologies are a new stage in the web-cartography.

The figure below is a conceptual framework for developing and sharing a web map to satisfy the current web mapping needs by clients

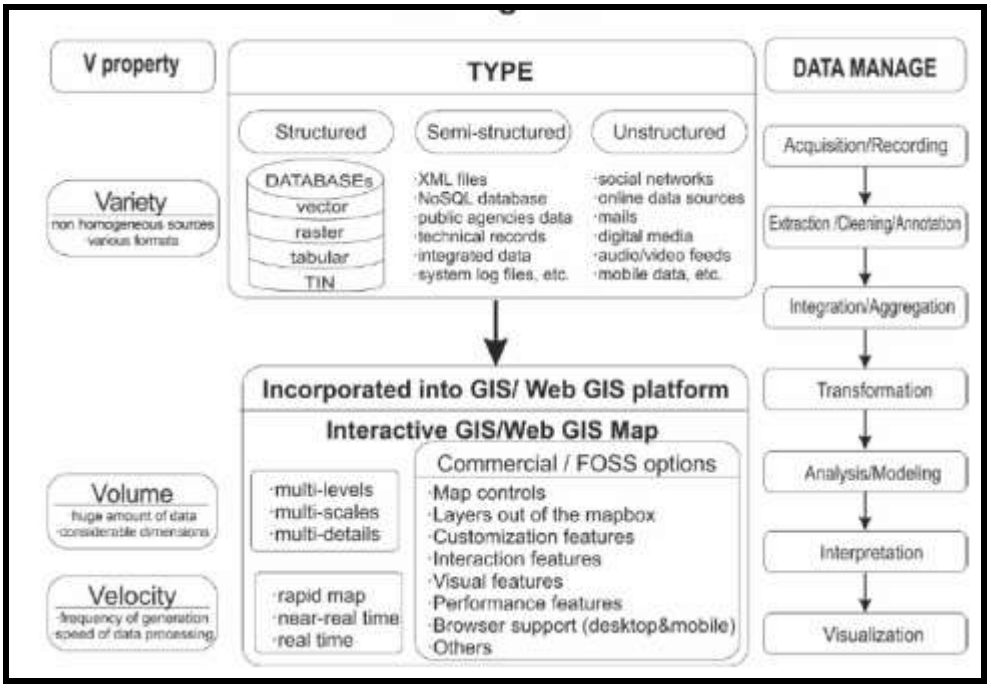


Figure 2-4 A conceptual framework for developing web map

2.8 Google Maps and OpenStreet Maps (OSM)

Worldwide coverage capability of Google maps, Bing Maps and OpenStreetMaps (OSM) provide the most useful and freely accessible web based mapping systems for locating places and services for users. Malarvizhia et al (2015) notes that Google satellite images provide clients with the most up-to-date imagery with a spatial resolution of 1meter, this when overlaid with accurately generated spatial data can provide most accurate way for visualization physical location of a particular phenomenon on earth.

Haklay et al (2008) states that the OpenStreetMaps maps are crowd sourced maps which are regularly updated. The OSM are produced through crowdsourcing and this has been done for over 15 years. The main factors driving this paradigm shift in map production not only being the rapid development of web 2.0, but also a combination of available high bandwidth of internet and a set of well-developed collaborative tools for both geospatial and non-geospatial professionals. Notably OSM has a vast number of users and contributors worldwide and the number of contributors continues to grow as well. Haklay also identifies that as of 2008 OSM had more than 33,000 registered system users and more than 3500 active contributors to the system, in 2020 this number is expected to have tripled. Therefore with a large number of users and dedicated contributors, OSM is updated regularly and provides a very accurate source for online geospatial information that is accessible to large variety of users.

Google maps also use the Google Map maker platform to engage users for regularly update of places and man-made features on Google maps platform, hence also provides a up to date source of place names and features on earth. Conclusively both OSM and Google maps are constantly updated and this has revolutionized the online geospatial data to provide up to date source of free and accessible data and information, such information may include business names, school names, property boundaries, street names, location names etc. OSM and Google maps are important tools for location based services for web mapping since the information and details accessible on this platforms is accurate and a real representation of the available features in an area of interest by users.

CHAPTER 3 MATERIALS AND METHODS

The main objective of this study is to develop a web-based LIS for KPA that will not only be used to manage parcels but also provide graphical display and visualization of the actual physical location of the land parcels overlaid on Google Physical Layers or OpenStreetMaps. The knowledge of the location of the parcel is very useful to the decision makers to make informed decisions concerning the type of function the parcel can be used for in the port operations.

Other information that can be obtained from this web application include: the area and perimeter of parcel and the user might want to get more information about the parcels such as if it is leased or how is the parcel being used. This information has to be added to the web application and be accessed through queries

Figure 3.1 is a flow chart that indicates the steps that were followed when developing a web-based LIS for fulfilling the project objectives. The steps include:

1. The user requirements are the size of parcels, physical location of parcels, and other parcel related information such as use and ownership or leaseholders identity,
2. Data collection using land reference details (attached to Appendix 7.1) to search for survey plans from Survey of Kenya offices and KPA offices,
3. Scanning, georeferencing and digitization of Survey plans in QGIS,
4. Data entry into attribute tables of the parcels shapefiles attribute tables in QGIS,
5. Using Notepad++ to write a web mapping application code and create a GeoJSON files(GIS file formats),
6. Creation of GeoJSON layer form shapefile digitized to integrate parcel data in vector format with the web mapping application code,
7. Web hosting and testing the web application to determine if it satisfies the user objectives efficiently and

8. Use application to search for parcels on the website using land references (see Appendix 7.1), view location of parcels, measure size and perimeter and view additional parcel information about the parcels.

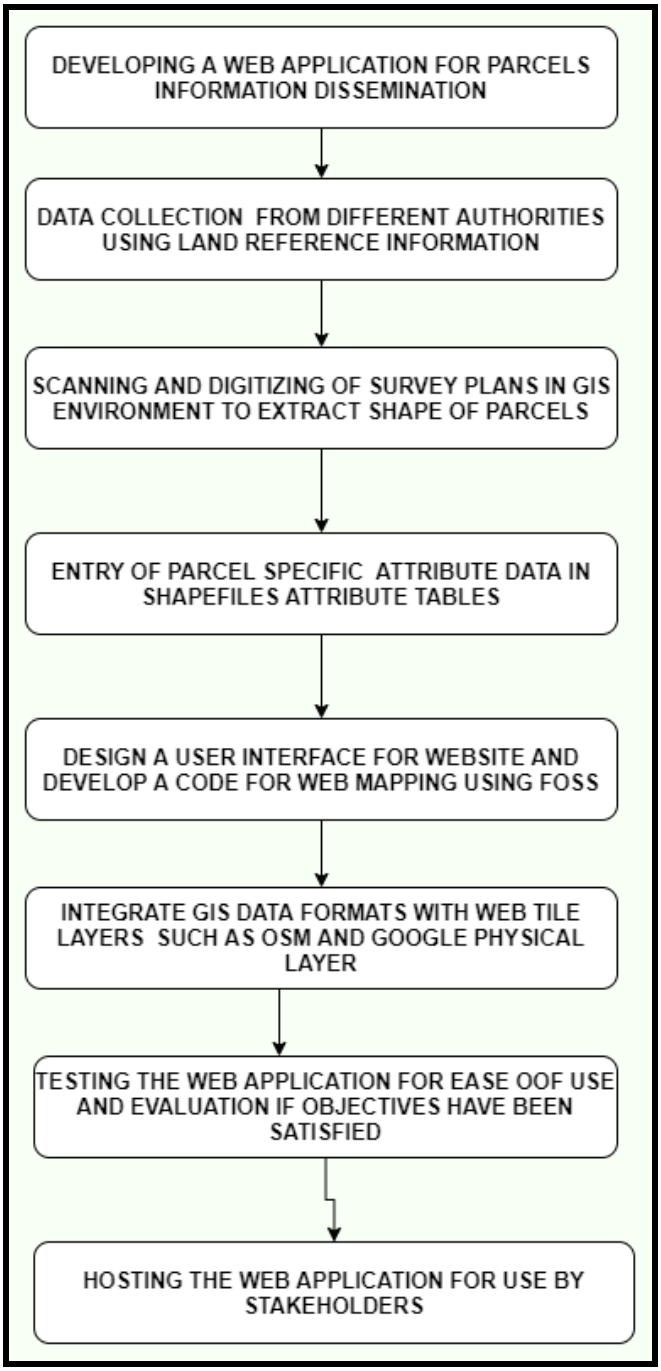


Figure 3-1 Methodology Flowchart

3.1 The research project objectives

The main purpose of this project is to provide a reliable source of information that can be quickly accessed by stakeholders involved in KPA land management and administration the specific user only requires having parcel land reference number (see Appendix 7.1) to search for a parcel on the web mapping application. The searched parcel will be graphically located on the website and some of the answers the website will provide include:

- ✓ The physical location of the parcels
- ✓ The size of parcel and perimeter of parcel for fencing purposes
- ✓ And additional parcel information that might be useful to decision makers at the agency

3.2 Data collection

From the parcel list (See Appendix 7.1) the **land reference** details were used to search for survey plans at SOK offices and all 171 parcels records were successfully collected. Figure 3.2 and Figure 3.3 are examples of scanned survey plan collected form SOK offices

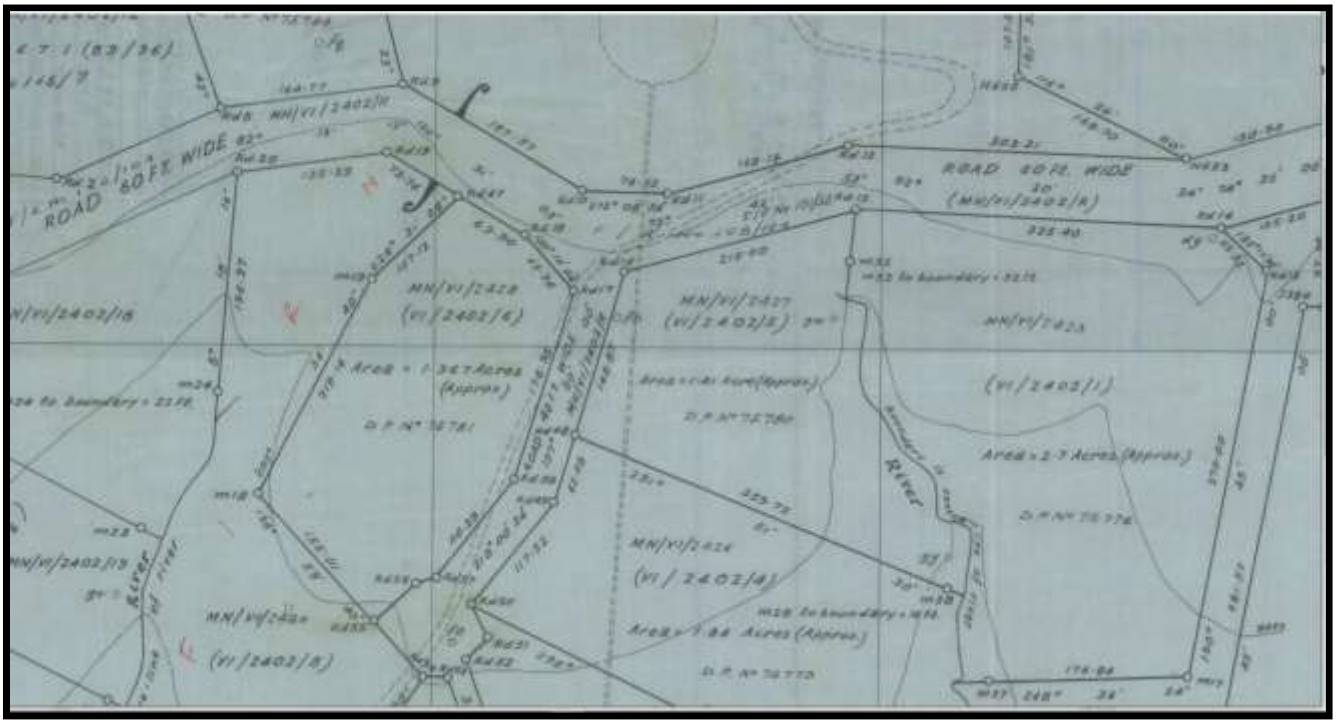


Figure 3-2 Scanned Survey Plan for a parcel in Mombasa

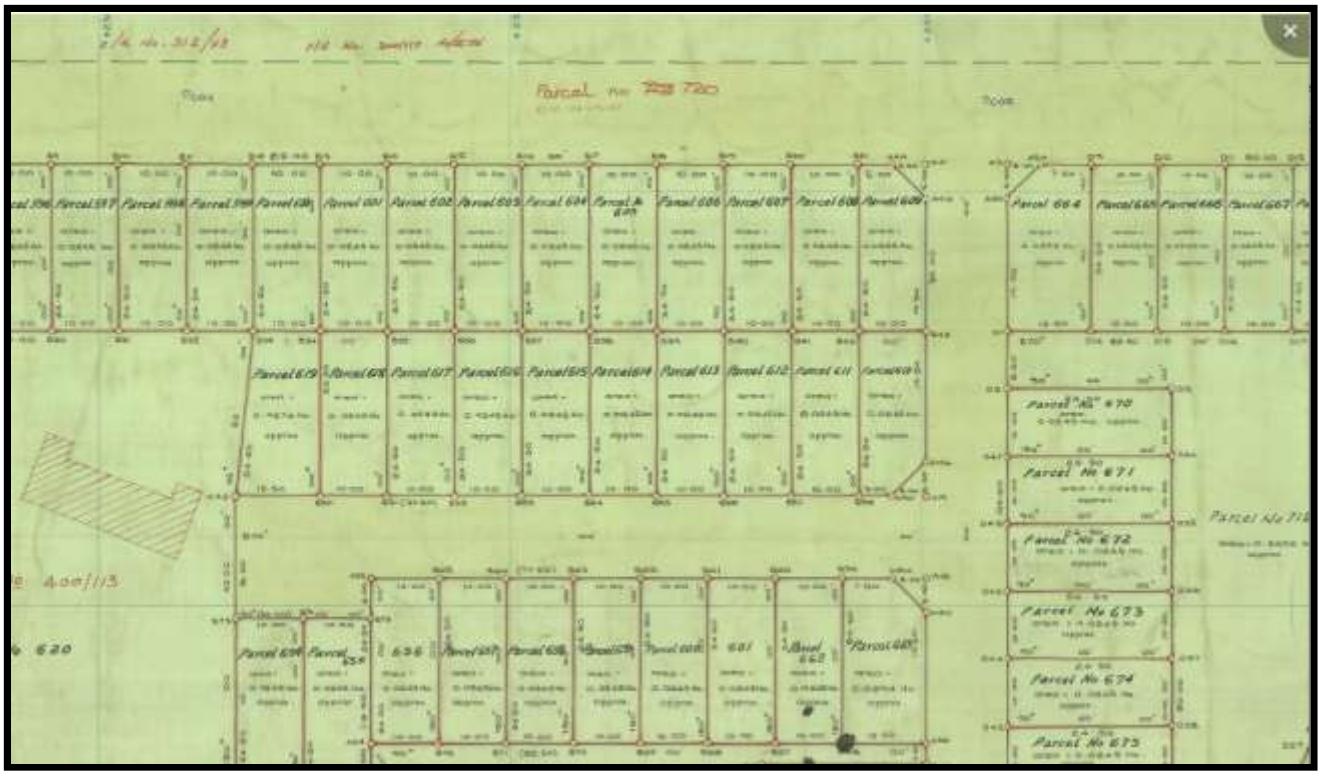


Figure 3-3 Survey plan for parcels in a block

Non spatial attribute data relating to the ownership of land and value of the respective land was collected from the Ministry of land registry offices and Valuation department within the ministry.

3.3 Scanning, Georeferencing and Digitization of Survey Plans

All the 171 survey plans were scanned, stored in a computer and georefrenced in GIS software environment known as QGIS, which is non-commercial GIS software available on the internet and can be downloaded and installed on any computer operating system. Figure 3.4 shows a georefrenced survey plan for Mombasa town and the two shapefiles captured during digitization are parcels belonging to KPA. This georeferencing and digitization process was repeated until all 171 parcels of interest were digitized and stored on a computer

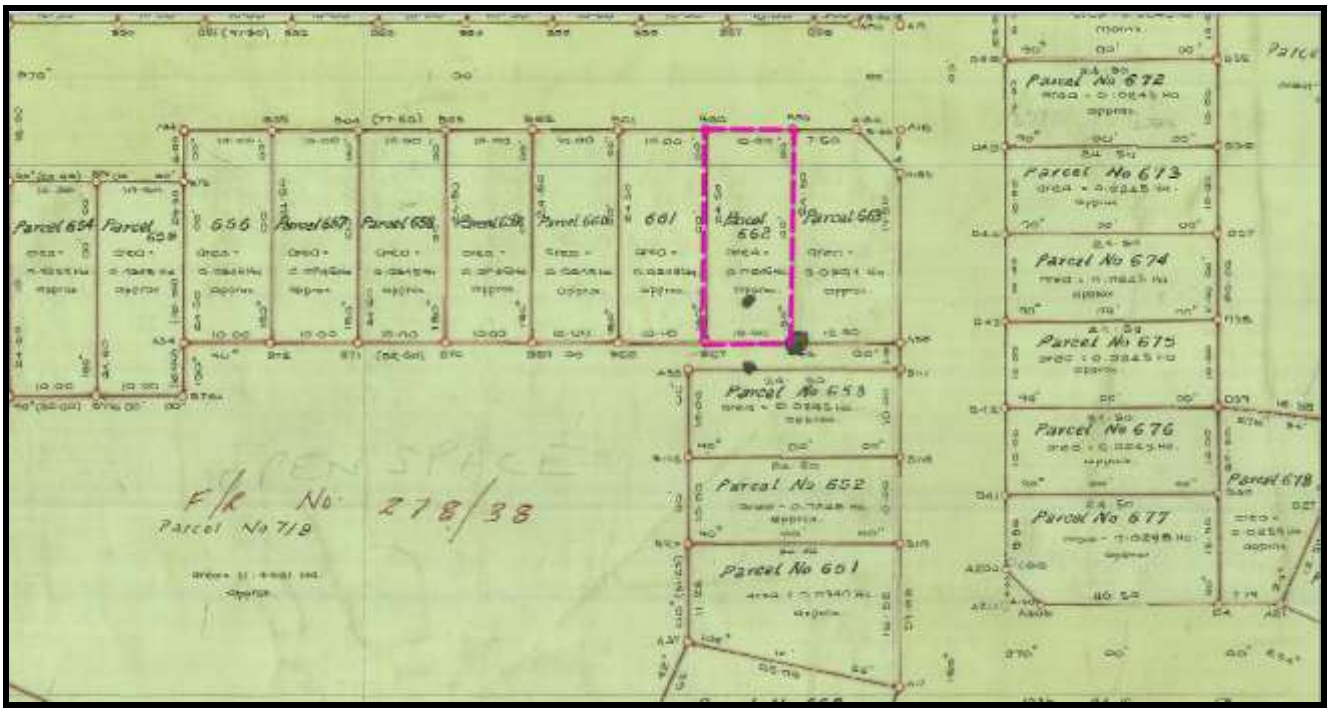


Figure 3-4 Plot number 662 digitized from Survey Plan

Figure 3.5 is an image of the resulting product from digitizing all 171 parcels belonging to KPA in Mombasa County.

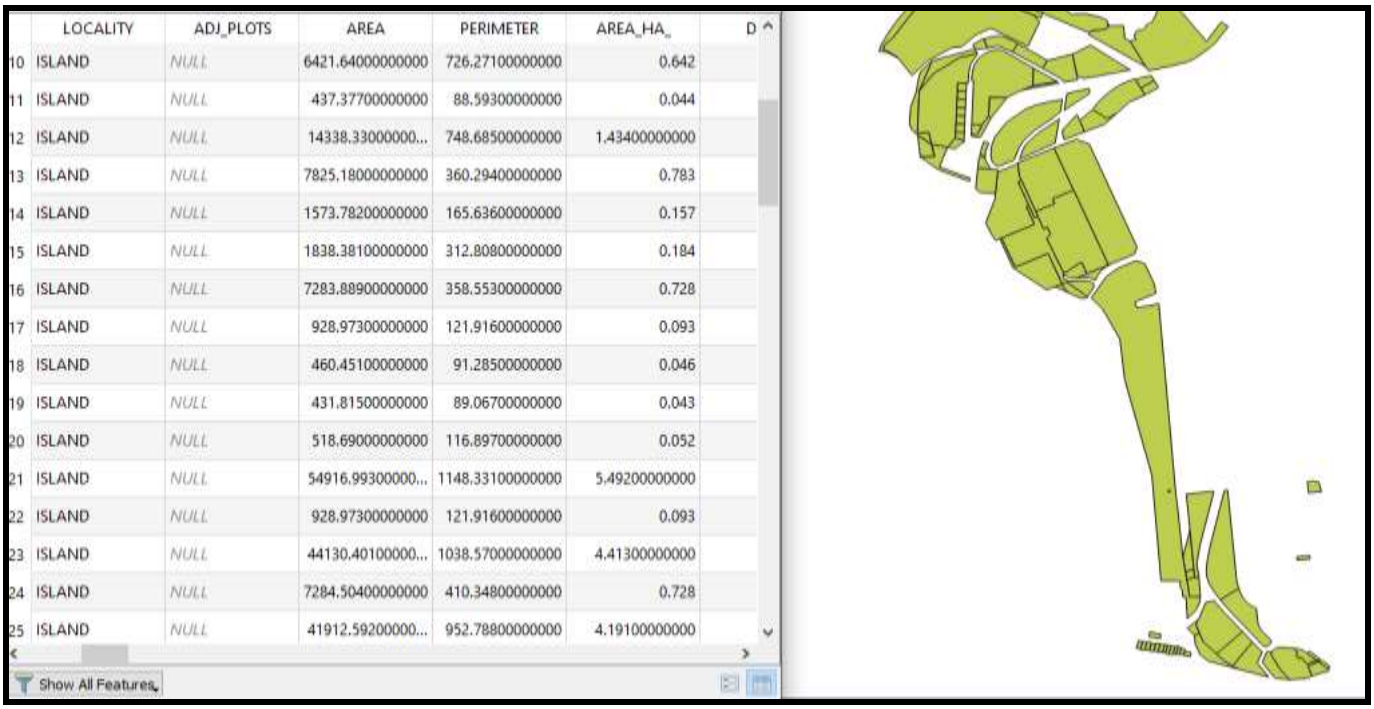
Figure 3-5 Some of the parcels digitized in GIS environment

3.4 Data Entry into Attribute Tables of the Parcels Shapefiles

When all the 171 parcels in Mombasa County were completely digitized, the information about parcels was added in the attribute tables of the shapefiles in QGIS environment. Some of the information added in the attribute table includes:

- Owner of the parcel either KPA or another lease holder
- Type of development on parcels or what the parcel is used for
- The market value of the parcel

Figure 3.6 is a QGIS interface that displays the KPA parcels shapefiles and the attribute table where the above listed information regarding the parcels was entered.



	LOCALITY	ADJ_PLOTS	AREA	PERIMETER	AREA_HA_	D
10	ISLAND	NULL	6421.64000000000	726.27100000000	0.642	
11	ISLAND	NULL	437.37700000000	88.59300000000	0.044	
12	ISLAND	NULL	14338.33000000...	748.68500000000	1.43400000000	
13	ISLAND	NULL	7825.18000000000	360.29400000000	0.783	
14	ISLAND	NULL	1573.78200000000	165.63600000000	0.157	
15	ISLAND	NULL	1838.38100000000	312.80800000000	0.184	
16	ISLAND	NULL	7283.88900000000	358.55300000000	0.728	
17	ISLAND	NULL	928.97300000000	121.91600000000	0.093	
18	ISLAND	NULL	460.45100000000	91.28500000000	0.046	
19	ISLAND	NULL	431.81500000000	89.06700000000	0.043	
20	ISLAND	NULL	518.69000000000	116.89700000000	0.052	
21	ISLAND	NULL	54916.99300000...	1148.33100000000	5.49200000000	
22	ISLAND	NULL	928.97300000000	121.91600000000	0.093	
23	ISLAND	NULL	44130.40100000...	1038.57000000000	4.41300000000	
24	ISLAND	NULL	7284.50400000000	410.34800000000	0.728	
25	ISLAND	NULL	41912.59200000...	952.78800000000	4.19100000000	

Show All Features

Figure 3-6 Data Entry into shapefiles attribute tables

3.5 Developing a Web Mapping Application Interface

Figure 3.7 is a simple concept design of a user interface for users of the KPA parcel management web application.

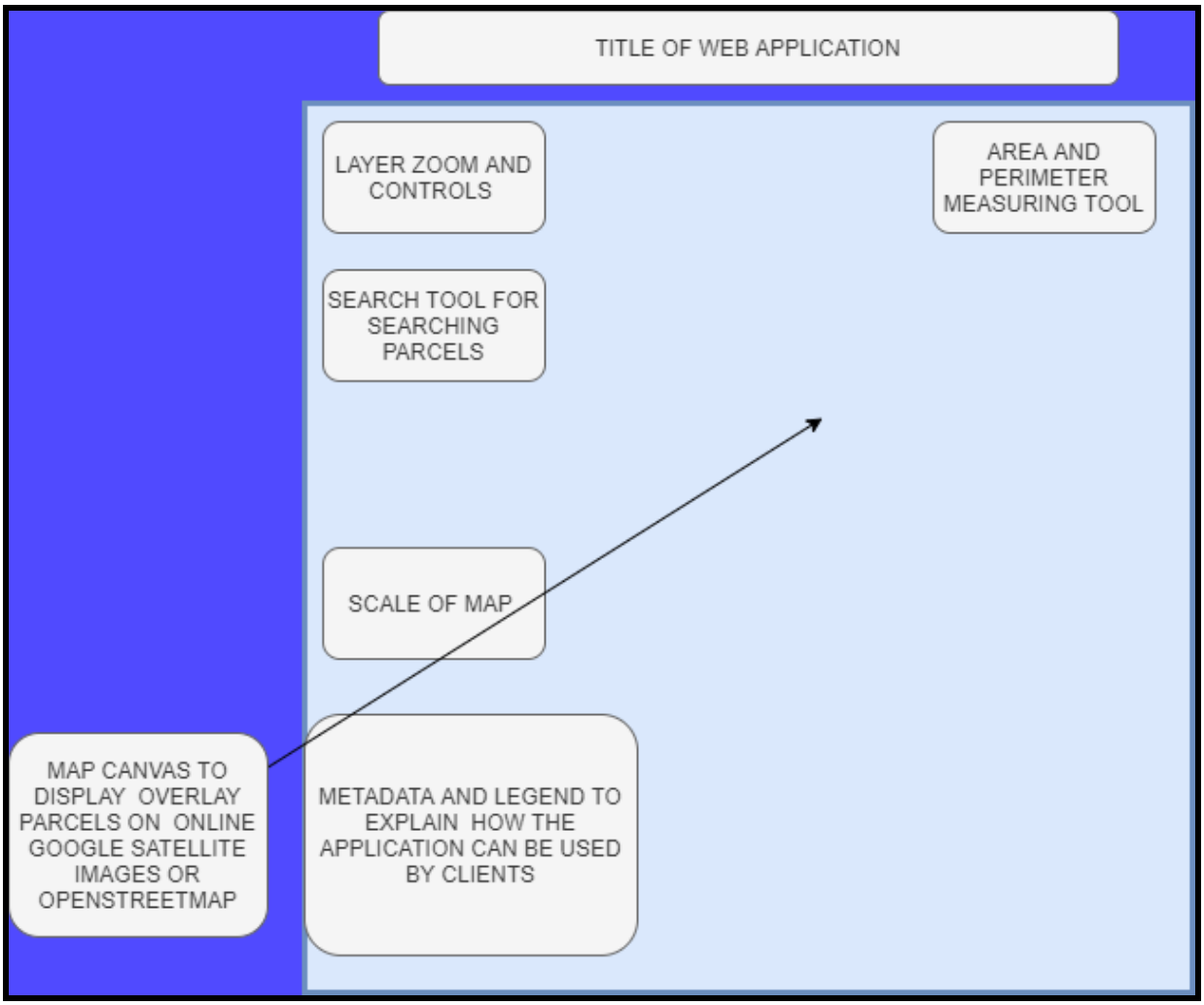


Figure 3-7 A mock design of User interface for web application

The client user interface of the application was developed by using HTML, JavaScript, GeoJSON and base map tiles from Google Satellite and OpenStreetMaps.

3.6 Creating GeoJSON from the Shapefile

The parcels shapefiles digitized in GIS environment were converted to a simple web format for GIS data known as GeoJSON. The GeoJSON files are simple web file formats that can be easily integrated into a web mapping code.GeoJSON is an open standard format designed for

representing simple geographical features, along with their non-spatial attributes. It is based on the JSON format.

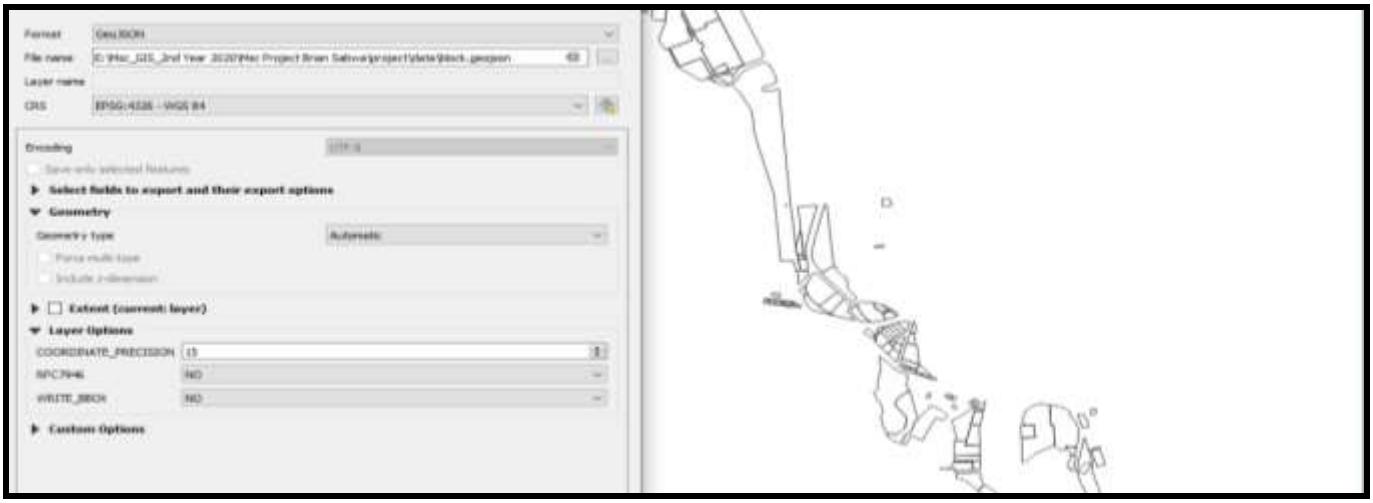


Figure 3-8 Creating a GeoJSON file from parcels shapefile

Figure 3.9 is a code of the parcels shapefiles converted to a GeoJSON file that will be integrated into a web mapping code

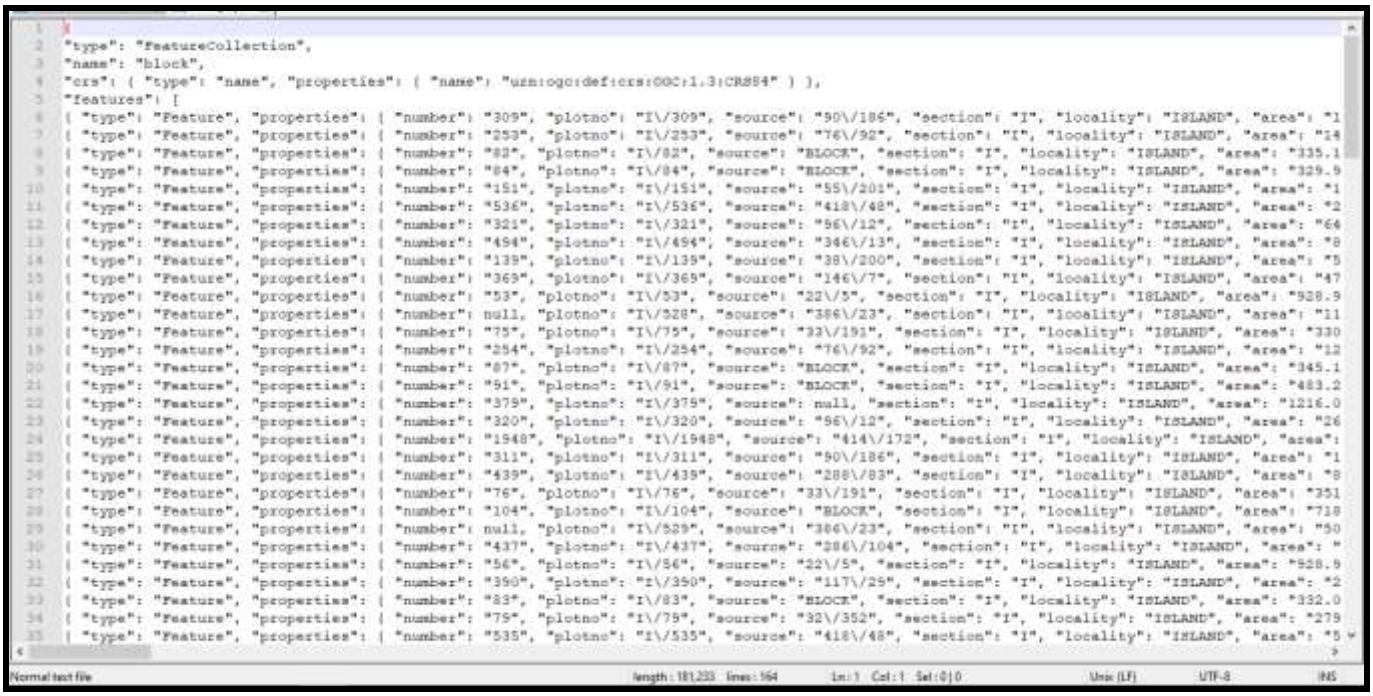


Figure 3-9 GeoJSON file viewed in Notepad++

3.7 Web Mapping Code with HTML and LeafletJS

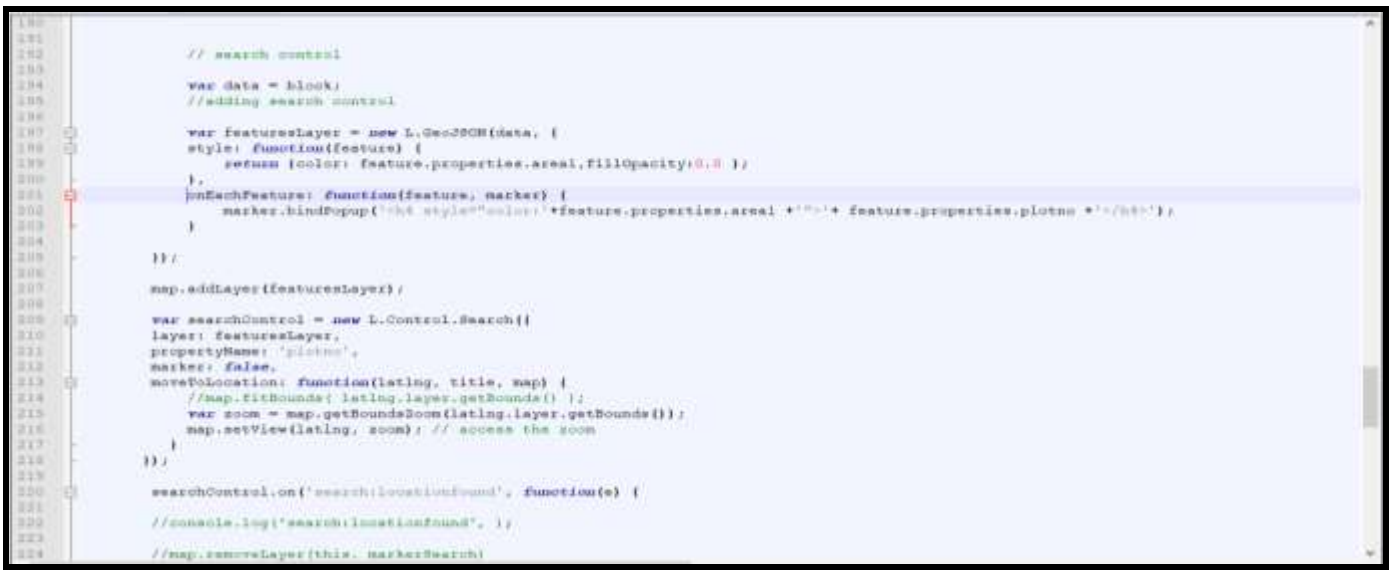
By developing a JavaScript code that allowed the GeoJSON code to overlay the parcel on an online image. Figure 3.10 is a JavaScript code for overlaying a GIS data format of parcel on top of an online imagery. This a simple code created using LeafletJS and HTML to overlay a parcels layer and the Google base layer.

```
  //baseTile Layers
 var satellite=new L.TileLayer('http://www.google.com/maps/vt?lyrs=s,h&x={x}&y={y}&z={z}', {attribution: 'Map data &copy; <a href="https://w
 //var Openstreetmap=new L.TileLayer('http://{s}.tile.openstreetmap.org/{z}/{x}/{y}.png', {attribution: 'Map data &copy; <a href="http://ope

// Adding GeoJSON for parcels
 blockLayer = L.geoJson(
      block,
      {
          style : countriesStyle,
          onEachFeature : blockOnEachFeature,

      }).bindPopup(function (layer) {
       return layer.feature.properties.plotno;
  }).addTo(map);
  map.fitBounds(blockLayer.getBounds());
```

Figure 3-10 Created JavaScript Map Overlay Code

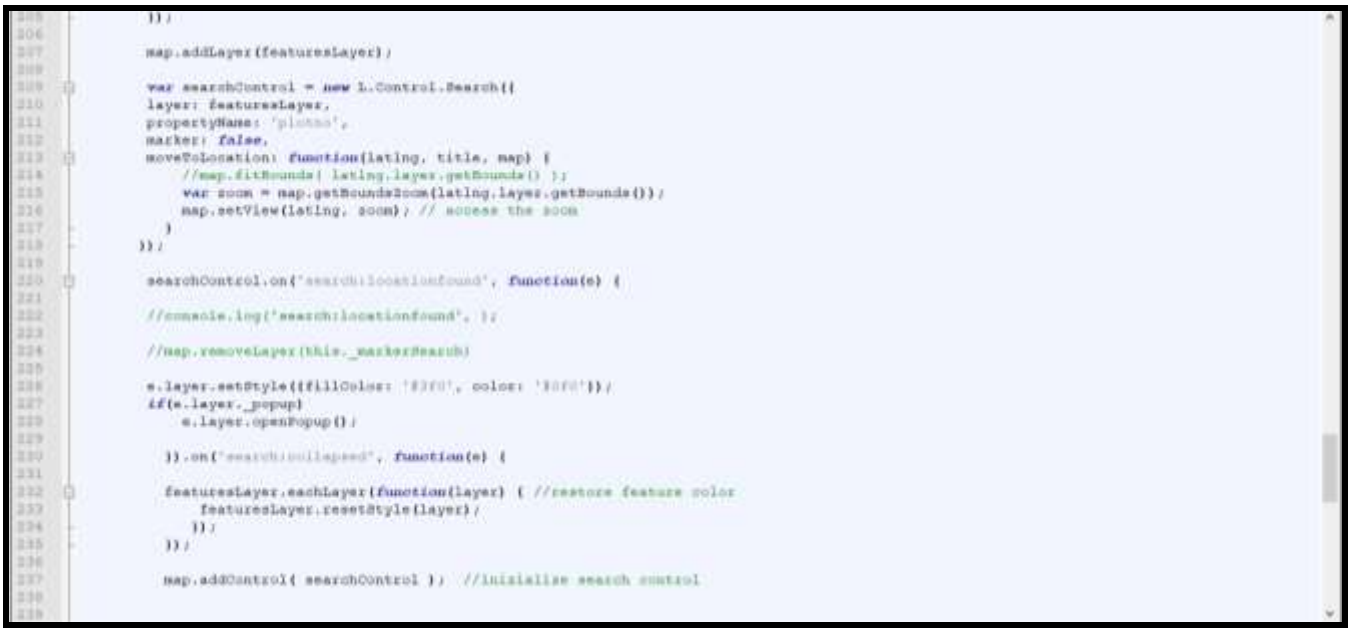
3.8 Developing of Search Tools

The search tool was developed using JavaScript. The code allows a user to use the land reference details of a specific parcel to search it, the parcel is located on the Map and zoomed into the location of base layer and highlighted in color green, hence a user can see the parcel shape and parcel location on the Google layer. The code used to create the search and display of the parcel location tool for the results above is displayed in Figure 3.11 and Figure 3.12.



```
        // search control

        var data = block;
        //adding search control

        var featuresLayer = new L.GeoJSON(data, {
        style: function(feature) {
            return {color: feature.properties.areal,fillOpacity:0.8 };
        },
        onEachFeature: function(feature, marker) {
            marker.bindPopup('<h4 style="color:'+feature.properties.areal +'">'+ feature.properties.plotno +'</h4>');
        }

    });

    map.addLayer(featuresLayer);

    var searchControl = new L.Control.Search({
    layer: featuresLayer,
    propertyName: 'plotno',
    marker: false,
    moveToLocation: function(latlng, title, map) {
        //map.fitBounds( latlng.layer.getBounds() );
        var zoom = map.getBoundsZoom(latlng.layer.getBounds());
        map.setView(latlng, zoom); // access the zoom
      }
    });

    searchControl.on('search:locationfound', function(e) {

    //console.log('search:locationfound', );

    //map.removeLayer(this._markerSearch)
```

Figure 3-11 A code created in JavaScript to Initialize the Parcel Search Tool



```
    });

    map.addLayer(featuresLayer);

    var searchControl = new L.Control.Search({
    layer: featuresLayer,
    propertyName: 'plotno',
    marker: false,
    moveToLocation: function(latlng, title, map) {
        //map.fitBounds( latlng.layer.getBounds() );
        var zoom = map.getBoundsZoom(latlng.layer.getBounds());
        map.setView(latlng, zoom); // access the zoom
      }
    });

    searchControl.on('search:locationfound', function(e) {

    //console.log('search:locationfound', );

    //map.removeLayer(this._markerSearch)

    e.layer.setStyle({fillColor: '#3f0', color: '#0f0'});
    if(e.layer._popup)
        e.layer.openPopup();

      }).on('search:collapsed', function(e) {

      featuresLayer.eachLayer(function(layer) { //restore feature color
          featuresLayer.resetStyle(layer);
        });
      });

      map.addControl( searchControl );  //initialize search control
```

Figure 3-12 A code written in JavaScript to initialize and Launch Search Tool

3.9 Development of Measuring Tools

This tool was developed to provide analysis about size of parcels and perimeter that can help in planning purposes by managers and field technicians. The code JavaScript code in figure 3.13 is the complete code developed to create the measuring tool above that provides accurate information about area and perimeter of parcels. This tool mainly provides for ease of

accessibility of measuring tools online for users who cannot immediately access paper based survey plans but require information about area and perimeter of land.

```
        // measuring area
        map.on('measurefinish', function(evt) {
            writeResults(evt);
        });

        function writeResults(results) {
         document.getElementById('eventoutput').innerHTML = JSON.stringify(
          {
          area: results.area,
          areaDisplay: results.areaDisplay,
          lastCoord: results.lastCoord,
          length: results.length,
          lengthDisplay: results.lengthDisplay,
          pointCount: results.pointCount,
          points: results.points
        },
        null,
        2
      );
    }
```

Figure 3-13 A code in JavaScript to initialize the Measurement Tool

3.10 Developing a tool to Provide Additional Information about a Parcel

Lastly this project objective was to create a web application that can provide additional non spatial information about the parcels displayed on a map canvas. This was done by adding parcel information in the shapefiles attribute table for a specific plot and then using JavaScript code to create a function that returns non spatial details about the ownership, use and market value of parcels when a parcel on the website is clicked on.

```
// returns the area of parcel and other associated information
L.geoJson(block, {
 style: function (feature) {
return {color: feature.properties.color};
 }
}).bindPopup(function (layer) {
 return layer.feature.properties.area1;
 //return layer.feature.properties.plotno;
 }).addTo(map);
```

Figure 3-14 JavaScript code for display of attribute information

CHAPTER 4 RESULTS AND DISCUSSIONS

4.1 Website for Managing KPA parcels

Figure 4.1 is an image of web application developed for the application. Appendix 7.2 is the complete programming code that was created to develop the website. In the image below are simple instructions of important tools on the website to utilize to provide required information about a parcel of interest. This website can be accessed via URL at www.kpalands.co.ke

Figure 4-1 User Interface Developed for Web Application

Using land references (see Appendix 7.1), a user can search a specific parcel to view location of the parcel of interest, measure size and perimeter and view additional parcel information about the parcels.

4.2 Overlay of Parcels on Online Imagery

By using the land reference details (See appendix 7.1) all the 171 parcels Survey files were digitized. The Parcels were then seamlessly overlaid onto a Google Physical map base map. The Google Physical map will provide up to date information on the adjacent business and types of developments to the parcels belonging to KPA. Therefore a user for this web mapping application can effectively and efficiently locate and visualize the location of all the 171 parcels belonging to KPA and are situated in Mombasa County. Additionally the user has the ability to visualize the true shape of the parcels; this will be more effective that the use of paper records to identify a parcel.

Figure 4-2 Web Application that displays the location of parcels on Google Maps

4.3 Verification of Accuracy of Areas of Parcels

The second objective of this project was to determine if a user can get accurate results from using the area measuring tools created. The report that was created from recording parcels acreages from land records such as allotments and title deeds and not actual measurements from cadastral surveys. Table 4.1 below shows the results from the KPA audit reports and the results achieved form measuring areas from digitized Survey Plans hosted on a web platform using the area measurement tools developed.

To check the accuracy of the measurement tool a test had to be carried out, the 65 parcels which had their sizes captured in the 2017 report from land documents provided during the audit, the parcels Survey plans were also digitized and uploaded online. The sizes of the 65 parcels which had areas in the report were also measured on the website using the measurement tool to check the discrepancy between the areas as shown in Table 4.1 below.

It's conclusive that the accuracy of the area measurement tool is high and the area measured does not vary from the area that is available on the land documents for the parcels. Therefore the Measurements tool could be confidently used to measure the areas of parcels whose areas were *unknown* from the report (see Appendix 7.1)

Table 4-1 Reported Areas s. Areas from Survey plans digitized

No.	LOCATION	LAND REFERENCE	Acreage in HA from Land documents provided during the 2017 audit	Verified acreage in Ha from Survey Plans Available online	variance in areas	Survey Plan No. from Survey of Kenya
1	Mombasa	XLVII/111	0.275	0.276	-0.001	107/96
2	Mombasa	I /104	0.073	0.072	0.001	BLOCK
3	Mombasa	I /107	0.495	0.495	0.000	35/186
4	Mombasa	I / 109	0.782	0.783	-0.001	40/37
5	Mombasa	I /139	0.541	0.541	0.000	38/200
6	Mombasa	I /149	0.138	0.139	-0.001	148/175
7	Mombasa	I /177	0.078	0.078	0.000	22/005
8	Mombasa	I / 179	5.504	5.492	0.012	61/7
9	Mombasa	I / 1948	0.619	0.609	0.010	414/172
10	Mombasa	I / 253	1.404	1.404	0.000	76/92
11	Mombasa	I /254	1.242	1.2442	-0.002	76/92

12	Mombasa	I /255	0.167	0.167	0.000	76/92
13	Mombasa	I / 302	0.184	0.184	0.000	86/148
14	Mombasa	I /304	0.003	0.003	0.000	86/148
15	Mombasa	I /309	0.197	0.197	0.000	90/186
16	Mombasa	I /310	0.234	0.281	-0.047	90/186
17	Mombasa	I/311	1.097	1.098	-0.001	90/186
18	Mombasa	I /315	1.267	1.265	0.002	96/12
19	Mombasa	I/317	0.117	0.117	0.000	96/12
20	Mombasa	I/318	0.407	0.426	-0.019	96/12
21	Mombasa	I/319	0.772	0.077	0.695	96/12
22	Mombasa	I/320	0.268	0.269	-0.001	96/12
23	Mombasa	I/321	0.642	0.642	0.000	96/12
24	Mombasa	I /401	0.728	0.728	0.000	260/56
25	Mombasa	I/466	0.045	0.045	0.000	306/20
26	Mombasa	I/476	1.734	1.734	0.000	322/32
27	Mombasa	I/490	14.730	14.699	0.031	277/41
28	Mombasa	I/492	66.320	1.605	64.715	277/41
29	Mombasa	I/494	0.089	0.088	0.001	346/13
30	Mombasa	I/52	0.093	0.093	0.000	22/005
31	Mombasa	/523	1.784	1.7843	0.000	BLOCK
32	Mombasa	I/53	0.093	0.093	0.000	22/005
33	Mombasa	I/533	2.163	2.115	0.048	176/39
34	Mombasa	I/534	0.264	0.264	0.000	418/48
35	Mombasa	I/535	0.505	0.505	0.000	418/48
36	Mombasa	I/536	0.213	0.213	0.000	418/48
37	Mombasa	I/54	0.093	0.093	0.000	22/005
38	Mombasa	I/58	0.093	0.093	0.000	22/005
39	Mombasa	/70	0.106	0.106	0.000	148/175
40	Mombasa	I/88	0.046	0.046	0.000	BLOCK
41	Mombasa	I/93	0.046	0.045	0.001	BLOCK
42	Mombasa	XLVII/106	1.395	1.395	0.000	106/35
43	Mombasa	XLVII/108	0.395	0.396	-0.001	106/35
44	Mombasa	XLVII/109	0.804	0.804	0.000	106/35
45	Mombasa	XLVII/110	0.971	0.966	0.005	106/166
46	Mombasa	XLVII/148	0.729	0..802	-0.009	171/41
47	Mombasa	XLVII/162	0.045	0.045	0.000	279/72
48	Mombasa	XLVII/167	0.050	0.05	0.000	279/72
49	Mombasa	XLVII/37	0.890	0.048	0.842	58/22

50	Mombasa	XLVII/84	0.185	0.187	-0.002	2/036
51	Mombasa	XLVII/85	0.084	0.084	0.000	2/036
52	Mombasa	XLVII/86	0.126	0.126	0.000	2/036
53	Mombasa	XLVII/95	0.100	0.100	0.000	2/036
54	Mombasa	XLVIII/155	0.182	0.449	-0.267	212/5
55	Mombasa	XLVIII/156	0.302	0.302	0.000	216/22
56	Mombasa	XLVIII/157	1.672	1.672	0.000	231/36
57	Mombasa	XLVIII/158	0.616	0.616	0.000	231/36
58	Mombasa	XLVIII/159	0.577	0.577	0.000	231/36
59	Mombasa	XLVIII/163	0.128	0.178	-0.050	243/43
60	Mombasa	XLVIII/164	0.202	0.199	0.003	252/72
61	Mombasa	XLVIII/165	0.191	0.191	-0.001	252/172
62	Mombasa	XLVIII/173	0.777	0.264	0.513	253/79
63	Mombasa	XLVII/170	6.421	6.421	0.000	424/118
65	Mombasa	I/378	0.933	0.933	0.000	164/70

By analysing Table 4.1 results, it is clear that using digitized survey plans hosted online will provide accurate information about the acreage of the parcels with unknown acreages. So applying the measuring tool to measure areas of parcels available online will provide accurate results for size and perimeter of parcels. Table 4.2 is a documentation of the Measured acreages of 106 parcels measured from the web mapping application using the measurements tool.

Table 4-2 106 Parcels Whose Size was Unknown, Measured Online and all Areas Determined

No.	LOCATION	LAND REFERENCE	Acreage in HA from Land documents provided during the 2017 audit report	Verified acreage in Ha from Survey Plans Available online	Survey Plan No. from Survey of Kenya
1	Mombasa	I /151	unknown	0.17	5/201
2	Mombasa	I/326	unknown	0.619	100/6
3	Mombasa	I/328	unknown	0.286	100/6
4	Mombasa	I/358	unknown	0.157	119/65
5	Mombasa	I/369	unknown	0.474	146/7
6	Mombasa	I/370	unknown	.056	147/11

7	Mombasa	I/371	unknown	2.646	147/11
8	Mombasa	I /379	unknown	0.122	176/39
9	Mombasa	I/388	unknown	1.243	176/39
10	Mombasa	I/390	unknown	2.792	117/29
11	Mombasa	I/391	unknown	0.375	180/71
12	Mombasa	I/400	unknown	1.434	180/71
13	Mombasa	I/402	unknown	0.728	260/56
14	Mombasa	I/403	unknown	0.387	260/56
15	Mombasa	I/437	unknown	1.632	286/104
16	Mombasa	I/439	unknown	8.328	288/83
17	Mombasa	I/450	unknown	0.313	306/59
18	Mombasa	I/451	unknown	0.373	306/101
19	Mombasa	I/467	unknown	0.052	306/101
20	Mombasa	I/471	unknown	4.413	163/11
21	Mombasa	I/475	unknown	0.218	322/167
22	Mombasa	I/55	unknown	0.093	22/005
23	Mombasa	I/56	unknown	0.093	22/005
24	Mombasa	I/67	unknown	2.71	211/86
25	Mombasa	I/75	unknown	3.303	33/191
26	Mombasa	I/76	unknown	3.514	33/191
27	Mombasa	I/77	unknown	3.825	34/200
28	Mombasa	/78	unknown	4.191	26/002
29	Mombasa	I/79	unknown	0.279	32/352
30	Mombasa	I/780	unknown	0.414	35/156
31	Mombasa	I/81	unknown	0.034	BLOCK
32	Mombasa	I/82	unknown	0.033	BLOCK

33	Mombasa	I/83	unknown	0.033	BLOCK
34	Mombasa	I/84	unknown	0.033	BLOCK
35	Mombasa	I/85	unknown	0.042	BLOCK
36	Mombasa	I/86	unknown	0.037	BLOCK
37	Mombasa	/87	unknown	0.035	BLOCK
38	Mombasa	I/89	unknown	0.048	BLOCK
39	Mombasa	I/90	unknown	0.044	BLOCK
40	Mombasa	I/91	unknown	0.048	BLOCK
41	Mombasa	I/92	unknown	0.043	BLOCK
42	Mombasa	XLVII/112	unknown	0.75	107/96
43	Mombasa	XLVII/113	unknown	0.216	107/96
44	Mombasa	XLVII/114	unknown	0.143	107/96
45	Mombasa	XLVII/115	unknown	0.171	107/96
46	Mombasa	XLVII/116	unknown	0.259	107/96
47	Mombasa	XLVII/117	unknown	0.225	107/96
48	Mombasa	XLVII/118	unknown	0.373	107/96
49	Mombasa	XLVII/119	unknown	0.101	111/71
50	Mombasa	XLVII/120	unknown	0.069	111/71
51	Mombasa	XLVII/121	unknown	0.368	111/71
52	Mombasa	XLVII/124	unknown	0.706	111/71
53	Mombasa	XLVII/149	unknown	0.22	`171/41
54	Mombasa	XLVII/150	unknown	0.156	284/163
55	Mombasa	XLVII/151	unknown	.145	290/194
56	Mombasa	XLVII/155	unknown	0.068	292/139
57	Mombasa	XLVII/156	unknown	0.277	320/3
58	Mombasa	XLVII/157	unknown	0.052	300/123

59	Mombasa	XLVII/158	unknown	0.527	300/123
60	Mombasa	XLVII/159	unknown	0.059	320/25
61	Mombasa	XLVII/163	unknown	0.053	279/72
62	Mombasa	XLVII/164	unknown	0.05	279/72
63	Mombasa	XLVII/165	unknown	0.05	279/72
64	Mombasa	XLVII/166	unknown	0.05	279/72
65	Mombasa	XLVII/168	unknown	0.05	279/72
66	Mombasa	XLVII/173	unknown	1.833	424/18
67	Mombasa	XLVII/174	unknown	4.789	424/18
68	Mombasa	XLVII/24	unknown	0.047	58/22
69	Mombasa	XLVII/25	unknown	0.047	58/22
70	Mombasa	XLVII/26	unknown	0.051	58/22
71	Mombasa	XLVII/43	unknown	0.043	58/22
72	Mombasa	XLVII/44	unknown	0.041	58/22
73	Mombasa	XLVII/45	unknown	0.043	58/22
74	Mombasa	XLVII/67	unknown	0.847	81/93
75	Mombasa	XLVII/72	unknown	0.194	36/285
76	Mombasa	XLVII/73	unknown	1.3	90/132
77	Mombasa	XLVII/75	unknown	0.122	93/58
78	Mombasa	XLVII/81	unknown	0.196	2/236
79	Mombasa	XLVII/82	unknown	0.175	2/236
80	Mombasa	XLVII/83	unknown	0.193	2/036
81	Mombasa	XLVIII/118	unknown	0.244	117/27
82	Mombasa	XLVIII/119	unknown	0.041	117/27
83	Mombasa	XLVIII/121	unknown	0.457	117/27
84	Mombasa	XLVIII/122	unknown	0.263	117/27

85	Mombasa	XLVIII/131	unknown	1.796	125/44
86	Mombasa	XLVIII/139	unknown	0.874	167/46
87	Mombasa	XLVIII/148	unknown	1.58	186/105
88	Mombasa	XLVIII/149	unknown	0.34	203/52
89	Mombasa	XLVIII/150	unknown	0.651	198/82
90	Mombasa	XLVIII/152	unknown	0.086	198/27
91	Mombasa	XLVIII/166	unknown	0.854	256/157
92	Mombasa	XLVIII/181	unknown	2.807	277/40
93	Mombasa	XLVIII/185	unknown	2.562	289/92
94	Mombasa	XLVIII/189	unknown	0.341	383/82
95	Mombasa	XLVIII/37	unknown	0.92	82/28
96	Mombasa	XLVIII/43	unknown	3.78	166/141
97	Mombasa	XLVIII/44	unknown	0.514	90/54
98	Mombasa	XLVIII/50	unknown	0.5	94/78
99	Mombasa	XLVIII/558	unknown	0.545	BLOCK
100	Mombasa	I/528	unknown	0.115	386/23
101	Mombasa	I/529	unknown	0.506	386/23
102	Mombasa	I/1310	unknown	0.218	90/186
103	Mombasa	I/439	unknown	8.328	288/83
104	Mombasa	I/30	unknown	0.056	Dec-27
105	Mombasa	XLVII/1731	unknown	1.833	279/72
106	Mombasa	XLVII/139	unknown	0.4047	125/39

The Table 4.3 below is a combination of all parcels, using the web application developed and the measurement tool all the parcel sizes with emphasis on parcels with Unknown size were measured and recorded for each individual parcel as shown.

Table 4-3 All Parcels List Complete With Actual Areas Measured From Web Application

No.	LOCATION	LAND REFERENCE	Acreage in HA from Land documents provided during the 2017 audit report	Verified acreage in Ha from Survey Plans Available online	Survey Plan No. from Survey of Kenya
1	Mombasa	XLVII/111	0.275	0.276	107/96
2	Mombasa	I /104	0.073	0.072	BLOCK
3	Mombasa	I /107	0.495	0.495	35/186
4	Mombasa	I / 109	0.782	0.783	40/37
5	Mombasa	I /139	0.541	38/200	0.541
6	Mombasa	I /149	0.138	0.139	148/175
7	Mombasa	I /177	0.078	0.078	22/005
8	Mombasa	I / 179	5.504	5.492	61/7
9	Mombasa	I / 1948	0.619	0.609	414/172
10	Mombasa	I / 253	1.404	1.404	76/92
11	Mombasa	I /254	1.242	1.2442	76/92
12	Mombasa	I /255	0.167	0.167	76/92
13	Mombasa	I / 302	0.184	0.184	86/148
14	Mombasa	I /304	0.003	0.003	86/148
15	Mombasa	I /309	0.197	0.197	90/186
16	Mombasa	I /310	0.234	0.281	90/186
17	Mombasa	I/311	1.097	1.098	90/186
18	Mombasa	I /315	1.267	1.265	96/12
19	Mombasa	I/317	0.117	0.117	96/12
20	Mombasa	I/318	0.407	0.426	96/12

21	Mombasa	I/319	0.772	0.077	96/12
22	Mombasa	I/320	0.268	0.269	96/12
23	Mombasa	I/321	0.642	0.642	96/12
24	Mombasa	I /401	0.728	0.728	260/56
25	Mombasa	I/466	0.045	0.045	306/20
26	Mombasa	I/476	1.734	1.051	322/32
27	Mombasa	I/490	14.730	14.319	277/41
28	Mombasa	I/492	66.320	1.605	277/41
29	Mombasa	I/494	0.089	0.088	346/13
30	Mombasa	I/52	0.093	0.093	22/005
31	Mombasa	/523	1.784	1.7843	BLOCK
32	Mombasa	I/53	0.093	0.093	22/005
33	Mombasa	I/533	2.163	2.115	176/39
34	Mombasa	I/534	0.264	0.264	418/48
35	Mombasa	I/535	0.505	0.505	418/48
36	Mombasa	I/536	0.213	0.213	418/48
37	Mombasa	I/54	0.093	0.093	22/005
38	Mombasa	I/58	0.093	0.093	22/005
39	Mombasa	/70	0.106	0.106	148/175
40	Mombasa	I/88	0.046	0.046	BLOCK
41	Mombasa	I/93	0.046	0.045	BLOCK
42	Mombasa	XLVII/106	1.395	1.395	106/35
43	Mombasa	XLVII/108	0.395	0.396	106/35
44	Mombasa	XLVII/109	0.804	0 .804	106/35
45	Mombasa	XLVII/110	0.971	0.966	106/166
46	Mombasa	XLVII/148	0.729	1.822	171/41

47	Mombasa	XLVII/162	0.045	0 .045	279/72
48	Mombasa	XLVII/167	0.050	0.05	279/72
49	Mombasa	XLVII/37	0.890	0.048	58/22
50	Mombasa	XLVII/84	0.185	0.187	2/036
51	Mombasa	XLVII/85	0.084	0 .084	2/036
52	Mombasa	XLVII/86	0.126	0 .126	2/036
53	Mombasa	XLVII/95	0.100	0 .100	2/036
54	Mombasa	XLVIII/155	0.182	0.449	212/5
55	Mombasa	XLVIII/156	0.302	0.302	216/22
56	Mombasa	XLVIII/157	1.672	1.672	231/36
57	Mombasa	XLVIII/158	0.616	0.616	231/36
58	Mombasa	XLVIII/159	0.577	0.577	231/36
59	Mombasa	XLVIII/163	0.128	0.178	243/43
60	Mombasa	XLVIII/164	0.202	0.199	252/72
61	Mombasa	XLVIII/165	0.191	0.191	252/172
62	Mombasa	XLVIII/173	0.777	0.264	253/79
63	Mombasa	XLVII/170	6.421	6.421	424/118
64	Mombasa	I/378	0.001	0.933	164/70
65	Mombasa	I /151	unknown	0.17	5/201
66	Mombasa	I/326	unknown	0.619	100/6
67	Mombasa	I/328	unknown	0.286	100/6
68	Mombasa	I/358	unknown	0.157	119/65
69	Mombasa	I/369	unknown	0.474	146/7
70	Mombasa	I/370	unknown	0 .065	147/11
71	Mombasa	I/371	unknown	2.646	147/11
72	Mombasa	I /379	unknown	0.122	176/39

73	Mombasa	I/388	unknown	1.243	176/39
74	Mombasa	I/390	unknown	2.792	117/29
75	Mombasa	I/391	unknown	0.375	180/71
76	Mombasa	I/400	unknown	1.434	180/71
77	Mombasa	I/402	unknown	0.728	260/56
78	Mombasa	I/403	unknown	0.387	260/56
79	Mombasa	I/437	unknown	1.632	286/104
80	Mombasa	I/439	unknown	8.328	288/83
81	Mombasa	I/450	unknown	0.313	306/59
82	Mombasa	I/451	unknown	0.373	306/101
83	Mombasa	I/467	unknown	0.052	306/101
84	Mombasa	I/471	unknown	4.413	163/11
85	Mombasa	I/475	unknown	0.218	322/167
86	Mombasa	I/55	unknown	0.093	22/005
87	Mombasa	I/56	unknown	0.093	22/005
88	Mombasa	I/67	unknown	2.71	211/86
89	Mombasa	I/75	unknown	3.303	33/191
90	Mombasa	I/76	unknown	3.514	33/191
91	Mombasa	I/77	unknown	3.825	34/200
92	Mombasa	/78	unknown	4.191	26/002
93	Mombasa	I/79	unknown	0.279	32/352
94	Mombasa	I/780	unknown	0.414	35/156
95	Mombasa	I/81	unknown	0.034	BLOCK
96	Mombasa	I/82	unknown	0.033	BLOCK
97	Mombasa	I/83	unknown	0.033	BLOCK
98	Mombasa	I/84	unknown	0.033	BLOCK

99	Mombasa	I/85	unknown	0.042	BLOCK
100	Mombasa	I/86	unknown	0.037	BLOCK
101	Mombasa	/87	unknown	0.035	BLOCK
102	Mombasa	I/89	unknown	0.048	BLOCK
103	Mombasa	I/90	unknown	0.044	BLOCK
104	Mombasa	I/91	unknown	0.048	BLOCK
105	Mombasa	I/92	unknown	0.043	BLOCK
106	Mombasa	XLVII/112	unknown	0.75	107/96
107	Mombasa	XLVII/113	unknown	0.216	107/96
108	Mombasa	XLVII/114	unknown	0.143	107/96
109	Mombasa	XLVII/115	unknown	0.171	107/96
110	Mombasa	XLVII/116	unknown	0.259	107/96
111	Mombasa	XLVII/117	unknown	0.225	107/96
112	Mombasa	XLVII/118	unknown	0.373	107/96
113	Mombasa	XLVII/119	unknown	0.101	111/71
114	Mombasa	XLVII/120	unknown	0.069	111/71
115	Mombasa	XLVII/121	unknown	0.368	111/71
116	Mombasa	XLVII/124	unknown	0.706	111/71
117	Mombasa	XLVII/149	unknown	0.22	`171/41
118	Mombasa	XLVII/150	unknown	0.156	284/163
119	Mombasa	XLVII/151	unknown	0.803	290/194
120	Mombasa	XLVII/155	unknown	0.068	292/139
121	Mombasa	XLVII/156	unknown	0.277	320/3
122	Mombasa	XLVII/157	unknown	0.052	300/123
123	Mombasa	XLVII/158	unknown	0.527	300/123
124	Mombasa	XLVII/159	unknown	0.059	320/25

125	Mombasa	XLVII/163	unknown	0.053	279/72
126	Mombasa	XLVII/164	unknown	0.05	279/72
127	Mombasa	XLVII/165	unknown	0.05	279/72
128	Mombasa	XLVII/166	unknown	0.05	279/72
129	Mombasa	XLVII/168	unknown	0.05	279/72
130	Mombasa	XLVII/173	unknown	1.833	424/18
131	Mombasa	XLVII/174	unknown	4.789	424/18
132	Mombasa	XLVII/24	unknown	0.047	58/22
133	Mombasa	XLVII/25	unknown	0.047	58/22
134	Mombasa	XLVII/26	unknown	0.051	58/22
135	Mombasa	XLVII/43	unknown	0.043	58/22
136	Mombasa	XLVII/44	unknown	0.041	58/22
137	Mombasa	XLVII/45	unknown	0.043	58/22
138	Mombasa	XLVII/67	unknown	0.847	81/93
139	Mombasa	XLVII/72	unknown	0.194	36/285
140	Mombasa	XLVII/73	unknown	1.3	90/132
141	Mombasa	XLVII/75	unknown	0.122	93/58
142	Mombasa	XLVII/81	unknown	0.196	2/236
143	Mombasa	XLVII/82	unknown	0.175	2/236
144	Mombasa	XLVII/83	unknown	0.193	2/036
145	Mombasa	XLVIII/118	unknown	0.244	117/27
146	Mombasa	XLVIII/119	unknown	0.041	117/27
147	Mombasa	XLVIII/121	unknown	0.457	117/27
148	Mombasa	XLVIII/122	unknown	0.263	117/27
149	Mombasa	XLVIII/131	unknown	1.796	125/44
150	Mombasa	XLVIII/139	unknown	0.874	167/46

151	Mombasa	XLVIII/148	unknown	1.58	186/105
152	Mombasa	XLVIII/149	unknown	0.34	203/52
153	Mombasa	XLVIII/150	unknown	0.651	198/82
154	Mombasa	XLVIII/152	unknown	0.086	198/27
155	Mombasa	XLVIII/166	unknown	0.854	256/157
156	Mombasa	XLVIII/181	unknown	2.807	277/40
157	Mombasa	XLVIII/185	unknown	2.562	289/92
158	Mombasa	XLVIII/189	unknown	0.341	383/82
159	Mombasa	XLVIII/37	unknown	0.92	82/28
160	Mombasa	XLVIII/43	unknown	3.78	166/141
161	Mombasa	XLVIII/44	unknown	0.514	90/54
162	Mombasa	XLVIII/50	unknown	0.5	94/78
163	Mombasa	XLVIII/558	unknown	0.545	BLOCK
164	Mombasa	I/528	unknown	0.115	386/23
165	Mombasa	I/529	unknown	0.506	386/23
166	Mombasa	I/1310	unknown	0.218	90/186
167	Mombasa	I/439	unknown	8.328	288/83
168	Mombasa	I/30	unknown	0.056	Dec-27
169	Mombasa	I /139	unknown	0.541	38/200
170	Mombasa	XLVII/1731	unknown	1.833	279/72
171	Mombasa	XLVII/139	unknown	0.4047	125/39

4.4 Querying of Additional Parcel Information about Specific Parcels

Some of the non-spatial information about a parcel of land is very important and this information helps in decision making. All The 171 parcels belonging to KPA and located in Mombasa had some additional information that when accessed from a single source becomes

very time saving. All the non-spatial information was added in the attribute table and a tool was developed so that on the website once a user clicks on a parcel the user can see information about who owns the parcels, what is the owner using the parcel for and market value of the parcel. Figure 4.2 displays information about a parcel that was leased by KPA to Kenya Power and Lightning Company (KPLC), the parcel host KPLC substation and parcel has a monetary value of Ksh.200, 000,000

Figure 4-3 Parcel I/358 with Additional Information about the Parcel

Figure 4.3 displays information about parcel with land reference I/439, owned by KPA, Hosts KPA Offices and is Valued at Ksh.1,000,000,000.

Figure 4-4 Parcel I/439 with Additional Parcel Information Displayed for the Users

Figure 4.4 displays information about parcel I/254, the parcel was leased to Solvochem East Africa, the parcel host Solvochem East Africa offices and Parcel is valued at Ksh. 300,000,000

Figure 4-5 Parcel I/254 Leased by KPA and Attached are Additional details About Parcel

CHAPTER 5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter discusses the conclusion of the project whose aim was to develop a website using survey plans and also creates a few applications that can make the web mapping application provide timely and efficient answers to all potential users. The conclusion is a brief explanation of the projects' achievement and the recommendations which also highlight further areas of study for the project.

5.2 Conclusion

This project aim was to create a web-based LIS that could be accessed anywhere by all users to retrieve information about land parcels in an efficient and time saving way. The first step was to collect the spatial and non-spatial data using the land reference information (Appendix 7.1). With effect to this the parcels Survey plans were collected and digitized, other non-spatial information were added to the attribute tables. A web application was developed with a purpose of managing all the 171 parcels belonging to KPA in Mombasa County. The web mapping application provides an interface that a user with a land reference number can search and view location of parcel on a Google web-map layer, measure the parcel size online and be able to view associated non spatial information about the parcel.

The application provided a tool that provides all information that is valuable in managing parcels using a web-based LIS for KPA parcels in Mombasa County.

5.3 Recommandations

The current labour-intensive manual processes used to collect, store and maintain land information contain a greater risk for human error for all organizations owning large parcels of land. Reliable land information and efficient retrieval of land information is crucial for planning and development of any country. There are various challenges that hinder proper retrieval of land information and management of land information stored in analogue paper formats. In Kenya rapid pace of development, coupled with high population growth rates brings with it heavy burdens on land management. Hence it is imperative that Kenya needs an effective Land Information System.

Therefore some of the recommendation of this study is to expand this project to include all KPA parcels in other 7 counties in Kenya and for all other organizations managing large number of parcels to customize and adopt web-based LIS to provide efficient management of land in the organizations.

More so the web mapping application can be adopted by other landed agencies such as Kenya Forest Services, Kenya Wildlife service and other public land management organizations that require up to date information on the land for ease of operations and service. This web application is accessible at any location and can help and user to easily navigate to the location of land and also have information on use of land. This ease of access to land information will reduce the time it takes to make land related decisions.

In Kenya, the National Land Commission is mandated by law to manage all public land and are in the process of creating a single database for all public land. This web mapping application can be adopted by agencies that use public land for their operations to easily and efficiently manage the specific organization land related activities.

5.4 Areas of further research

There is room for more research on this web application project that can include procedures for regular updating on changes in land use, land ownership and changes in shape size and perimeter of parcels. These changes have to be updated in the web application in an efficient and timely manner to ensure that the web application will provide accurate and desired information. The web application should also be developed further to limit the extents of information that can be accessed by users, for instance a mason may want to only know about the parcel perimeter while constructing the fence or perimeter wall and a senior manager may only be interested in ownership and use of parcel and accessibility of parcel of land to users.

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APPENDICES

APPENDIX 1: KPA Parcels List

No.	LOCATION	LAND REFERENCE	Acreage from Land documents provided during the 2017 audit
1	Mombasa	XLVII/111	0.115295117
2	Mombasa	I /104	0.072624997
3	Mombasa	I /107	0.494688493
4	Mombasa	I / 109	0.781853868
5	Mombasa	I /139	0.540660853
6	Mombasa	I /149	0.138402703
7	Mombasa	I /14R	2.950162886
8	Mombasa	I /151	unknown
9	Mombasa	I /177	0.077780701
10	Mombasa	I / 179	5.503733231
11	Mombasa	I / 1948	0.6188
12	Mombasa	I / 253	1.404261346
13	Mombasa	I /254	1.24238684
14	Mombasa	I /255	0.167135428
15	Mombasa	I / 302	0.183727565
16	Mombasa	I /303	0.014204488
17	Mombasa	I /304	0.002792335
18	Mombasa	I /309	0.196677526
19	Mombasa	I /310	0.233503976
20	Mombasa	I/311	1.096699783
21	Mombasa	I /315	1.266668016
22	Mombasa	I/317	0.117116206

23	Mombasa	I/318	0.407114385
24	Mombasa	I/319	0.771736711
25	Mombasa	I/320	0.268306995
26	Mombasa	I/321	0.641832419
27	Mombasa	I/326	unknown
28	Mombasa	I/328	unknown
29	Mombasa	I/358	unknown
30	Mombasa	I/369	unknown
31	Mombasa	I/370	unknown
32	Mombasa	I/371	unknown
33	Mombasa	I /379	unknown
34	Mombasa	I/388	unknown
35	Mombasa	I/390	unknown
36	Mombasa	I/391	unknown
37	Mombasa	I/400	unknown
38	Mombasa	I /401	0.7284
39	Mombasa	I/402	unknown
40	Mombasa	I/403	unknown
41	Mombasa	I/437	unknown
42	Mombasa	I/439	unknown
43	Mombasa	I/450	unknown
44	Mombasa	I/451	unknown
45	Mombasa	I/466	0.045
46	Mombasa	I/467	unknown
47	Mombasa	I/471	unknown
48	Mombasa	I/475	unknown

49	Mombasa	I/476	1.734
50	Mombasa	I/490	14.73
51	Mombasa	I/492	66.32
52	Mombasa	I/494	0.0885
53	Mombasa	I/52	0.092899779
54	Mombasa	/523	1.7843
55	Mombasa	I/53	0.092899779
56	Mombasa	I/533	2.163
57	Mombasa	I/534	0.2638
58	Mombasa	I/535	0.5052
59	Mombasa	I/536	0.2131
60	Mombasa	I/54	0.092899779
61	Mombasa	I/55	unknown
62	Mombasa	I/56	unknown
63	Mombasa	I/58	0.092899779
64	Mombasa	I/581	unknown
65	Mombasa	I/588	unknown
66	Mombasa	I/67	unknown
67	Mombasa	I/68	unknown
68	Mombasa	I/69	unknown
69	Mombasa	/691	6.475
70	Mombasa	/70	0.106027802
71	Mombasa	I/75	unknown
72	Mombasa	I/76	unknown
73	Mombasa	I/77	unknown
74	Mombasa	/78	unknown

75	Mombasa	I/79	unknown
76	Mombasa	I/780	unknown
77	Mombasa	I/81	unknown
78	Mombasa	I/82	unknown
79	Mombasa	I/83	unknown
80	Mombasa	I/84	unknown
81	Mombasa	I/85	unknown
82	Mombasa	I/86	unknown
83	Mombasa	/87	unknown
84	Mombasa	I/88	0.046451565
85	Mombasa	I/89	unknown
86	Mombasa	I/90	unknown
87	Mombasa	I/91	unknown
88	Mombasa	I/92	unknown
89	Mombasa	I/93	0.046451565
90	Mombasa	XLVII/106	1.3946
91	Mombasa	XLVII/108	0.39456911
92	Mombasa	XLVII/109	0.803706926
93	Mombasa	XLVII/110	0.9713
94	Mombasa	XLVII/112	unknown
95	Mombasa	XLVII/113	unknown
96	Mombasa	XLVII/114	unknown
97	Mombasa	XLVII/115	unknown
98	Mombasa	XLVII/116	unknown
99	Mombasa	XLVII/117	unknown
100	Mombasa	XLVII/118	unknown

101	Mombasa	XLVII/119	unknown
102	Mombasa	XLVII/120	unknown
103	Mombasa	XLVII/121	unknown
104	Mombasa	XLVII/124	unknown
105	Mombasa	XLVII/148	0.7285
106	Mombasa	XLVII/149	unknown
107	Mombasa	XLVII/150	unknown
108	Mombasa	XLVII/151	unknown
109	Mombasa	XLVII/152	unknown
110	Mombasa	XLVII/153	unknown
111	Mombasa	XLVII/154	unknown
112	Mombasa	XLVII/155	unknown
113	Mombasa	XLVII/156	unknown
114	Mombasa	XLVII/157	unknown
115	Mombasa	XLVII/158	unknown
116	Mombasa	XLVII/159	unknown
117	Mombasa	XLVII/162	0.0451
118	Mombasa	XLVII/163	unknown
119	Mombasa	XLVII/164	unknown
120	Mombasa	XLVII/165	unknown
121	Mombasa	XLVII/166	unknown
122	Mombasa	XLVII/167	0.0502
123	Mombasa	XLVII/168	unknown
124	Mombasa	XLVII/173	unknown
125	Mombasa	XLVII/174	unknown
126	Mombasa	XLVII/179	unknown

127	Mombasa	XLVII/185	unknown
128	Mombasa	XLVII/225	unknown
129	Mombasa	XLVII/24	unknown
130	Mombasa	XLVII/25	unknown
131	Mombasa	XLVII/26	unknown
132	Mombasa	XLVII/37	0.8903
133	Mombasa	XLVII/43	unknown
134	Mombasa	XLVII/44	unknown
135	Mombasa	XLVII/45	unknown
136	Mombasa	XLVII/67	unknown
137	Mombasa	XLVII/72	unknown
138	Mombasa	XLVII/73	unknown
139	Mombasa	XLVII/75	unknown
140	Mombasa	XLVII/81	unknown
141	Mombasa	XLVII/82	unknown
142	Mombasa	XLVII/83	unknown
143	Mombasa	XLVII/84	0.18534631
144	Mombasa	XLVII/85	0.083608183
145	Mombasa	XLVII/86	0.126302584
146	Mombasa	XLVII/87	unknown
147	Mombasa	XLVII/88	unknown
148	Mombasa	XLVII/89	unknown
149	Mombasa	XLVII/90	unknown
150	Mombasa	XLVII/91	unknown
151	Mombasa	XLVII/92	unknown
152	Mombasa	XLVII/93	unknown

153	Mombasa	XLVII/94	unknown
154	Mombasa	XLVII/95	0.099755165
155	Mombasa	XLVIII/118	unknown
156	Mombasa	XLVIII/119	unknown
157	Mombasa	XLVIII/121	unknown
158	Mombasa	XLVIII/122	unknown
159	Mombasa	XLVIII/131	unknown
160	Mombasa	XLVIII/135	unknown
161	Mombasa	XLVIII/138	unknown
162	Mombasa	XLVIII/139	unknown
163	Mombasa	XLVIII/140	unknown
164	Mombasa	XLVIII/148	unknown
165	Mombasa	XLVIII/149	unknown
166	Mombasa	XLVIII/150	unknown
167	Mombasa	XLVII/151	unknown
168	Mombasa	XLVIII/152	unknown
169	Mombasa	XLVIII/155	0.181744602
170	Mombasa	XLVIII/156	0.3024
171	Mombasa	XLVIII/157	1.672
172	Mombasa	XLVIII/158	0.6163
173	Mombasa	XLVIII/159	0.5771
174	Mombasa	XLVIII/163	0.1281
175	Mombasa	XLVIII/164	0.2017
176	Mombasa	XLVIII/165	0.1905
177	Mombasa	XLVIII/166	unknown
178	Mombasa	XLVIII/173	0.777402319

179	Mombasa	XLVIII/18	2.5373
180	Mombasa	XLVIII/181	unknown
181	Mombasa	XLVIII/185	unknown
182	Mombasa	XLVIII/189	unknown
183	Mombasa	XLVIII/194	unknown
184	Mombasa	XLVIII/37	unknown
185	Mombasa	XLVIII/43	unknown
186	Mombasa	XLVIII/44	unknown
187	Mombasa	XLVIII/45	unknown
188	Mombasa	XLVIII/50	unknown
189	Mombasa	XLVIII/558	unknown
190	Mombasa	XLVII/169	unknown
191	Mombasa	I/528	unknown
192	Mombasa	I/529	unknown
193	Mombasa	XLVII/170	6.421
194	Mombasa	I /3/70	0.6354
195	Mombasa	I/378	0.0010684
196	Mombasa	XLVIII/75	unknown
197	Mombasa	XLVII/88	unknown
198	Mombasa	I/1310	unknown
199	Mombasa	I/439	unknown
200	Mombasa	I/30	unknown
201	Mombasa	I/1A	unknown
202	Mombasa	XLVII/1731	unknown
203	Mombasa	I/1762	unknown
204	Mombasa	I/1763	unknown

205	Mombasa	XLVIII/72	unknown
206	Mombasa	I/576	unknown
207	Mombasa	XLVIII/145	unknown
208	Mombasa	XLVIII/146	unknown
209	Mombasa	XLVII/139	unknown

(Source is Kenya Ports Authority Audit Report, 2017)

APPENDIX 2: Web Application Source Code

```
<!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Strict//EN"
"http://www.w3.org/TR/xhtml1/DTD/xhtml1-strict.dtd">

<html xmlns="http://www.w3.org/1999/xhtml">

<head>

  <meta http-equiv="Content-Type" content="text/html; charset=utf-8" />

  <title>Kenya Ports Authority Mombasa</title>

  <link rel="stylesheet" href="https://unpkg.com/leaflet@1.6.0/dist/leaflet.css" />

  <link rel="stylesheet" href="https://unpkg.com/leaflet@1.3.0/dist/leaflet.css" />

  <link rel="stylesheet" href="src/leaflet-search.css" />

  <link rel="stylesheet" href="leaflet-measure.css">

  <script src="block.js"></script>

  <style type="text/css">

  <link rel="stylesheet" href="style.css" />

 <style>

  body {

    font-size: 14px;

    font-family: Helvetica, sans-serif;
```

```
  font-weight: 400;
  line-height: 1;
  color: #222;
  text-rendering: optimizeLegibility;
  -webkit-font-smoothing: antialiased;
}
body {
  margin: 0 20px 20px;
}
h1, h2 {
  margin: 20px 0 0;
  font-size: 1.4em;
  font-weight: normal;
  line-height: 1;
}
h1 {
  display: inline-block;
  font-size: 1.4em;
}
h2 {
  font-size: 1.1em;
```

```
    }
    pre {
      line-height: 1.5em;
    }
    p.github {
      display: inline-block;
      margin: 20px 0 0 20px;
      font-size: 1.2em;
    }
    a, a:visited, a:hover, a:active, a:focus {
      text-decoration: none;
    }
    #map {
      height: 680px;
      margin: 20px 20px 0 0;
    }
          .legend { background : white; line-height : 1.5em}
          .legend i { width : 5em; float : left }
  </style>
</head>
<body>
```

```
<p class="github"><a href="https://github.com/ljagis/leaflet-measure"></a></p>

<div id="map"></div>

<script src="https://unpkg.com/leaflet@1.6.0/dist/leaflet.js"></script>

<link rel="stylesheet" href="https://unpkg.com/leaflet@1.3.0/dist/leaflet.css" />

<script src="src/leaflet-search.js"></script>

<script src="leaflet-measure.js"></script>

<script src="data/block.js"></script>

<script>



   var map = L.map('map', {

     center: [-4.06, 39.63],

     zoom: 15,



     measureControl: true,


   });

         // Styling GeoJSOn


         var blockLayer;
```

```
function highlightFeature(e){
	var layer = e.target;
	layer.setStyle(
		{
			weight : 10,
			color : 'black',
			fillColor : 'white',
			fillOpacity : 0.0
		}
	);
	if(!L.Browser.ie && !L.Browser.opera){
		layer.bringToFront();
	}
}

function resetHighlight(e){
	blockLayer.resetStyle(e.target);
}

function zoomToFeature(e){
```

```
        map.fitBounds(e.target.getBounds());
}

function blockOnEachFeature(feature, layer){
        layer.on(
                {
                        mouseover : highlightFeature,
                        mouseout : resetHighlight,
                        click : zoomToFeature
                }
        );
}

function getCountryColor(areaEst){
        if(areaEst > 20){
                return 'red';
        }else if(areaEst > 50){
                return 'blue';
        }else{
                return 'green';
        }
```

```
}

function countriesStyle(feature){
    return {
        fillColor : getCountryColor(feature.properties.area1),
        weight : 2,
        opacity : 1,
        color : 'black',
        dashArray : 3,
        fillOpacity : 0.0
    }
}

// adding a legend
var legend = L.control({position: "bottomleft"});
legend.onAdd = function(map) {
var div = L.DomUtil.create("div", "legend");
 div.innerHTML =
    '<p><b>Kenya Ports Authority Parcel Management</b></p><hr>' +
    '<p>Here the application allows ' +
```

```
        'for the following procedures.</p>' +
        'The procedure include:<br>' +
        '<p><ul>' +
        '<li>visualization of parcels</li>' +
        '<li> verification of areas</li>' +
        '<li>querrying of additional information</li>' +
        '</ul></p>' +
        'The application has a <b>popup</b>. ' +
        'Click on the parcels to see it!<hr>' +
        'Created with the Leaflet library<br>' +
        '<img src="images/leaflet.png">';
       return div;
      };
         legend.addTo(map);
                    // adding popup window
                    //var popup = L.popup();
// function onMapClick(e) {
     //  popup
       //  .setLatLng(e.latlng)
       //  .setContent(
            //  "You clicked the map at -<br>" +
```

```
                //  "<b>lon:</b> " + e.latlng.lng + "<br>" +
                //  "<b>lat:</b> " + e.latlng.lat
            //   )
              // .openOn(map);
            //    }
        // map.on("click", onMapClick);


                    //baseTile Layers
        var satellite=new
L.TileLayer('http://www.google.com/maps/vt?lyrs=s,h&x={x}&y={y}&z={z}', {attribution:
'Map data &copy; <a href="https://www.google.com">Googlemaps</a> contributors, <a
href="http://creativecommons.org/licenses/by-sa/2.0/">CC-BY-SA</a>'}).addTo(map);
        //var Openstreetmap=new L.TileLayer('http://{s}.tile.openstreetmap.org/{z}/{x}/{y}.png',
{attribution: 'Map data &copy; <a href="http://openstreetmap.org">OpenStreetMap</a>
contributors, <a href="http://creativecommons.org/licenses/by-sa/2.0/">CC-BY-
SA</a>'}).addTo(map);


                // Adding GeoJSON for parcels
        blockLayer = L.geoJson(
                            block,
                            {
                                style : countriesStyle,
                                onEachFeature : blockOnEachFeature,
```

```
                }).bindPopup(function (layer) {
return layer.feature.properties.plotno;
                }).addTo(map);
                map.fitBounds(blockLayer.getBounds());




                // search control


                var data = block;
                //adding search control


                var featuresLayer = new L.GeoJSON(data, {
                style: function(feature) {
                        return {color: feature.properties.area1,fillOpacity:0.0 };
                },
                onEachFeature: function(feature, marker) {
```

```
                    marker.bindPopup('<h4 style="color:'+feature.properties.area1
+'">'+ feature.properties.plotno +'</h4>');
                }

            });

        map.addLayer(featuresLayer);

            var searchControl = new L.Control.Search({
            layer: featuresLayer,
            propertyName: 'plotno',
            marker: false,
            moveToLocation: function(latlng, title, map) {
                //map.fitBounds( latlng.layer.getBounds() );
                var zoom = map.getBoundsZoom(latlng.layer.getBounds());
                map.setView(latlng, zoom); // access the zoom
              }
        });

        searchControl.on('search:locationfound', function(e) {
```

```
    //console.log('search:locationfound', );

    //map.removeLayer(this._markerSearch)

    e.layer.setStyle({fillColor: '#3f0', color: '#0f0'});
    if(e.layer._popup)
            e.layer.openPopup();

}).on('search:collapsed', function(e) {

     featuresLayer.eachLayer(function(layer) {   //restore feature color
             featuresLayer.resetStyle(layer);
        });
});

map.addControl( searchControl );  //inizialize search control

    //scale of map
    L.control.scale().addTo(map);
```

```
                    // returns the area of parcel and other associated information
                L.geoJson(block, {
    style: function (feature) {
   return {color: feature.properties.color};
    }
   }).bindPopup(function (layer) {
    return layer.feature.properties.area1;
                    //return layer.feature.properties.plotno;
    }).addTo(map);




     // measuring area
map.on('measurefinish', function(evt) {
    writeResults(evt);
 });

 function writeResults(results) {
```

```
        document.getElementById('eventoutput').innerHTML = JSON.stringify(
         {
         area: results.area,
         areaDisplay: results.areaDisplay,
         lastCoord: results.lastCoord,
         length: results.length,
         lengthDisplay: results.lengthDisplay,
         pointCount: results.pointCount,
         points: results.points
        },
        null,
        2
       );
     }



  </script>


</body>
```

</html>

APPENDIX 3: Web Application Interface

URL: www.kpalands.co.ke

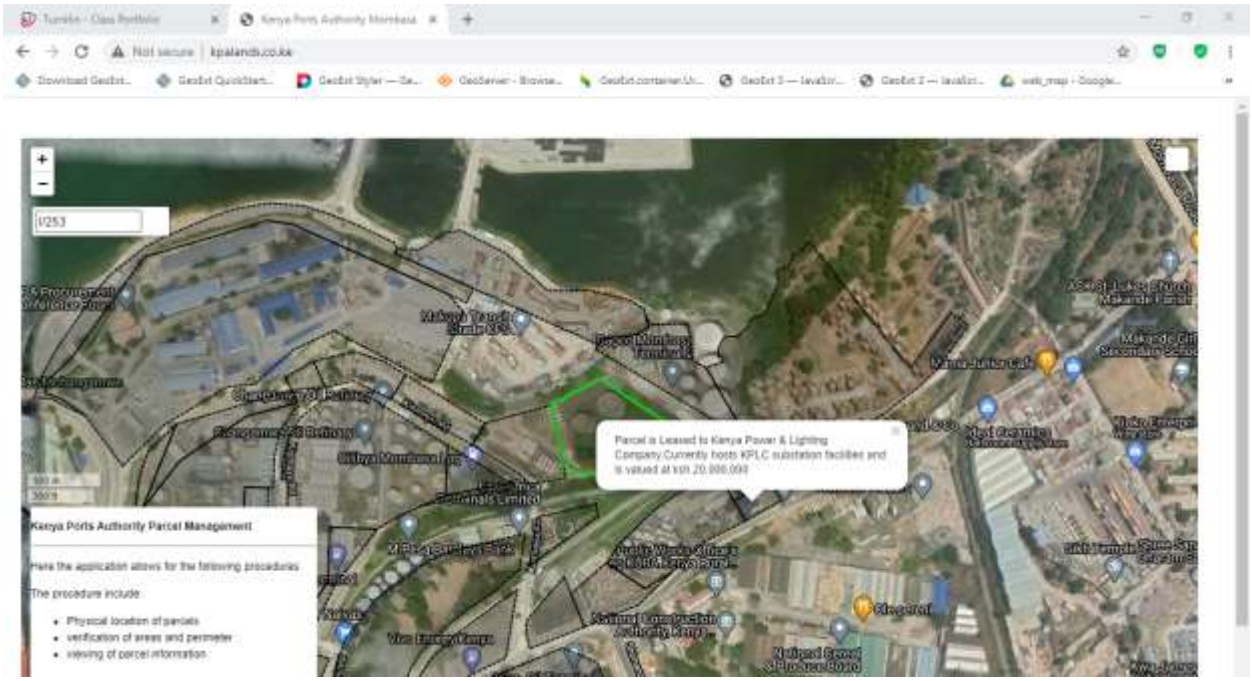

Figure 0-1 Web page for KPA parcels of land in Mombasa