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DEVELOPMENT OF A GEOVISUALISATION TOOL FOR CLEAN DEVELOPMENT MECHANISM PROJECTS IN KENYA

BY

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Declaration

I, Alexandra Mutungi, hereby declare that this project is my original work. To the best of my knowledge, the work presented here has not been presented for a degree in any other Institution of Higher Learning.

Alexandra Mutungi   03/05/2019

Name of student   Date

This project has been submitted for examination with our approval as university supervisor(s).

Dr. Faith Karanja   …………………

Name of supervisor   Date

Turn it in report summary

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Abstract

Kenya is one of the developing countries that are a party to the United Nations Framework Convention on Climate Change, the Kyoto Protocol and the Paris Agreement. These agreements are the world's advancement towards reducing emission which is being addressed by the Clean Development Mechanism. The National Environment Management Authority is currently responsible for reporting Kenya's progress towards emission reductions from various sectors. However, there is need to map and visualise these project activities and support their monitoring by all relevant stakeholders. This research project explored how web GIS can be used to map these projects to support collaboration, information sharing, reporting and sustainable development implementation. The aim was to provide a free and open-source application, to generate and visualise more geospatial data on Clean Development Mechanism projects in Kenya.

The methodology involved data extraction from excel sheets, development of data models relevant to user needs, developing the conceptual, logical and physical model of the database which was queried through PostgreSQL. An account was set up in Geoserver to host the feature services and geospatial data. A web based GIS application was developed and linked to the server and internet. HTML, CSS and JavaScript were used to develop the web app. The project resulted in a web-based GIS platform in which users can query and overlay CDM and reference layers.

67 CDM projects were identified and it was discovered that majority of these projects in Kenya have been registered (65%), are small in size and 32.8% of the projects are mainly focused on reforestation and clean cooking mechanisms. Only 17% of the projects have generated credits. The CDM projects are located within Meru and Nakuru counties. Low performance could be attributed to lack of institutional capacity, policy and legislative frameworks.

The web GIS is a thin-client based platform that will be available for embedding in websites. It also provides an information solution for governments, private sector, academia, research funding agencies and the general public.

The project recommends further research to explore mobile platforms that can be used to access the visualization tool and increased development of data models for the display of the most appropriate sustainable data.

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Abbreviations

AJAX   Asynchronous JavaScript XML

API   Application Programming Interface

CAC   Computer Assisted Cartography

CAM   Computer Assisted Mapping

CSS   Cascading Stylesheet

CDM   Clean Development Mechanism

DBMS   Database Management System

EIA/EA   Environmental Impact Assessment and Audit

EPA   Environment Protection Agency

GIS   Geographic Information Systems

HTML   Hypertext Markup Language

HTTP   Hypertext Transfer Protocol

KASNEB   Kenya Accountants and Secretaries National Examination Board

KODI   Kenya Open Data Initiative

MEMR   Ministry of Environment and Natural Resources

NEMA   National Environment Management Authority

OGC   Open Geospatial Consortium

QGIS   Quantum Geographic Information System

SDI   Spatial Data Infrastructure

SOA   Service Oriented Architecture

TCP/IP   Transfer Control Protocol/Internet Protocol

UML   Unified Modeling Language

UNFCCC   United Nations Framework Convention on Climate Change

UNEP   United Nations Environment Programme

WCED   World Commission on Environment and Development

WFS   Web Feature Service

WMS   Web Map Service

XML   eXtensible Markup Language

1 INTRODUCTION

1.1 Background to the study

The Brundtland report defines sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." (World Commission on Environment and Development, 1987) Sustainability forms the basis for development framework today. It is a universal agreement to alleviate poverty by providing a well-constructed framework centered around 17 goals. Development challenges vary from country to country and their approach to achieving these goals may vary, however, the common long-term goal of improving livelihoods despite minimal resources is cross-cutting globally. (Kaimuri & Kosimbei, 2017) This project looks at how a web-GIS tool can be used to visualize key development projects reducing emissions in Kenya following the signing of the Kyoto Protocol and Paris Accord.

Beginning in 2006, the clean development mechanism (CDM) is a credit and investment scheme that allows emission-reduction projects based in developing countries to earn certified emission reductions (CERs) credits, each equal to a tonne of carbon dioxide. CDM encourages developed countries to invest in infrastructure and technology in developing countries to offer an opportunity to reduce greenhouse gas emissions. The investing country therefore claims the certified emission reductions as a form of credit for meeting the targets of the Kyoto Protocol. (https://www.britannica.com/event/Kyoto-Protocol#ref302351 accessed on 16th January 2019).) The certified emission reductions can then be sold, traded and used by industrialised countries to meet their emission reduction goals in accordance with the Kyoto Protocol. CDM is designed in form of 3 market mechanisms to encourage the participation of private sector and developing countries towards emission reductions. These market mechanisms are - emissions trading, Joint Implementation and the Clean Development Mechanism (CDM) which will be the main focus of this project. (https://cdm.unfccc.int/about/index.html accessed on 16th January 2019)

Kenya's public sector is currently participating in sustainable development. Implementation of the sustainable development goals is presently being managed by (i) the Ministry of Devolution and Planning and (ii) the National Environment Management Authority. (https://ayubmacharia.com/2016/11/25/framework-for-implementing-sustainable-development-

goals-sdgs-in-kenya/ accessed on 16th January 2019). The research project will focus on visualizing emission reduction projects that are under NEMA's mandate.

A current review of the database for all CDM projects highlights the use of a website with a webpage dedicated to searching these projects. Queries can be done using the following criteria: Title, sectoral scope, scale, status, reference number. There is the option of sorting the data using the registration date, reference number, title, amount of reductions and host country. Tables and graphs are the main tools for visualizing these non-spatial attributes.

1.2   Problem Statement

Kenya's advancement towards sustainable development can be achieved through maximising on the Clean Development Mechanism. The country has already established NEMA as its Designation National Authority to supervise and support this tool. (https://www.nema.go.ke/index.php?option=com_content&view=article&id=15&Itemid=152 accessed on 10th January 2019) However, there is a challenge in accessing all profiles for development projects in one place. Majority of the project information is compiled as pdf reports or excel sheets that are mostly non-spatial, and only accessible through separate web-pages and websites. The separation of the data and the pdf nature of the geospatial data that is contained in these project documents makes it difficult to visualise and manipulate project attributes. This therefore poses a challenge in easily analysing the sustainable development process. The continuing increase in number of CDM projects based in Kenya means it will eventually make overall country performance assessment more complicated.

A visualization tool in the form of an interactive web map would equip various stakeholders from the private and public sector with information to better understand the distribution of these projects and strategically plan future projects. It will allow users to visually identify trends in project type at a county level and overall country level which is an ability that is currently lacking.

In addition, the interactive map will provide a tool to enhance assessment of various parameters for clean development projects at a glance and the relevant information customised to the user's needs. The information can then be manipulated further to uncover new information for monitoring reporting and verification of greenhouse gas emission reductions that could assist the policy development process and implementation.

1.3 Objectives

1.3.1 Overall Objectives

The overall objective was to provide an interactive tool that contributes more geospatial information about clean development projects which would aid the country in monitoring its nationally determined contributions under the Paris Agreement.

1.3.2 Specific Objectives

The specific objectives were to:-

    i) Identify clean development mechanism projects in Kenya

    ii) Create a GIS database of the clean development mechanism projects

    iii) Develop a web-based GIS platform for clean development mechanism

    iv) Populate the web-based GIS platform with clean development mechanism projects

1.4 Justification for the Study

By 2020 developed countries hope to mobilise US 100 billion dollars to support developing countries implement their Paris Agreement contributions. Kenya is a developing country and therefore is a beneficiary of investments, technology and capacity building from advanced countries and international organisations to support its sustainable development projects such as those under the CDM. Technology will aid the transfer of funds between the two countries and this will involve public and private sector as well as the general public. The spatially referenced map will offer more project location visibility to the various stakeholders on a platform that can be customised to meet the user needs. (The National Treasury, 2016)

This web-GIS service will make it easier and cost effective to view sustainable development projects therefore raising awareness of the projects and how they could potentially impact the local communities socially, economically and environmentally. The public will not need to download or own the application to access the information as only internet connection will be required. This GIS data can be modelled by public sector such as the ministries or investors to plan their activities. For example, they can assess the proximity of projects to each other, or overlay other spatial data. The web-GIS solution will offer more functionality to the spatial data on the CDM projects.

The establishment of the DBMS to complement the interactive map will allow users to make queries and discover new information which can be presented on a map.

1.5   Scope of work

This project intends to develop an object relational geodatabase and web-based visualisation tool for sustainable development through Clean Development Mechanism projects situated in Kenya. This visualisation tool focuses on mapping the CDM projects in the renewable energy sub-sector. These maps are stored in a geodatabase that is hosted on the web through Geoserver and can be displayed on the visualisation application. The tool was designed using HTML, CSS and JavaScript and contains simple pop-up query tool with the option of overlaying the WMS. The project extracts official CDM data from the UNFCCC and UNEP websites and therefore did not require field data collection. This data only cover projects that are reducing emissions and their parameters and not emission sources.

1.6   Organization of the report

The report is organized into 5 chapters. Chapter one introduces the concept of Clean Development Mechanism, its background within a global and Kenyan context. This chapter also provides an introduction to GIS.

Chapter 2 is the literature review which focuses on the policies that guide CDM projects and CDM implementation in Africa and Kenya. It also discusses the technologies that are currently being used to visualise CDM projects. The chapter delves into GIS, its use in sustainable development mapping, geodatabase design, the progression of Web GIS and Web 2.0 technology.

Chapter 3 discusses the materials and methodology used to meet the project objectives. This includes the data sources, how the data was processed and used to develop the object relational database, developing and populating the web-based GIS platform.

Chapter 4 presents the results and discussion on the web-based GIS platform.

Chapter 5 covers the conclusions and recommendations from the project.

2   LITERATURE REVIEW

2.1   Introduction

The chapter covers the Clean Development Mechanism, international, regional and local frameworks guiding CDM projects, Sustainable development mapping, Geographic information systems, visualisation advancements from Computer Aided Cartography to Web-Based Mapping, Geodatabase development and the advantages of using GIS in decision making with global, regional and local examples of the Web GIS application.

2.2   Clean Development Mechanism

It is the first mechanism that provides a standard way of measuring certified emission reductions. CDM projects enhance sustainable development by lowering the emission reductions that would otherwise be generated in a business as usual scenario. Since the mechanism was established the Clean Development Mechanism has registered more than 1650 projects which were projected to generate 2.9 billion tonnes of Carbon Dioxide between the first commitment period between 2008-2012. Currently, Kenya has 67 CDM projects at various stages of development as per the publicly available CDM excel database on the UNFCCC website. They range from wind and solar projects to clean, energy efficient, cooking stoves.

Some of the projects include Lake Turkana 310MW Wind Power Project, Olkaria III Phase 2 Geothermal Expansion Project and Karan Biofuel CDM project. (Barris, 2019)

2.3   Framework for Clean Development Mechanism Projects

2.3.1   The Kyoto Protocol

The Kyoto Protocol of the United Nations Framework Convention on Climate Change is an international treaty that was signed in the Japanese city, Kyoto, in 1997 and was adopted in February 2005. The treaty is aimed at reducing emission reductions of 6 main greenhouse gases that contribute to global warming, namely:

- Carbon Dioxide (CO2)
- Methane (CH4)
- Nitrous Oxide (N2O)
- Hydrofluorocarbons (HFCs)
- Perfluorocarbons (PFCs) and

- Sulphur hexafluoride (SF6)
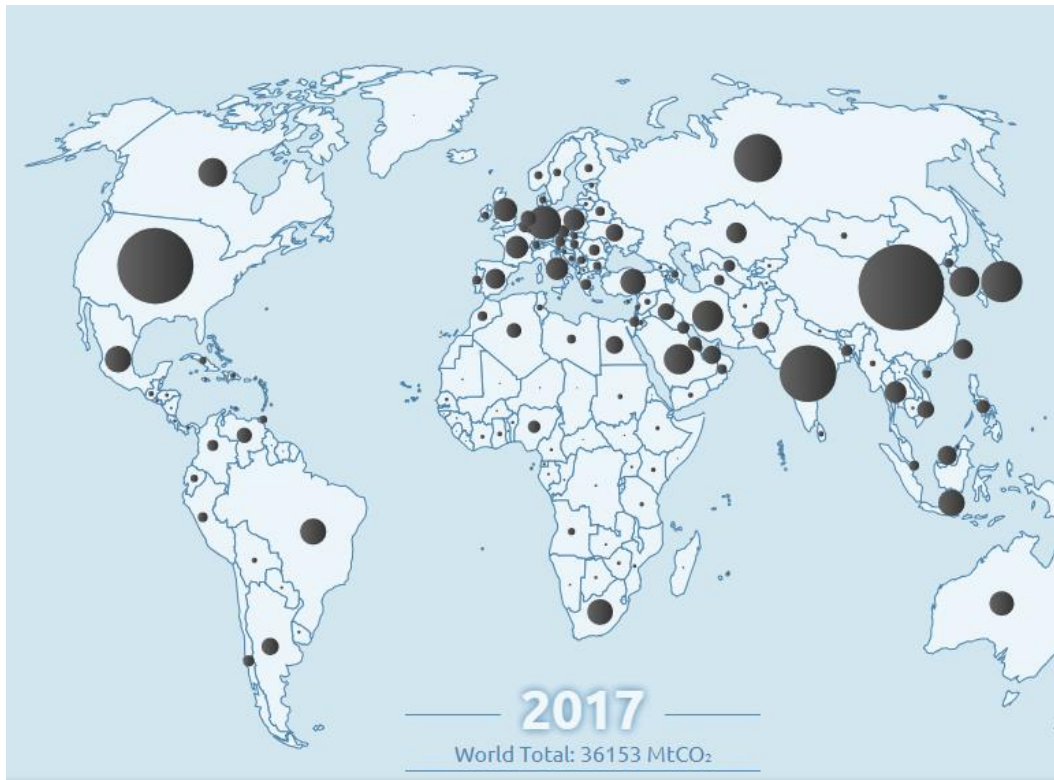
Figure 2.1: Global emissions from fossil fuels (Global Carbon Atlas, 2017)

According to the International Panel on Climate Change, the effects of global warming from these gases would cause long-term effects such as rise in sea level, extreme weather conditions, extinction of 20-30% of flora and fauna.

The protocol tailors to the specific needs of the most vulnerable developing countries. Annex 1 Parties (industrialised countries) are obligated to declare how they are working towards achieving their emission reductions. This gave rise to the Clean Development Mechanism.

2.3.2   Paris Agreement

The Paris Climate Agreement was adopted at the 21st United Nations Climate Conference (COP21) held in Paris on December 2015. (Clemencon, 2016) Whereas the Kyoto Protocol has legally binding commitments, Paris Agreement is geared towards a bottom-up approach of building consensus and voluntarily creating nationally determined contributions. (Birnie et al., 2009) Article 6.4 describes the Paris agreement as a mechanism to contribute the mitigation of greenhouse gases and support sustainable development. Countries shall aim:

- To promote the mitigation of greenhouse gases alongside working towards sustainable development
- To incentivise public and private entities authorised by the host country to participate in the mitigation of greenhouse gas emissions
- To contribute to lower emissions levels and therefore benefit the host country. This can also be used by another country to achieve their nationally determined contributions
- To achieve overall mitigation worldwide (United Nations Framework Convention on Climate Change, 2015)

2.3.3 Regional and local implementation

As part of CDM requirements, countries that have accepted the Kyoto protocol are expected to set targets to limit or reduce greenhouse gas emissions. These countries are answerable to the CDM executive board. (https://unfccc.int/process-and-meetings/the-kyoto-protocol/mechanisms-under-the-kyoto-protocol/the-clean-development-mechanism accessed on 16th January 2019)

In order to participate in the CDM, it is mandatory for countries to set up a Designated National Authority (DNA). DNAs are organizations granted the power to authorise and approve participation in CDM projects. They establish the potential of a project and determine whether it will contribute to achieving sustainable development for the country that will host it. (https://cdm.unfccc.int/about/index.html accessed on 16th January 2019) In Kenya, this responsibility has been given to the National Environment Management Agency- an agency under the Ministry of Environment and Natural Resources (MEMR). NEMA is one of 48 DNAs in Africa. The designated national authority has 2 roles which are to regulate and promote project ideas from various sectors. The projects need to conform to the following:

- The national CDM guidelines
- The National development strategy
- Kenya Vision 2030 blueprint
- Environmental Impact Assessment and Audit (EIA/EA)
- Any other relevant environmental management regulations including sectoral laws and guidelines.

  (https://www.nema.go.ke/index.php?option=com_content&view=article&id=117:clean-development-mechanism-dna&catid=13&Itemid=250 accessed on 16th January 2019)

Kenya being a party to the United Nations Convention on Climate Change, the Kyoto Protocol and the Paris Agreement, developed the National Policy on Climate Finance (2016) as a guide to achieving its obligations to these accords. Energy is viewed as an enabling sector for development economically, socially and environmentally, if its large greenhouse gas emissions are regulated. (The National Treasury, 2016)

2.4   Sustainable development mapping

The Open Geospatial Consortium writes "environmental data is spatial data describing features and phenomena and their locations relative to Earth coordinate reference systems." There is a need to combine artificial and natural environment data as well as create a general consensus for international encoding and interface standards which will help the data users. This will call for a joint effort between government, private sector, NGOs, funding agencies and academia.

Sustainability will depend on the information technology that will aid us in gaining knowledge on the Earth changes. The OGC has suggested having an integrated IT standard and data integration between domains which are focused on the environment. They have listed among others, greenhouse gases sources, sinks, reductions and effects as a viable domain to support sustainability. (Open GIS Consortium, 2015)

2.4.1   Geographic information systems

Almost everything that happens happens somewhere. Knowing where something happens can be critically important. (Longley et al., 2005). A geographic information system (GIS) can be defined as a framework for capturing, gathering, managing and analysing data that can be geographically referenced. (Deakin, 2002) GIS is an integration of an array of datasets. This technology analyses the spatial component of these datasets and organizes them into layers for visualisation in maps and 3D scenes. GIS data may include base maps, imagery, features which can be utilised alongside data from spreadsheets and tables. Maps are easily shared, embedded in apps and are accessible to anyone, anywhere. The advantage of using GIS is its ability to evaluate suitability, predict, estimate, interpret and understand information leading to new perspectives for decision making. (https://www.esri.com/en-us/what-is-gis/overview accessed on 13th January 2019) Geographic information systems are a unique type of information system that keeps track of events, activities and things including where these events, activities and things are occurring. GIS help users make smarter and well informed decision from the deeper insights that

it provides. Similar to other information systems, GIS assists people to manage the data that they have. Data – raw facts and figures are assembled together in a database. This data can be used to generate information – data that can be interpreted and can be digitized to serve a particular purpose. Value can also be added to information. Knowledge from information is obtained through the interpretation of relevant information to derive evidence which has been analysed and understood. Knowledge is strongly linked to a person and their experience with the information. Wisdom is the ultimate level in the decision making hierarchy in any field including electrification policy development. However, it is highly individualised and based on the knowledge and evidence that has been collected. (Longley et al., 2005).
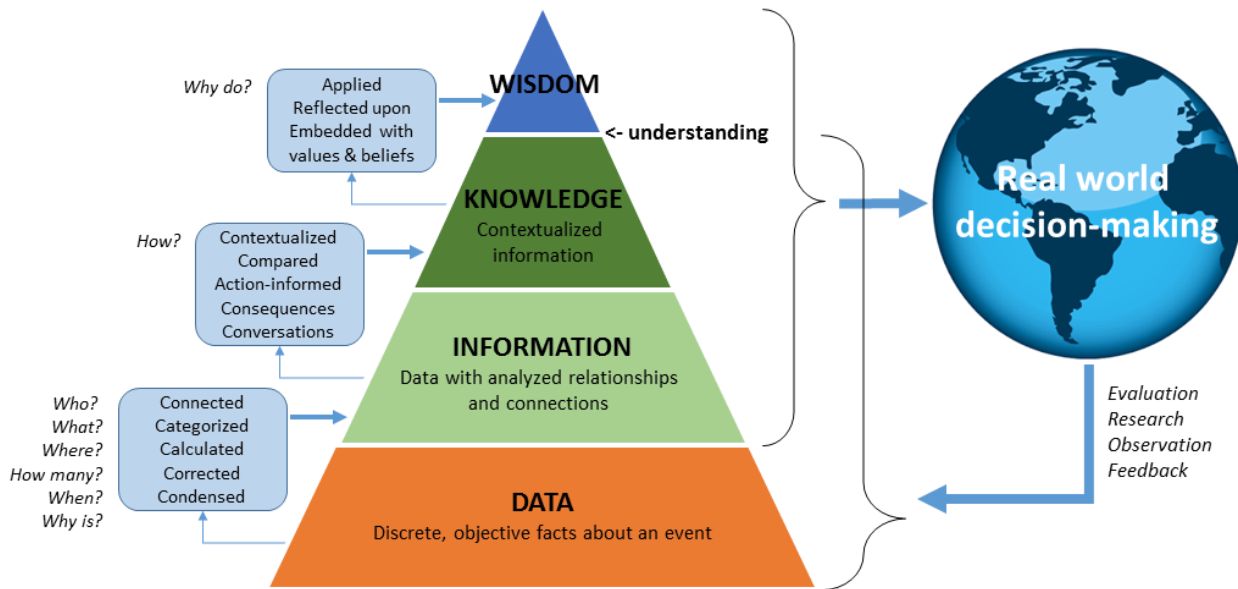
Figure 2.2: Decision-making hierarchy (Earth-eval.org, 2015)

GIS can be applied to various disciplines shown by the number of available specialized extensions of GIS software which continue to increase. For example GIS applications have been developed for transportation, oil exploration, health, business, human services, health, emergency services and energy. (Deakin, 2002)

2.5   Technologies for visualisation of CDM projects

Currently, the most common method of visualising CDM project data is through tables and graphs that are available on the UNFCCC CDM insights page and other UN agencies websites such as UNEP-DTU that are supporting the process. Observing the UNFCCC website there are graphs highlighting the various stages of project development for countries that have committed to the Kyoto Protocol against time or location. Some of the visualised information includes the number of projects around the world that are reducing greenhouse gas emissions, registration of projects under the CDM, accuracy check (validation) of the projects, projects that have contributed to reducing greenhouse gas pollution, the methodology being used by the project to minimize emissions and registration of projects in Least Developed Countries.
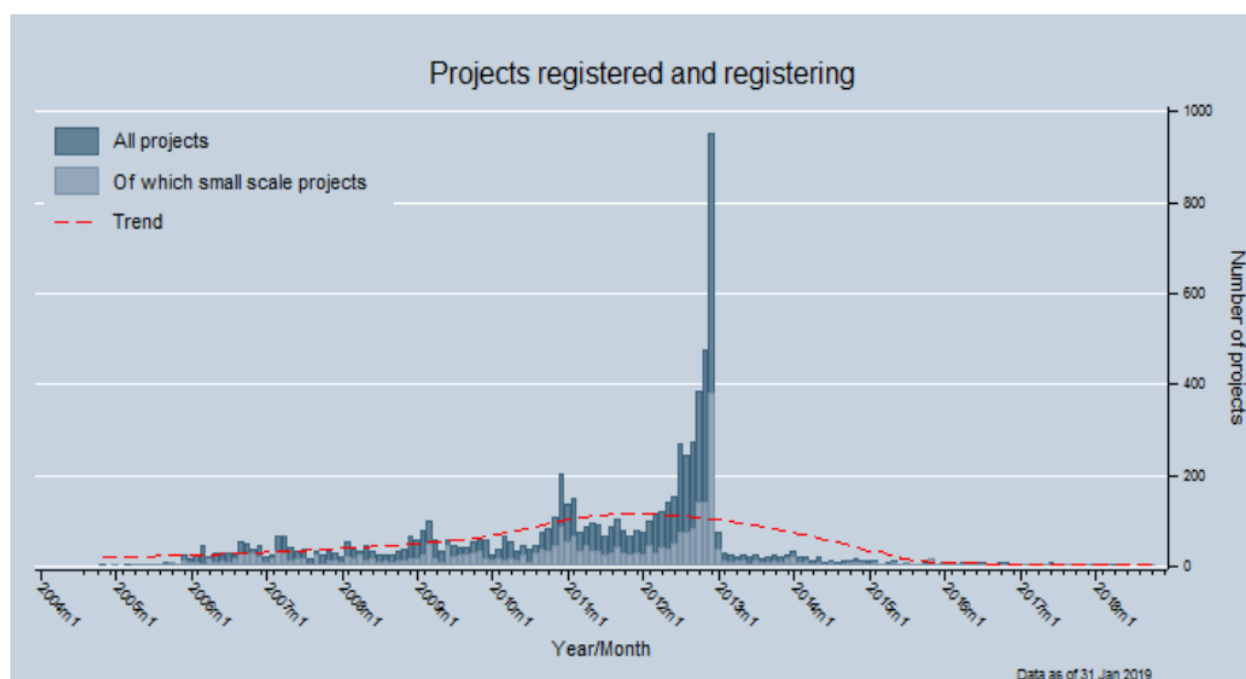
Figure 2.3: Visualisation sample used for CDM project data (UNFCCC, 2018)

There is also a web-map available that visualises the geographic distribution of CDM projects in countries with less than 10 projects. It only indicates the location and number of projects. However, the map can be enhanced to show more country projects and attributes which can be useful for various public, private and civil society stakeholders.

Previous studies undertaken were focused on analysing and visualizing the text within the project documents. Softwares that were used include Nvivo7, Atlas.ti were used to qualitatively analyse the contribution of CDM projects to sustainable development. Environmental, social and economic sustainability areas were the main focus and it was discovered that these projects contribute mostly to the economic aspect. (Nyambura & Nhamo, 2014) Despite the widespread

use of climate visualization tools, they are not as well advanced in use for communication, decision-making and analytical purposes for different stakeholders in developing countries. (Sanga et al., 2013).

2.6 Web GIS

Visualization systems provide a 3D representation of space or temporal cartographic animations. They allow users to explore and understand large volumes of complex data using tools. Geographic visualization is an integration of cartography, image analysis, information visualization, exploratory data analysis and geographic information systems. GIS and visualization complementary each other and therefore build each other into technology such as web-based mapping. (Deakin, 2002)

2.6.1 Web mapping progression

The advancement of technology has transformed the manner in which geospatial information is handled. ICT offers many options for handling and managing data. For instance, spatial data handling shifted from computer assisted mapping (CAM) and computer assisted cartography (CAC) to GIS systems which has more functionality for analyzing data. However, even with desktop GIS there was lack of interoperability, steeper learning curve and cost to utilize only a fraction of the GIS functionality. Distributed computing such as the internet and the World Wide Web were used to resolve this issue and offer enterprise GIS. Enterprise GIS offers an integrated environment in which data is managed on a database that is accessible to a whole institution. Each department has a dedicated gateway to the database. Further efforts have attempted to create spatial data infrastructure to channel geographic information within a networked environment. Countries such as Kenya have attempted to establish SDI. (Onchaga, 2008) Its current SDI development status is considered average. Besides South Africa, most other Africa countries are at the phase of establishing legislation, policy, institutional collaborations, databases and metadata, standards, technology and human capacity in order to set up NSDIs. (Mulaku et al., 2007)

The Open Geospatial Consortium (OGC) was developed to promote the interoperability, accessibility and ease of implementing GIS. They have identified 5 categories of GIS services that are being standardized which include: application services, data access services, portrayal services, catalog service and processing services. (Onchaga, 2008) An application service which

this study will be focusing on will be based on the 3-tier architecture as shown in the figure below.
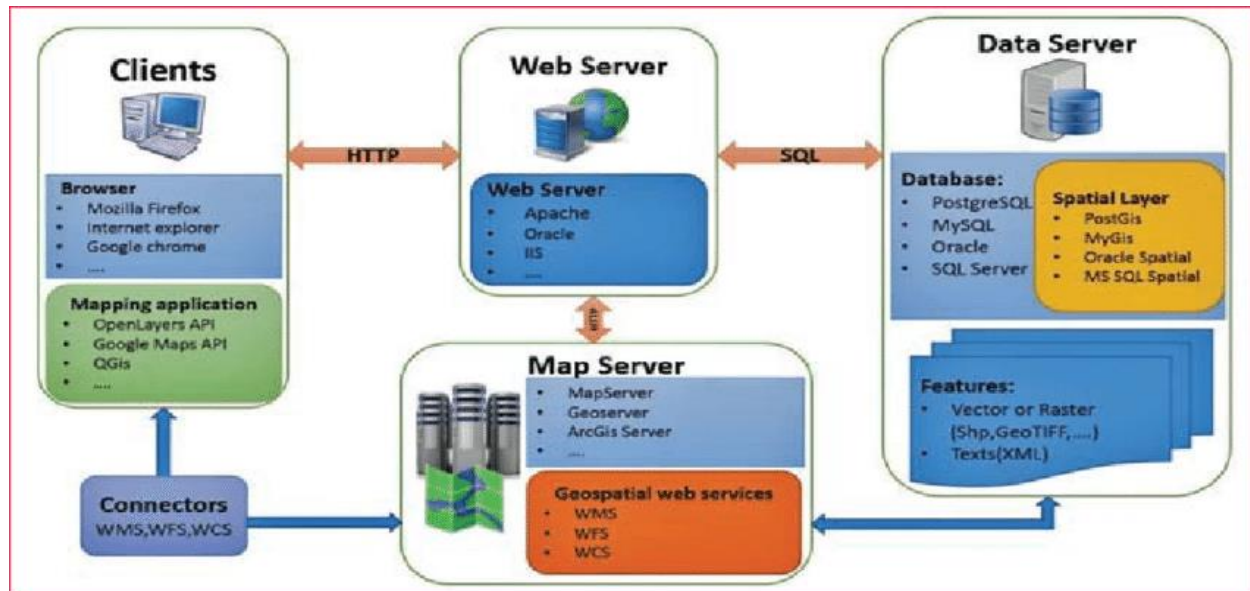
Figure 2.4: Components of a web-based GIS (mycoordinates.org, 2015)

It is a distributed system in which data is shared from different locations over the internet. Web mapping combines the access and interactivity of the internet with the customization ability of GIS. The 3 tiers are connected through:

- Hyper-text Mark-up Language – language used to display the webpage content on a client's computer. The HTML code is transmitted to the client through HTTP.
- HyperText Transfer Protocol – this protocol defines how messages will be formatted and transmitted and forms the protocol used by the web. It also transmits a signal that determines what action the web servers and browsers will take in response to various client requests.
- Web-based Application Programming Interfaces (APIs) – these are software with defined functions that are open source and developers can customize to make use of the software's functionalities. Web-based APIs can be used to create plug-ins and to give mapping features additional features for instance search and querying tools. (Onchaga, 2008)

2.6.2 Web 2.0 technology

The internet consists of physical computing, network structure and standard protocols such as HTTP, Transmission Control Protocol/Internet Protocol (TCP/IP) and eXtensible Markup Language (XML). Software Oriented Architecture is a method for providing services from distributed computers where the result of the request is managed. SOA offers translation and management layer within the cloud architecture eliminating any restrictions to services required. SOA enables access to Web services over the internet. SOA is advantageous to developing software including web GIS as (i) it is capable of enabling communication with various services regardless of the coding language utilised, (ii) once the application component for an entity is developed it can be reused, (iii) it allows services to be recombined and integrated to meet institutional requirements. (iv) Furthermore, SOA can be used to classify applications created previously and avail them for use among various organisations. (https://www.w3schools.in/service-oriented-architecture/ accessed on 19th January 2019)

The OGC Geography Markup Language (GML) encoding standard outlines the when and where of data. It is an XML for expressing geographic features. Services such as Web Map Services and Web Feature Services are designed to read GML-encoded data. (Open GIS Consortium, 2015) With these capabilities available, the GIS industry has maximised on these technologies to develop distributed GIS. (Tait, 2004)

Asynchronous Javascript and XML (AJAX) is an interactive application development technology that increases the performance of browsers through the exchange of small packets of data with the server. It also enables compatibility with many languages and browsers such as PHP and Mozilla Firefox respectively, allows easy navigation between web pages and increased website response rates. (AJAX Developers Journal, 2017)

2.7 Geodatabase design

Data modelling for a geodatabase will make data analysis more efficient. Prerequisites for data modelling would include establishing user needs which therefore defines the purpose of the database. Thereafter the definition of the external model which constitutes the database objects and their relationships, formulation of a logical model and physical model need to be developed. UML language and CASE tool are useful for creating logical models. The physical model will be database with tables and the relationships between them. (Longley et al., 2005)

Generally most methodologies follow the process for creating a web GIS system:

```
┌─────────────────────────────┐
│  Conceptual Design/Needs     │
│        assessment            │
└─────────────────────────────┘
        ┌─────────────────────────────┐
        │       Logical Design         │
        └─────────────────────────────┘
                ┌─────────────────────────────┐
                │       Physical Design        │
                └─────────────────────────────┘
                        ┌─────────────────────────────┐
                        │       Implementation         │
                        └─────────────────────────────┘
                                ┌─────────────────────────────┐
                                │  On-going System Management  │
                                └─────────────────────────────┘
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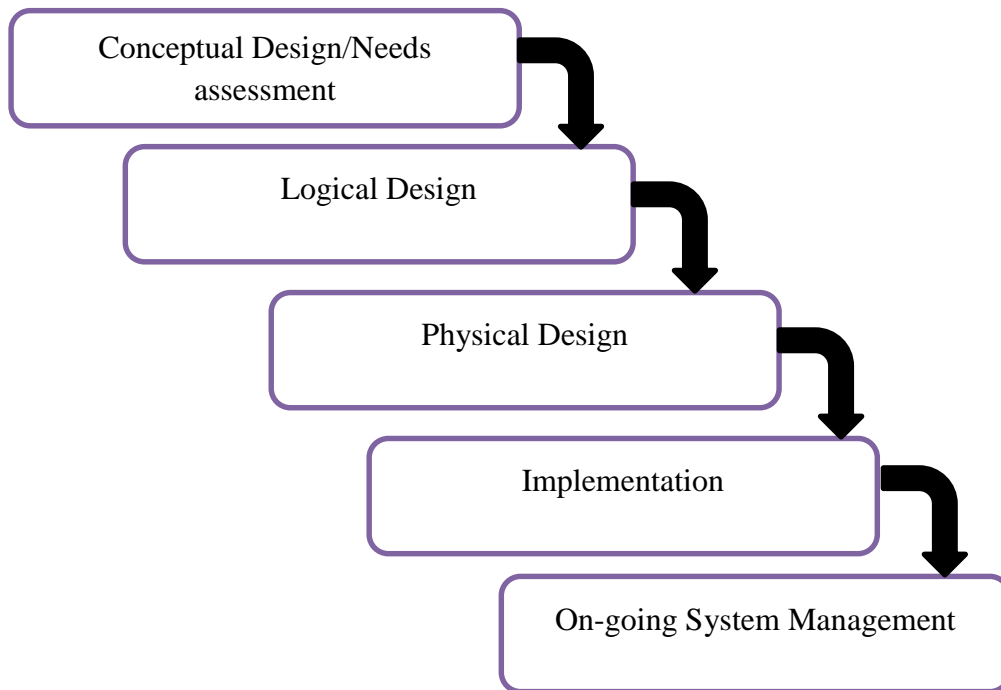
Figure 2.5: Web GIS system development Cycle adopted from (Ananda et al., 2016)

2.8   Web GIS in public agency data management

Under the Paris agreement all countries are responsible for monitoring, verification and reporting their greenhouse gas emission reductions. Governments will need to scale up their governance of this process and will need the most appropriate technologies to do so. (United Nations Framework Convention on Climate Change, 2015) Such technology could be web-based GIS as it offers additional functionalities to users who may have limited GIS background and resources. Below are international, regional and local case studies of web-GIS application in public sector for various types of sustainable development initiatives, the challenges they were attempting to overcome and the advantages.

   a) International application of Web-GIS

In America there are several geovisualization tools that are used by local governments, state departments, federal agencies, non-profit organizations and universities. The geo-tools have simple capabilities such as search and printing options. Majority of the geovisualisation applications make use of local government data which they have made available on the internet. The Environment Protection Agency of the United States has created NEPAssist (https://nepassisttool.epa.gov/nepassist/nepamap.aspx) which is a geovisualisation tool that uses

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the EPA database to allow users to review environmental issues related to a project. Another similar thin client application is the Census Data Mapper, a mapping tool offered by the US census bureau to display county population and housing information. These applications have successfully allowed users to perform geospatial queries and analyses without the need to download the data.

Z. Asligul et.al carried out a survey on users in public planning agencies within Wisconsin to determine what these applications are generally used for. They discovered 6% of web-GIS users use it for modelling and 31% for information access. They concluded that it was common for users to use the web GIS service for accessing and mapping current conditions. However, the authors noted a few barriers to web GIS adoption which included lack of awareness, funding, internet capabilities of the agencies, available hardware and software and poor tool performance for large files. However, the web GIS comes with several advantages because the data is easily available in one click, departments no longer have to duplicate efforts as they have access to the same data and improvement to administrative tasks. (Gocmen, 2016)

b) Regional application of Web-GIS

A geoportal for sustainable development datasets for Africa is searchable and accessible as was showcased during the 2002 World Summit on Sustainable Development. This data was provided by Africa GIS and Earth imaging professionals. The geoportal implements the OpenGIS Catalog Interface Implementation Specification and data is available in an array of formats covering the entire world. (Open GIS Consortium, 2004)

High cost and training in desktop GIS, inability to visualise health related spatial information and the need for real time data are some of the reasons that have prohibited the use of GIS in Zambian Public Health Management. (Mushonga et al., 2017) created a web-based GIS to enable the Ministry of Health to collect data from health facilities, encourage public participation and better decision making by the public health administrators. The system was designed to carry out spatial functions on the client side in order to minimise data traffic on the servers and browser. Some of the main GIS functionalities included in the web application were layer overlay, nearest neighbour search, routing, point buffering, geocoding and heat map generation. The GIS development process experienced a few challenges in technology and data transfer. Nevertheless, the project was successful in providing a tool for the monitoring and evaluation of health facilities which encouraged the development of a geoportal. (Mushonga et al., 2017)

c) Local application of Web-GIS

Within the Kenyan context a case study of web GIS application within the public sector, is a web geographic information system that was created for the Kenya Accountants and Secretaries National Examination Board (KASNEB). The system is purposed to monitor professional institutions for quality assurance with a bid to promote development in Kenya through quality education. KASNEB accredits training institutions. The web GIS enhances the accreditation system by offering visualisation services, cartographic classification, automation of manual processes. The application was designed by members of Dedan Kimathi University. (Ngunyi & Makokha, 2017) who carried out a user requirements survey, digitization of training institutions using Google Earth, database design in ArcGIS which culminated into an Accreditation Web App.

The Accreditation web app allows users to display data with contrasting symbols to distinguish between institutions. Pop-ups gave a summary of basic information on accreditation status of various institutions. The pop-ups were also linked to relevant attachments such as accreditation documents. The web app is accessible through laptop and mobile platforms and has simplified access to the accreditation process. The app was successful in highlighting the institutions and their spatial and non-spatial attributes in a concise and informative manner. Administration is able to integrate the application into other platforms including utilising the spatial advantage that the app offers them to carry out market research. KASNEB is able to develop strategic marketing strategies from the geospatial information and services offered by this app. (Ngunyi & Makokha, 2017)

3   MATERIALS AND METHODS

3.1   Area of study

Kenya is an East African country with a coastline along the Indian Ocean. It lies within the latitude/longitude bounding box 33.870914, -4.852348, 41.946724 and 5.462734. Its neighbouring countries are Tanzania to the south, Ethiopia to the North, Uganda to the west, South Sudan to the North West and Somalia to the North-East (https://www.britannica.com/place/Kenya accessed on 10th January, 2019). Kenya has a population of approximately 49 million people as of 2017, 4 million of whom reside in Nairobi, the capital city of the country. (Kenya National Bureau of Statistics, 2017)
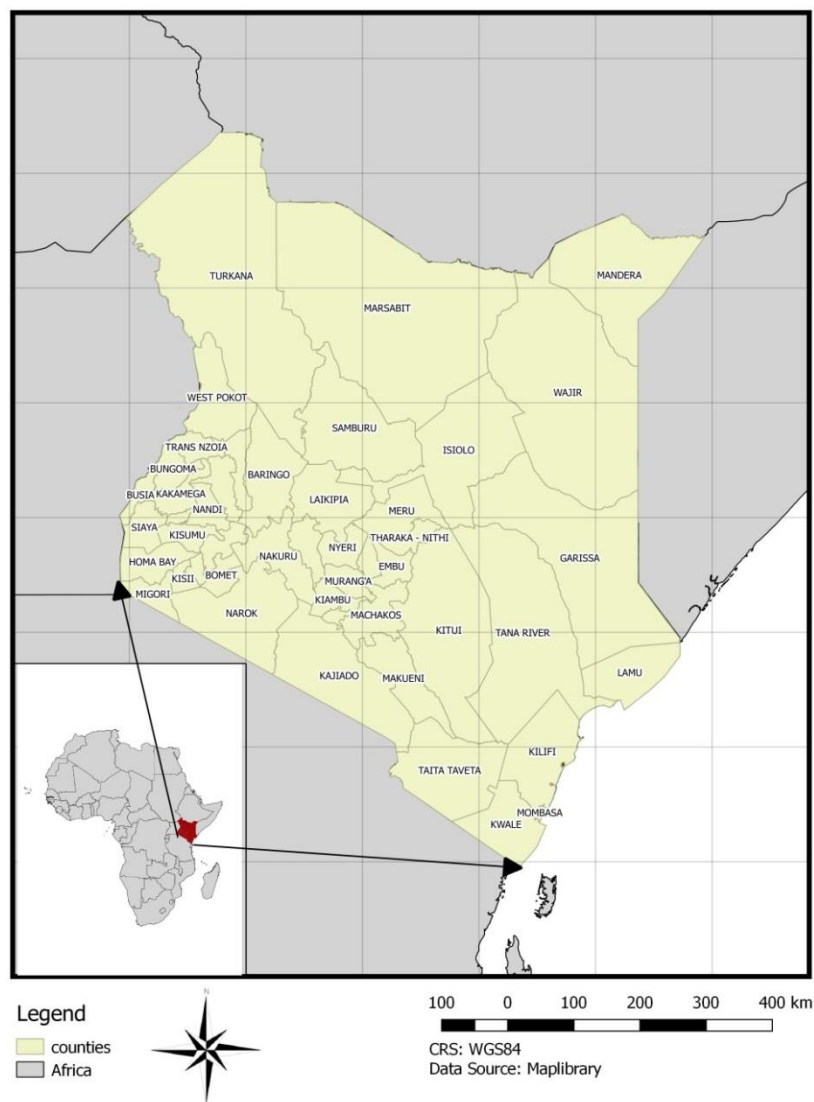
Figure 3.1: Study Area Map

The agricultural sector, tourism, manufacturing, transport and infrastructure, information and communication are the main contributors to the economy. (http://www.kenyarep-jp.com/business/key_sectors_e.html accessed on 10th January 2019)

3.2 Data sources and tools

3.2.1 Data sources

Data on sustainable projects in Kenya was gathered from the Clean Development Mechanism, NEMA and UNEP DTU that also keep records of CDM projects in Kenya. The correctness of the CDM information was assessed by comparing the 3 data sources with the CDM database from the Institute of Global Environmental Strategies (IGES) which implements further collaboration and analysis on this type of data. Additional data sources were added to complement the CDM GIS data. These included reference layers such as: county administrative boundaries, roads and protected areas data. These layers were obtained from various open source sites such as Survey of Kenya and World Resource Institute.

Table 3.1: Datasets used

Data	Type	Use	Source
Counties	Feature layer	Provide location reference for the CDM projects	ILRI
Major roads	Feature Layer	General Kenya road network	WRI, Survey of Kenya, KNBS
Protected areas	Feature Layer	National parks and game reserves	WRI, IUCN, UNEP, WRI, KNBS, ILRI
World map	Tile	Basemap	Openlayers

3.2.2 Tools

Software

Geoserver, PostgreSQL, Brackets, were used to handle the data as follows:

Table 3.2: Software

Software	Use	Source
Geoserver	Data storage	Geoserver
PostgreSQL	Data Querying	PostgreSQL Global Development Group
Brackets	Visualization tool design	Adobe Inc.
Microsoft Word	Project report writing	Microsoft
Microsoft Excel	Data collection and preparation	Microsoft
Microsoft Powerpoint	Presentation of project	Microsoft
QGIS	Desktop visualisation of data	OsGeo
Web-based visualization tool	Visualization of data from database	Openlayers

Hardware

The following devices were used to for data collection, processing and visualization

Table 3.3: Hardware

Hardware	Specifications
Laptop	HP 2GB RAM i3
Printer	HP laser printer
Memory Card	32GB
External Hard Drive	1TB

3.3   Methodology

Figure 3.2 is a flowchart giving an overview of the methodology.

```
┌─────────────────┐      ┌─────────────────┐      ┌─────────────────────┐
│      DATA       │ ───> │      DATA       │ ───> │ COMBINING SPATIAL   │
│ IDENTIFICATION  │      │   EXTRACTION    │      │  AND NON-SPATIAL    │
│                 │      │                 │      │       DATA          │
└─────────────────┘      └─────────────────┘      └─────────────────────┘
                                                            │
                                                            v
┌─────────────────┐      ┌─────────────────┐      ┌─────────────────────┐
│    CREATING     │      │   INSTALL AND   │      │ DESIGNING DATABASE- │
│  SERVER AND     │ <─── │  CONFIGURATION  │ <─── │      EXTERNAL,      │
│   DATABASE      │      │  OF POSTGRESQL  │      │  CONCEPTUAL AND     │
│                 │      │                 │      │ PHYSICAL MODELING   │
└─────────────────┘      └─────────────────┘      └─────────────────────┘
        │
        v
┌─────────────────┐      ┌─────────────────┐      ┌─────────────────────┐
│ IMPORTING DATA  │      │   INSTALL AND   │      │    IMPORTING &      │
│ INTO DATABASE   │ ───> │  CONFIGURATION  │ ───> │ PUBLISHING DATA IN  │
│                 │      │  OF GEOSERVER   │      │     GEOSERVER       │
└─────────────────┘      └─────────────────┘      └─────────────────────┘
                                                            │
                                                            v
┌─────────────────┐      ┌─────────────────┐      ┌─────────────────────┐
│ POPULATING THE  │      │  DESIGNING THE  │      │                     │
│ GEOVISUALIZATION│ <─── │ FUNCTIONALITIES │ <─── │    INSTALLING       │
│     TOOL        │      │     OF THE      │      │    JAVASCRIPT       │
│                 │      │ INTERACTIVE MAP │      │     LIBRARY         │
└─────────────────┘      └─────────────────┘      └─────────────────────┘
```
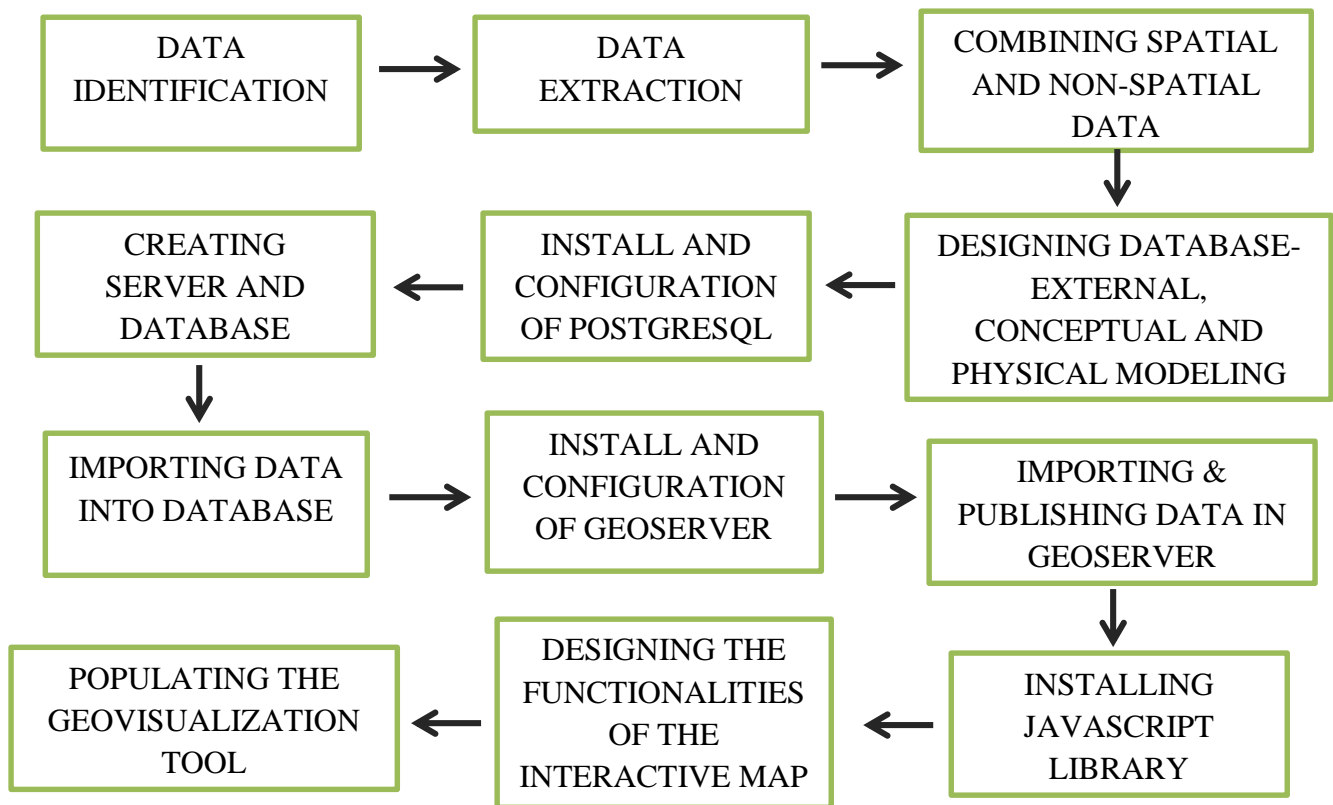
Figure 3.2: Overview of the methodology used

The methodology above involved the identification of CDM projects from various UN sources. The spatial data was extracted from each of the 67 project profiles which are in pdf format. The spatial and non-spatial datasets were combined in a csv file. An object relational database was designed which entailed carrying out a user needs assessment, developing external, conceptual, logical and physical models of the database. Thereafter, PostgreSQL was installed and configured. A PostgreSQL server was created and included a "CDM" database with public schema. The csv and reference layers were imported into the "CDM" database. Geoserver was installed and configured and an account was created online. The views created in PostgreSQL were uploaded into Geoserver where they were published along with the reference layers. Openlayers 2 Javascript library was downloaded in order to design the functions of the map. HTML, CSS and the JavaScript library were used to design the layout and controls of the web-based GIS platform. The code was also used to populate the web-based geovisualization tool. The materials and methods shall be discussed in greater detail in the sub-chapters below.

3.3.1 Data collection

A folder for all the CDM files was created on the desktop. Data on the clean development mechanism projects was obtained from the UNFCCC website. It consisted of a compilation of data from both UNFCCC and UNEP DTU that maintain CDM datasets. Examining the spreadsheets a unique project identifier is assigned to each project. This identifier was used to search for the design documents for each project. Searching through them latitude and longitude data was extracted. The spatial data was inserted into the spreadsheet to generate a CDM project csv. The CDM data was collected from secondary sources.

3.3.2 Creating a GIS database for clean development mechanism projects

The GIS database followed the ANSI-SPARC design methodology (American National Standards Institute – Standards Planning and Requirements Committee). The methodology to create the CDM database followed the general outline below:

External modelling entails establishing the possible users of the database and the information they will require. This stage is also used to determine user needs assessment.

Potential users were identified to be mainly government and private sector in particular the Ministry of Environment and for private sector were project developers.

A user needs assessment was done through an informal consultation with the Ministry of Environment since they are the agency leading and coordinating CDM project implementation in Kenya. Therefore, their needs were given first priority. It was established that there was a previous initiative by the DNA to visualise CDM projects. However, the previous web map showed a simplified map of the general location and name of the project. Therefore, they recommended the inclusion of more detailed project information such as its start date, credits generated among other attributes.

The selected attributes were determined from the user needs assessment and from the available ArcGIS Carbon Footprint data model that suggests the attributes to be visualised with regards to greenhouse gas projects. Specifically the FEMP Projects schema was used to determine the attributes.

Programs	Feature Dataset that contains summary level Program/Project information

FEMPProject	Federal Energy Management Amendments Program Point Locations
ProjectNumber	Project Number
ProjectName	Name
ProjectType	FEMP Energy Conservation Measures Type
Description	Description of Project
CurrentUse	Current Energy Consumption
CurrUseUnits	Energy Consumption Use Units of Measure
CurrUsePeriod	Energy Consumption Use Period
UseCostConversion	Multiply CurrentUse by this number to obtain Cost in Dollars for Period
YearPlanned	Year the Project is planned to be conducted
DateCompleted	Date of Project completion
EstCost	Estimated Project Cost
ActCost	Actual Project Cost
CostUnits	Cost Measurement Units
EstSavings	Estimated Energy Savings
ActSavings	Actual Energy Savings
SavingsUnits	Savings Measurement Units

Figure 3.3: ArcGIS Carbon Footprint-FEMP Project data model
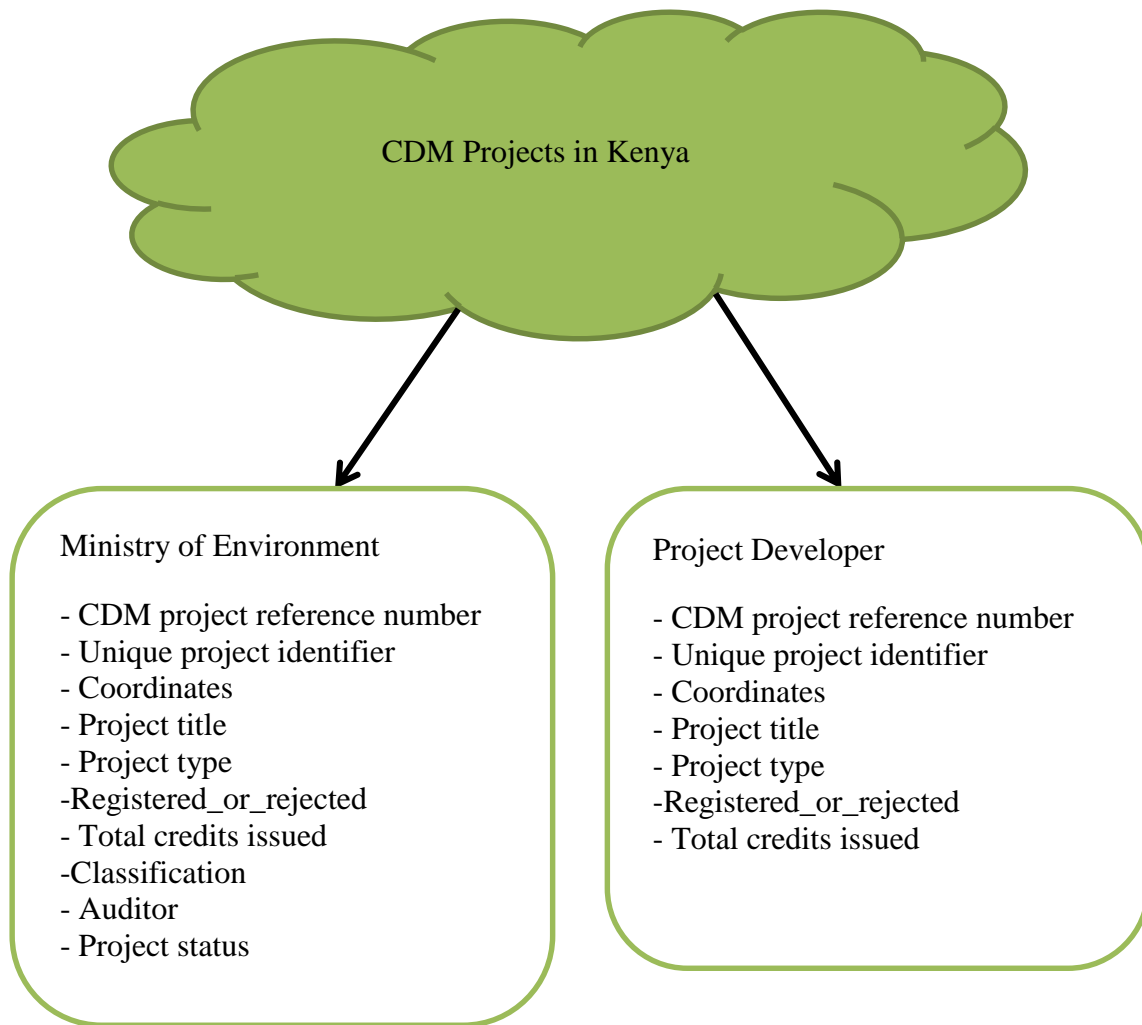
Figure 3.4: External model

Conceptual modelling involves the linking of the external models through an entity-relationship diagram that visualises all the relevant users, their attributes and relationships. An Entity-Relationship (E-R) model was developed.
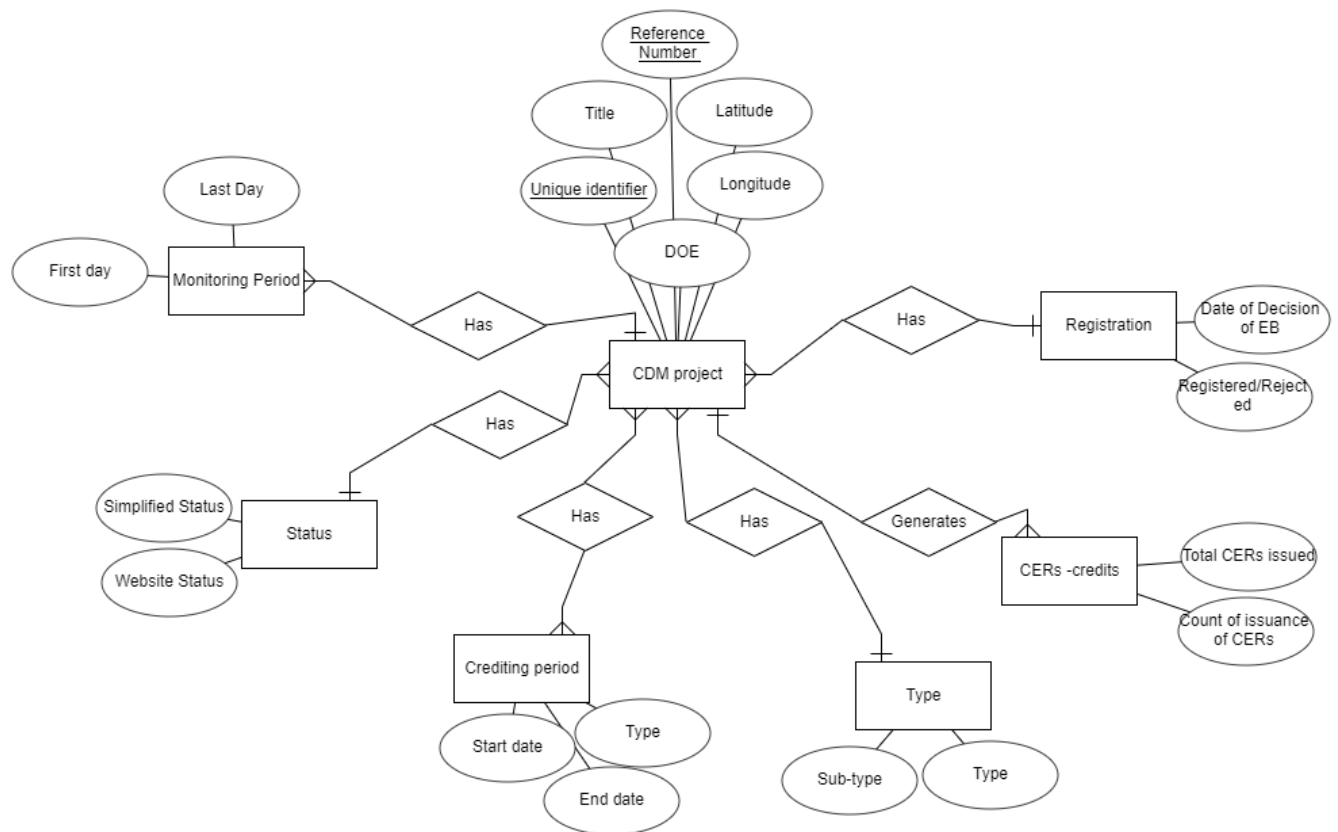
Figure 3.5: Conceptual model for CDM projects

Logical modelling is the design and normalisation of the relations. The relations were analysed to ensure that they conform to the normalization principles. It also involves pairing object types with the specific data types that the geodatabase supports. (Longley, et.al, 2005)

Since the design of the database will be object relational, the logical model will be in the Unified Language Model (UML). The logical model is hardware independent but software dependent.
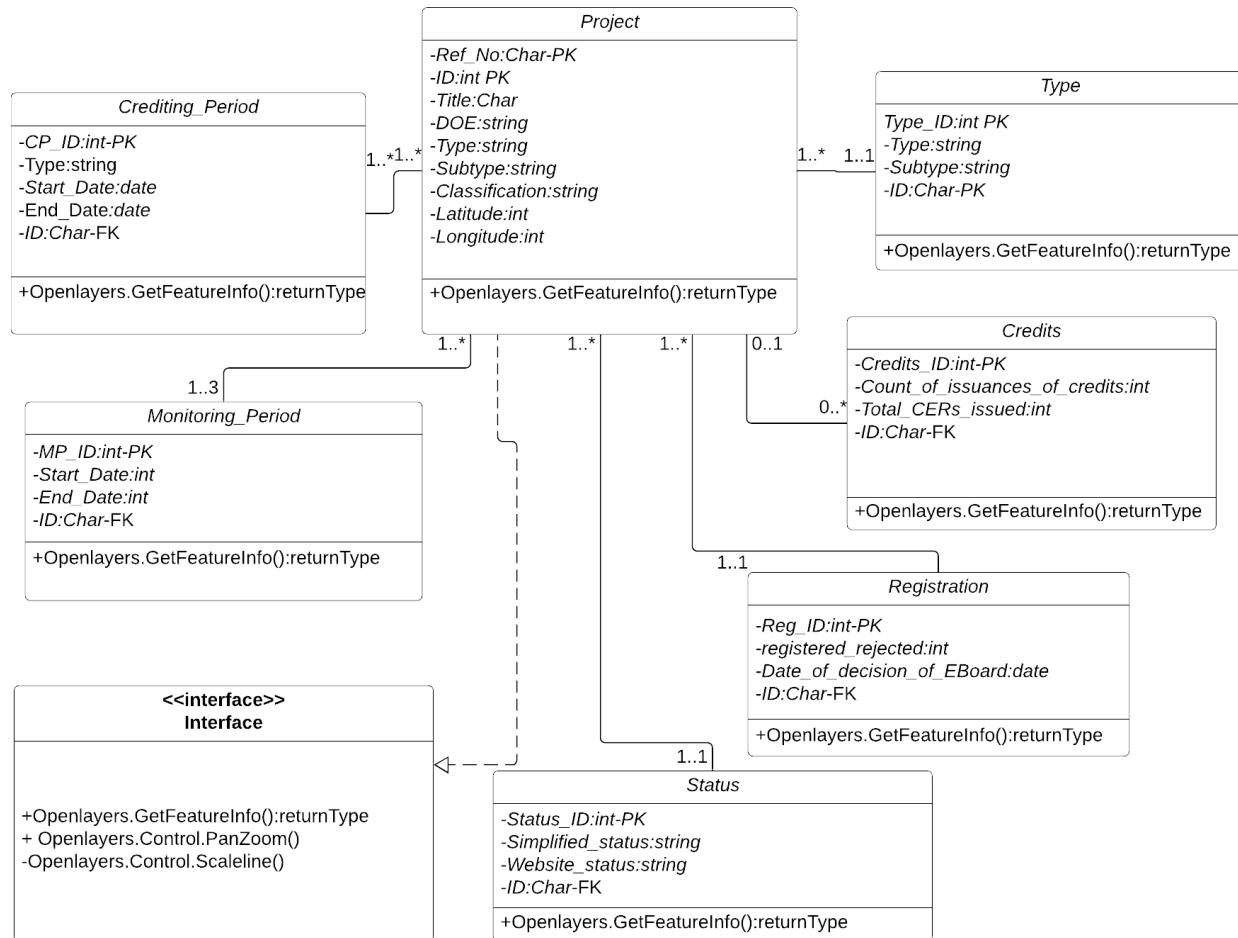
Figure 3.6: UML logical model

Below are the entities that were identified to generate schemas for the logical model: CDM Project, Certified Emission Reductions, Status, Crediting Period, Registration, Type and Monitoring Period.

Certified Emission Reductions (CERs) [Unique_ID, Count_of_issuance_of_CERs, Amount_ex_ante, Total_CERs_issued…]

Status [Unique_ID, simplified_status, website_status…]

Crediting Period [Unique_ID, Start_date, End_date, type…]

Registration [Unique_ID, registered_rejected, Date_of_Decision_of_EB…]

Monitoring Period [Unique_ID, First_day, Last_Day,MP_ID…]

CDM Project [Unique_ID, Reference_number, Title, DOE, Latitude, Longitude…]

Type [Unique_ID, Type, Subtype,]

Physical modelling will determine how the data will be stored. (Longley, et.al, 2005) A data model was built off the ArcGIS Carbon Footprint. The data was initially visualised and manipulated on QGIS. The data model guided the structure of the schema with regards to the most ideal data types to use. PostgreSQL was used to develop the database which was connected to Geoserver that also hosted layers for the interactive map.

Table 3.4: ArcGIS Carbon Footprint FEMP project information data model

Fields				
FieldName	**Type**	**Length**	**Description**	**AliasName**
ProjectNumber	String	50	Project Number	Project number
ProjectName	String	100	Name	Project Name
ProjectType	String	100	FEMP Energy Conservation Measures Type	Project Type
Description	String	255	Description of Project	Description
CurrentUse	Double	8	Current Energy Consumption	Current Consumption
CurrUseUnits	String	30	Energy Consumption Use Units of Measure	Consumption Units
CurrUsePeriod	String	30	Energy Consumption Use Period	Consumption Period
UseCostConversion	Double	8	Multiply CurrentUse by this number to obtain Cost in Dollars for Period	Cost Conversion
YearPlanned	Integer	4	Year the Project is planned to be conducted	Year Planned
DateCompleted	Date	8	Date of Project completion	Date Completed
EstCost	Double	8	Estimated Project Cost	Estimated Cost

ActCost	Double	8	Actual Project Cost	Actual Cost
CostUnits	String	30	Cost Measurement Units	Cost Units
EstSavings	Double	8	Estimated Energy Savings	Estimated Savings
ActSavings	Double	8	Actual Energy Savings	Actual Savings
SavingsUnits	String	30	Savings Measurement Units	Savings Units

3.3.3 Developing a web based GIS platform for clean development mechanism projects

PostgreSQL and Geoserver are the main software that was used to create the web-based GIS platform for the clean development mechanism projects. PostgreSQL was installed and configured. A new database "CDM" was created in a PostgreSQL server. The CDM project csv and reference layers were first visualized in QGIS to determine whether the data would appear on the map. New tables were created in the CDM Postgres database. The data from the csv files was then imported into the new tables. The reference layers (major roads, protected areas and counties) were uploaded into PostgreSQL using the DBF shapefile loader since the layers were in shapefile format.

Geoserver was also installed. A workspace and store were developed for the project data. Workspace organizes similar data layers within a container. (https://docs.geoserver.org/stable/en/user/data/webadmin/workspaces.html accessed 15th March 2019) The store provides Geoserver the connection to the data source (Geoserver) in this case PostgreSQL. The CDM project data and the reference layers were all added into the same workspace. The visualization style was set in Geoserver and assigned to each respective layer. Thereafter, the layers were published in the WGS84 coordinate reference system. The bounding box for each layer was automatically computed from the layer attributes.

HTML and CSS were used to set up the webpage for the geovisualization tool. The Openlayers Javascript library was used to design the functionalities of the map. Openlayers library was downloaded from the Openlayers website and added to folder containing the CDM data.

3.3.4 Populating the web-based GIS platform

An Openlayers tile was used as the basemap.

The CDM and reference layers were added to the web-map as WMS. This was achieved through the JavaScript code.

4 RESULTS AND DISCUSSIONS

4.1 Introduction

The chapter covers the results from the designed geovisualization tool for CDM projects in Kenya. This is followed by a discussion on the same.

4.2 Clean Development Mechanism projects in Kenya

Data extraction and compilation of resulted in the identification of 67 CDM projects within the country. These projects in Kenya are at various stages of development. Each of them has been assigned an auditor, a unique Google identifier and Title. 23 of them have not been assigned a reference number. This is either due to being invalid or undergoing public validation.

Registration and status - 44 projects are registered, 5 are undergoing public validation, 1 project has had its validation replaced and 17 projects have had their validation terminated. Majority of the projects (65%) have therefore undergone registration.
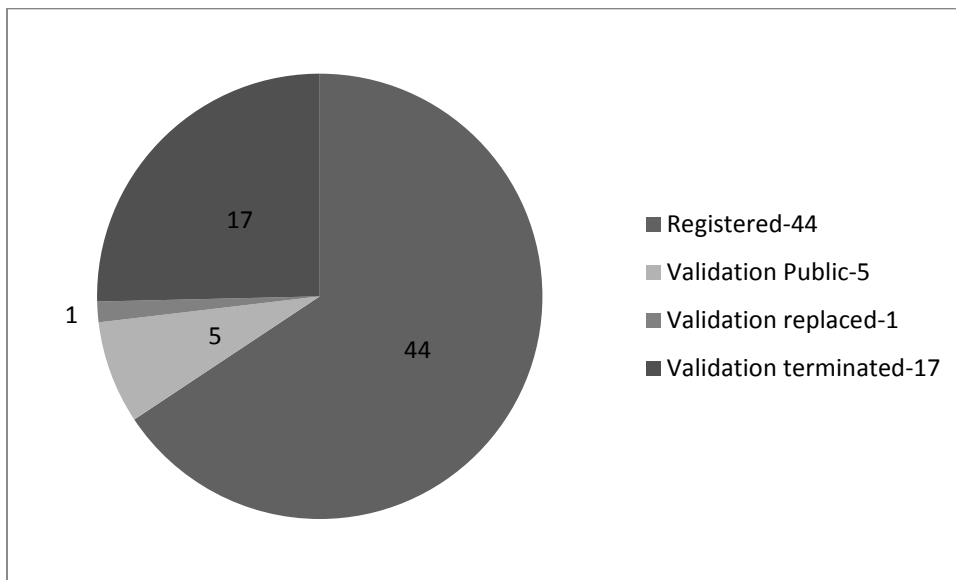
Figure 4.1: Status of CDM projects

Classification by Size - 28 projects can be classified as being "Large" and 39 as "Small". Projects are classified as large or small dependent on the scale of activities or credits they intend to generate. (UNFCCC, 2011) An example, from the projects is Lake Turkana Wind project as the largest registered CDM project.
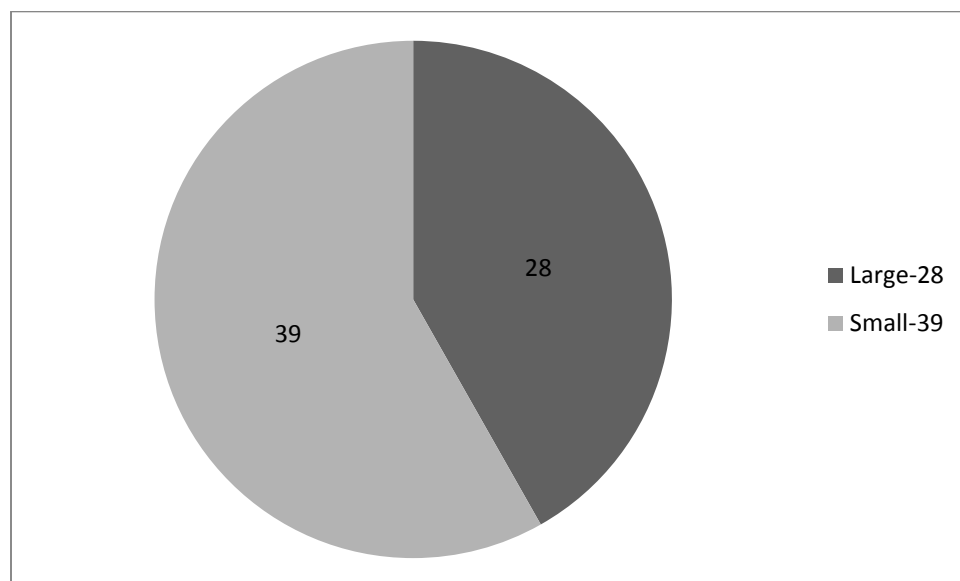
Figure 4.2: Number of projects per classification of CDM project size

Crediting period - 8 projects have a fixed crediting period, 44 can have their crediting periods renewed, whereas 15 have not been assigned a type of crediting period in which they can reduce carbon emissions. This is due to not being registered yet. A fixed crediting period runs for 10 years whereas a renewable crediting period is 21 years. (UNFCCC, 2011) More projects have the renewable type of crediting period enabling them to secure a longer duration to reduce greenhouse gas emissions.
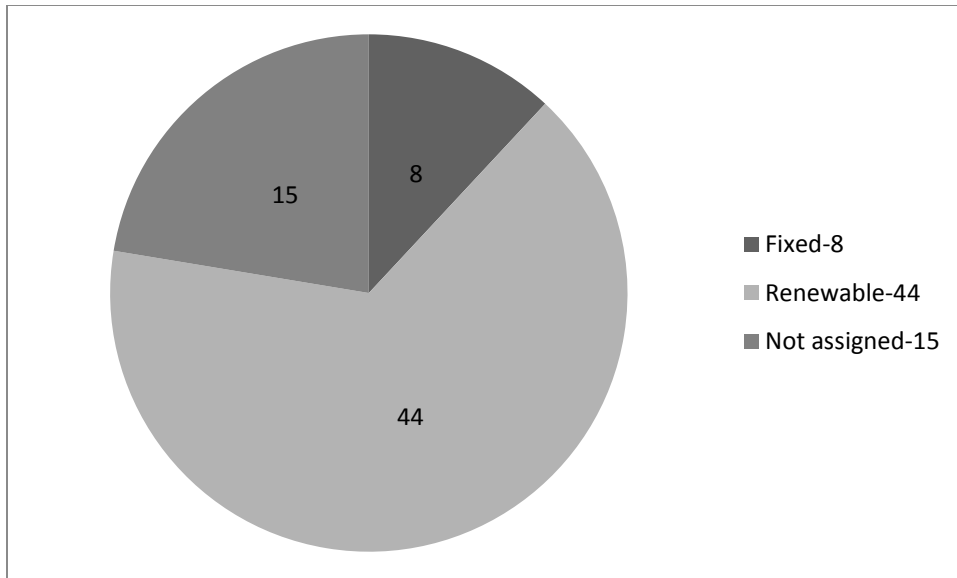
Figure 4.3: Number of CDM projects per category of crediting periods

Start dates - The start dates for the CDM projects range between 2008 and 2018. The earliest project began in 2008 which was "35 MW Bagasse Based Cogeneration Project by Mumias Sugar Company Limited". 46 of the 67 projects started after 2011 with 31 of them starting in 2012 alone. This appears to be in line with the trend of registration as highlighted in the literature review. The projects so far have end dates set between 2017 and 2041. The project appears to end in 2041 is "Restoration of Degraded Lands through Reforestation in Aberdare Forest Complex & National Park area, Kenya".

Monitoring period – Only 9 projects have start and end dates for their monitoring periods.

Generation of credits - 56 projects are yet to generate credits. The remaining 11 can be classified into 4 groups:

- 3 generated between approximately 2500 – 8300 credits
- 2 generated between 18,300 and 18,600 credits
- 2 projects 47,000 – 51,000 credits and
- 4 project have generated credits between 117,000 – 346,000

The project that has generated the most credits at 345628, is Olkaria II Geothermal Expansion Project located in Nakuru county (-0.891388000000000, 36.295833000000002). However, the trends show that most CDM projects have not been successful in generating carbon credits.

Type – There are 8 biomass projects, 1 cement, 12 energy efficient household projects, 1 energy efficient industry projects, 3 energy efficient service, 1 energy efficient supply side, 1 energy distribution, 6 geothermal, 5 hybrid renewables (combination of solar, wind, hydro and another energy type), 4 hydro, 3 methane avoidance, 10 reforestation, 6 solar and 6 wind projects. Reforestation and energy efficient household projects are seen to be the most common type of projects and mostly located around Mt Kenya National Park in Meru. These projects are mostly focused on providing an alternate source of energy for cooking as opposed to firewood.

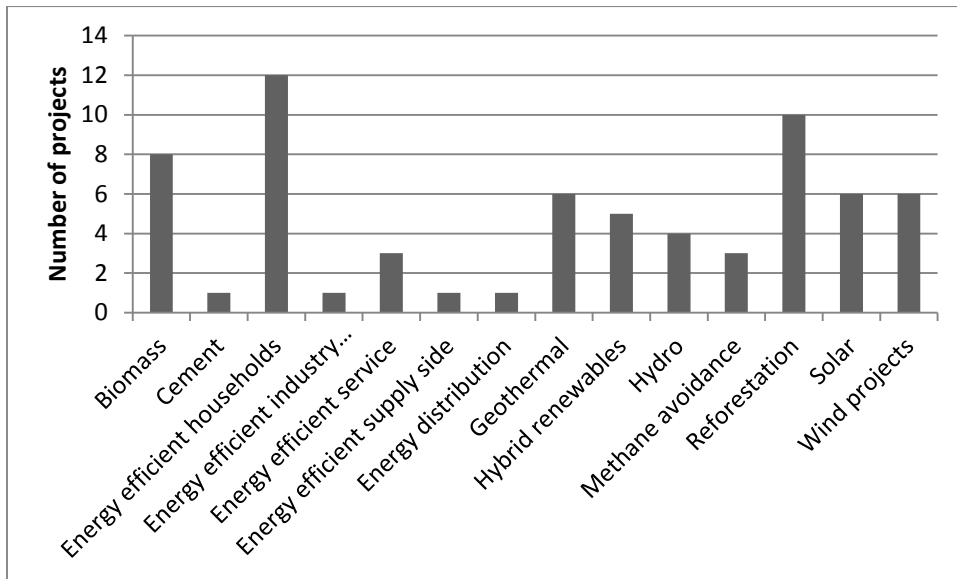**Figure 4.4: Types of CDM projects**

Observing the spatial distribution on the map, it appears that most of the CDM projects are located in Meru and Nakuru counties with 8 projects each and Kajiado and Samburu counties with 4. On average each county has at least 1 project. The projects are also in close proximity protected areas and the major roads hence justifying the selection of the 2 reference layers.
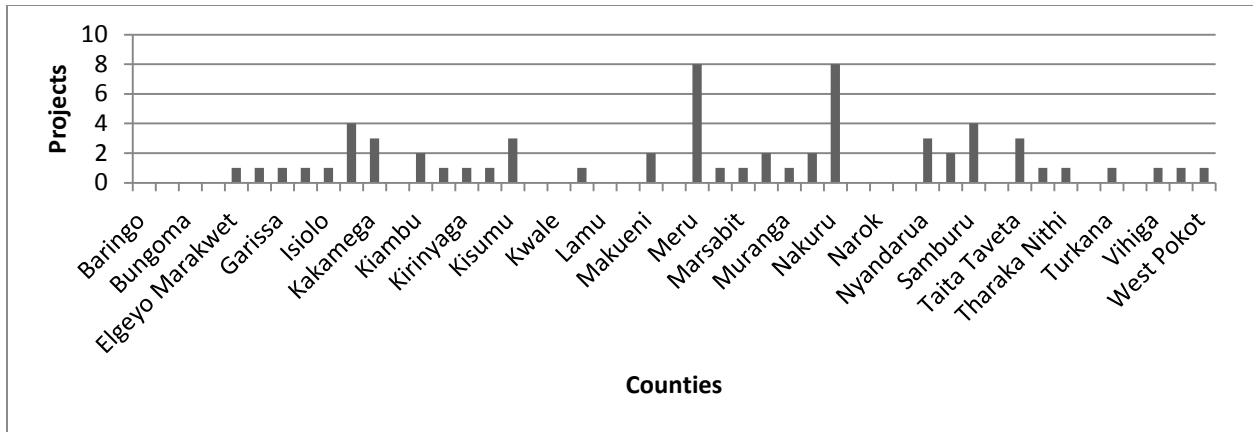
Figure 4.5: Number of projects per county

Challenge: Some of the documents only provide a general location of the project e.g." the project is located or will be in Kenya". 9 projects have not been assigned coordinates as their location in Kenya is yet to be determined.

The main trends in the CDM data show that 65% of the projects in Kenya have been registered but only 17% of the registered projects have generated credits. The most common types of projects are small in scale (58.2%). Majority of the projects are focused on improving efficiency in household energy use and reforestation activities within the forested parts of Kenya at 32.8%.

4.3   GIS database for the Clean Development Mechanism projects

An object-relational database was designed. It provides the capability of querying the CDM data relations to develop tailored views. To obtain the "project developer" and the "Ministry of Environment" view, the tables were queried in PostgreSQL as follows:

Project developer view

CREATE VIEW projdev_cdm_view AS

SELECT   cdm_projects.ref_no,   cdm_projects.uniq_id   AS   "id",   cdm_projects.title, cdm_projects.latitude,   cdm_projects.longitude,   cdm_projects.geom,, cdm_registration.Registered_or_rejected, cdm_credits.Total_CERs_Issued, cdm_type.type

FROM cdm_projects

INNER JOIN cdm_registration USING (uniq_id)

INNER JOIN cdm_credits USING (uniq_id)

INNER JOIN cdm_type.USING (uniq_id);

Ministry of Environment view

CREATE VIEW moe_cdm_view AS

SELECT

cdm_projects.ref_no, cdm_projects.uniq_id AS "id", cdm_projects.title, cdm_projects.classification, cdm_projects.doe, cdm_projects.latitude, cdm_projects.longitude, cdm_projects.geom, cdm_status.Simplified_Status

FROM cdm_projects WHERE cdm_projects.uniq_id = cdm_status.uniq_id;

The resulting views are shown in the Appendix.

4.4 Functionalities of the Web-based GIS platform for Clean Development Mechanism Projects

A web-based platform was designed with the Openlayers library and contains the following functionalities:

Overlay tool
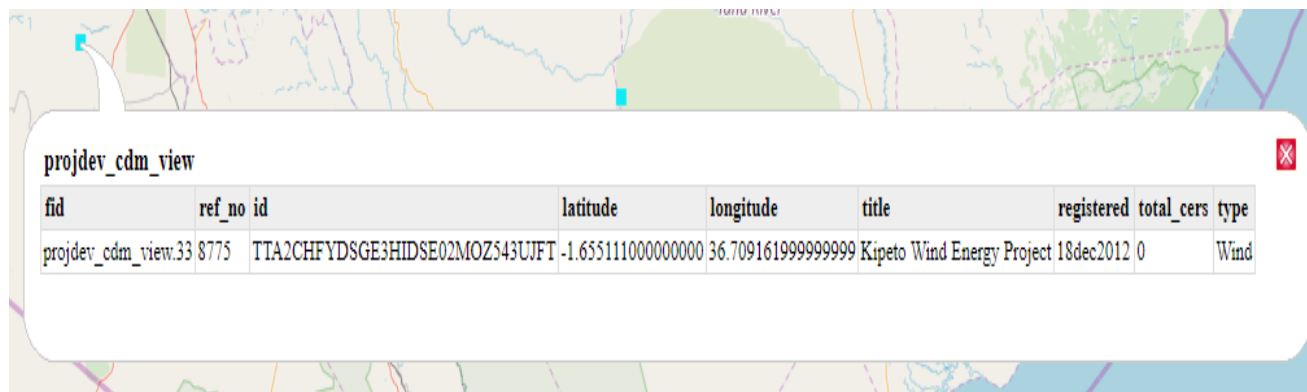
Figure 4.6: Overlay menu

The overlayer tool displays all the layers that were used to design the map. An OpenStreetMap tile was used as the basemap. The operational layers are the 2 CDM projects layers, counties,

major roads and protected areas. The counties layer has labels for ease of identification. Users can toggle the layers by switching them on and off to view the CDM projects in spatial reference to any of the reference layers.

Pop up query

Figure 4.7: Pop up query

The information on each individual CDM project can be queried by clicking the layer. The attribute table is displayed in a pop-up as per the project developer and Ministry of Environment user needs. The attribute "ID" in the popup can be copied into the web browser search bar. This ID is a unique Google identifier and directs the map user to the UNFCCC website where all the relevant and more detailed information about the project can be found. Such detailed information includes the project design, the methodology it uses and the amount of credits it has generated as illustrated in Figure 4.11.

Home | CDM | JI | CC:iNet | TT:Clear

CDM glossary | Sitemap | FAQ | Contact us | Disclaimer | Extranet | My CDM / Login | Join

Your location: Home > Project Search

21:43 27 Apr 19

Project 8775 : Kipeto Wind Energy Project

Project title	Kipeto Wind Energy Project - project design document (4802 KB) PDD appendices Appendix 1 - Kipeto Emission Reduction Calculation v3.3 (2757 KB) Appendix 2 - Kipeto Investment Analysis v03.2 (249 KB) - registration request form (133 KB)
SDC description report	Not Available. Please refer to our Further Information on SD-Tool
Host Parties	Kenya , involved indirectly approval (1222 KB) authorization (1222 KB) Authorized Participants: Kipeto Energy Limited
Other Parties Involved	n/a
Sectoral scopes	1 : Energy industries (renewable - / non-renewable sources)
Activity Scale	LARGE
Methodologies Used	ACM0002 ver. 13 - Consolidated baseline methodology for grid-connected electricity generation from renewable sources
Standardized baselines used	N/A
Amount of Reductions	254,125 metric tonnes CO2 equivalent per annum
Fee level	USD 49325.0
Validation Report	VVS/VVM version: VVS 3.0 Validation report (848 KB) Public availability information Link to information uploaded for public availability
Modalities of Communication	MoC Annex 1 Modalities of Communication valid as of 04/07/2013

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  Issuance of CERs
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Stakeholder Interaction
Newsroom

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Figure 4.8: Example of project page on UNFCCC website (UNFCCC)

Inset map
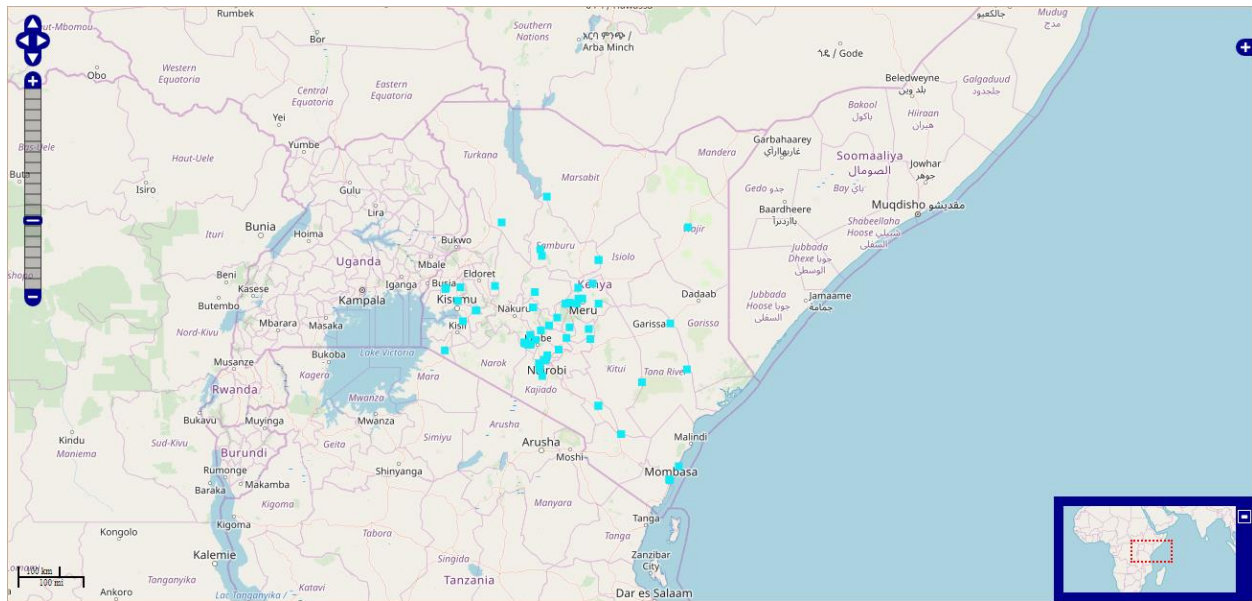
Figure 4.9: Inset map

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The inset map offers the functionality of viewing the CDM projects within a wider geographical context. It automatically adjusts depending on the panning and zooming of the map user.

Other interactive tools available on the web-based GIS platform are the coordinates, scale, pan and zoom functions.

4.5 Clean Development Mechanism Projects data in web-based GIS platform

Data can be viewed either in "Project Developer" view or the "Ministry of Environment" view which appear as blue and orange points respectively in the web map. Table 4.1 shows the distinction between the 2 views. This is due to varying user needs between public and private sector.

Table 4.1: Difference between project developer view and Ministry of Environment view

Project Developer	Ministry of Environment
Reference Number	Reference Number
ID	ID
Latitude	Latitude
Longitude	Longitude
Title	Title
Registered/Rejected	Registered/Rejected
Total credits issued (CERs)	Total credits issued (CERs)
Type of CDM project	Type of CDM project
	Classification
	Project status

The resulting views were added to the web-based GIS platform as evidenced in Figures 4.6 to 4.8. Major roads, protected areas and a counties layer were added to give the views spatial context.

Figure 4.10: Project Developer view of CDM projects

Figure 4.11: Ministry of Environment view of CDM projects

Figure 4.12: General view of CDM projects with overlays

4.6   Discussion of the results

The specific objectives of the project were to identify the clean development projects in Kenya, create a database for these projects, develop a web-based GIS platform for the CDM projects and populate the web-based GIS platform with the CDM projects. Previous a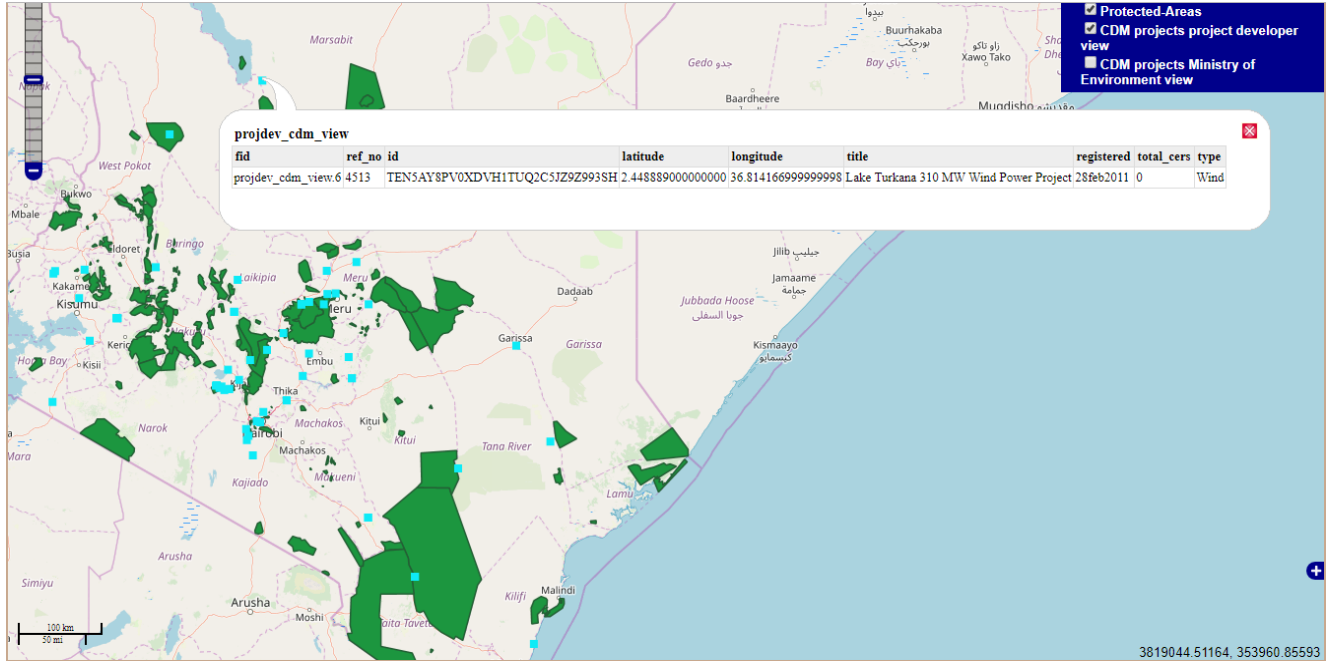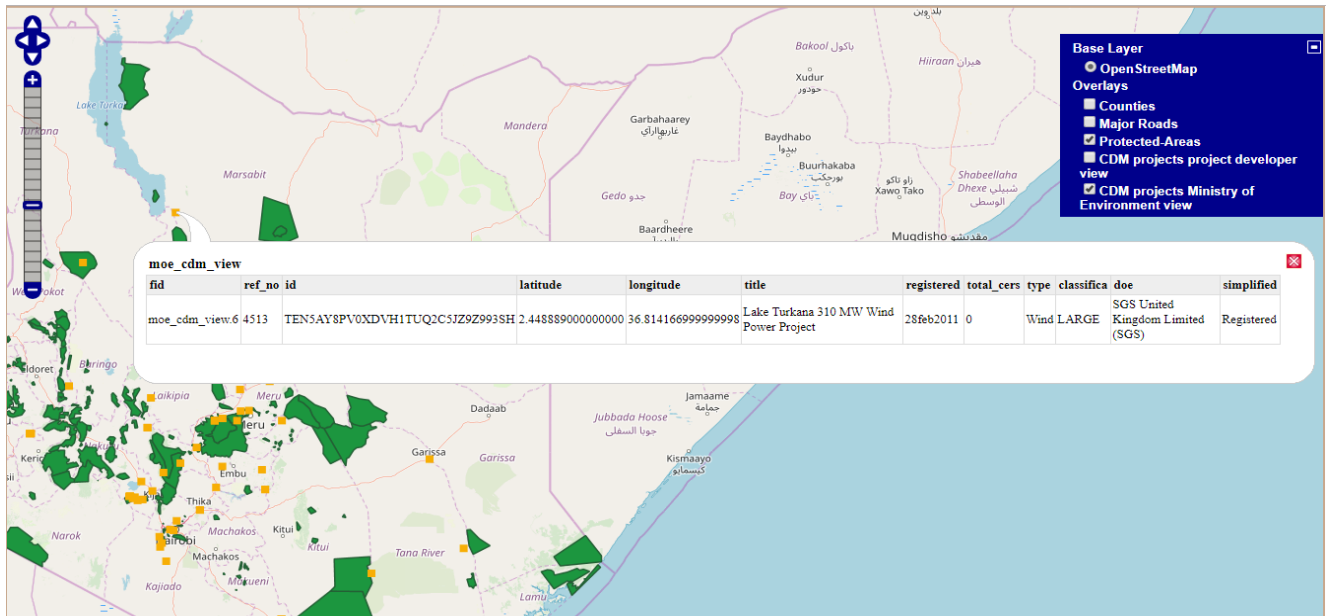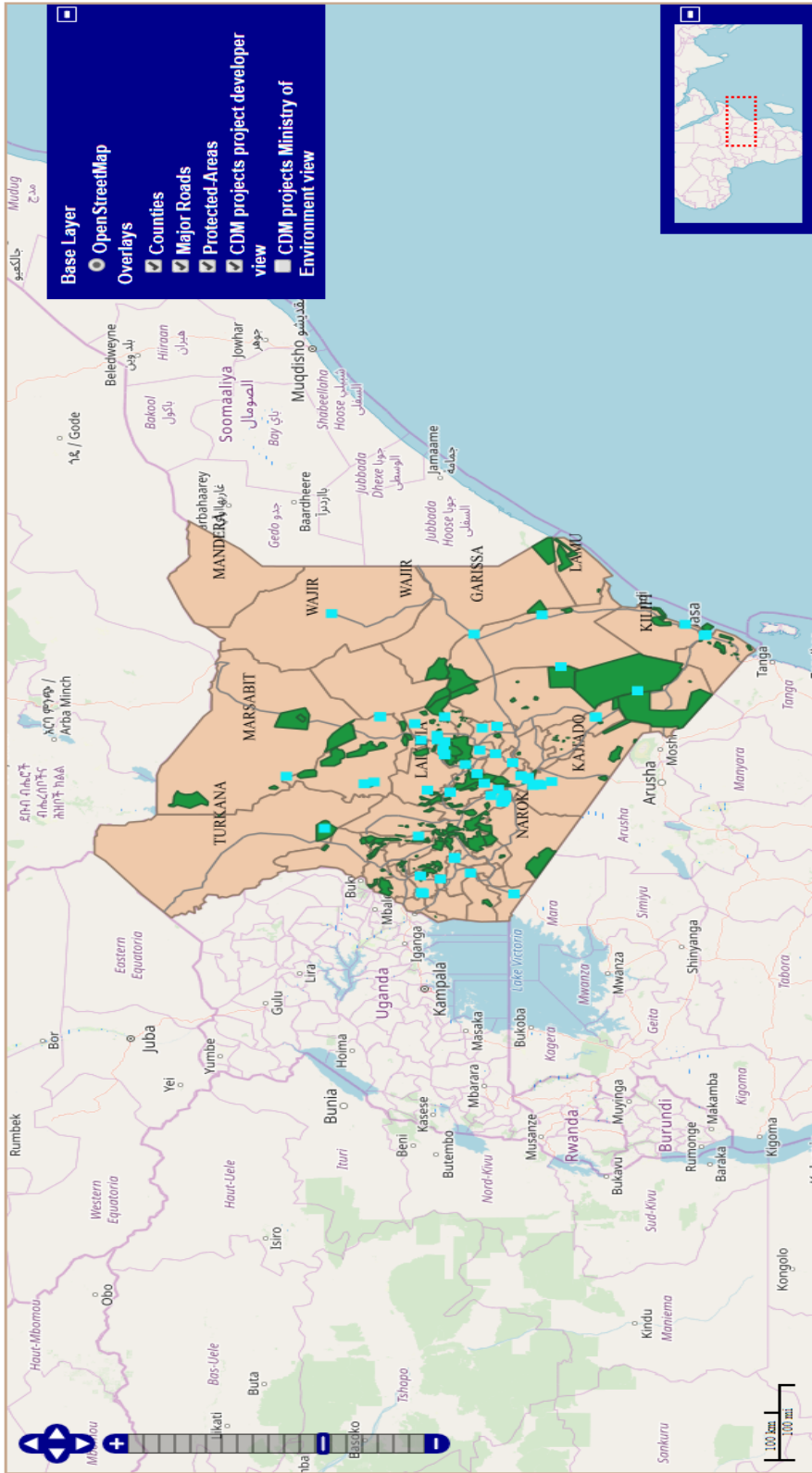ttempts to display the Kenyan CDM projects only provided their general location and titles. The geovisualization tool created provides more information about these projects in a brief, efficient and effective manner that caters to project developers and the Ministry of Environment.

The CDM projects were identified and trends in their characteristics were analysed. In addition, their coordinates were extracted and combined to generate GIS data. Therefore, the project has enabled the access to geospatial CDM data which the public and private sector can utilise to generate more detailed models. Previous studies on CDM project were focused on analysing and visualizing the project document text. However, this project has generated more quantitative data that can complement the earlier study methods.

The utilisation of part of the ArcGIS Carbon Footprint data model assisted in the selection of the most appropriate attributes for the CDM projects and helped validate the user needs. It also guided the design of a more effective database. An object relational database for the projects enables the classification, querying and presentation of the most relevant spatial and non-spatial information. The database provides the ability to further refine the data for other kinds of users.

Deployment of the system over the web allows more users to access the data. The web-map on the UNFCCC website only indicates the location and number of projects. However, the platform created in this research project highlights about 10 project attributes which also includes an ID that can be copied into a browser to access all the project data. This platform can also be reused and replicated for other sustainability mapping as the source code is made available in the Appendix section.

Geospatial data on the manmade (CDM projects, roads, administrative boundaries) and natural environments (protected areas) has been combined exposing the spatial relationships between the two. According to the Open Geospatial Consortium this kind of sustainable development mapping is lacking and is viewed as essential. Sustainability will be dependent on technology use and data integration between domains focused on the environment. The project has identified

that gap and created a solution in form of web-based GIS platform that is populated with greenhouse gas information to support sustainability.

5   CONCLUSIONS AND RECOMMENDATIONS

5.1   Conclusions

The project was successful in developing a geovisualisation tool for Clean Development Mechanism projects in the following aspects:

- The development of the web-GIS platform for CDM projects has enabled access to the project profiles in a central location. This is due to combination of spatial and non-spatial data on CDM projects. Therefore a spatial component has enabled the mapping of CDM projects while simultaneously providing access to more detailed project information.

- Developing an object relational database has enabled more effective querying of spatial and non-spatial data to create different views. In this case the information was tailored to suit the relevant data the Ministry of Environment and project developers may require in order to support their roles. The views were developed as 2 layers that have a pop-up functionality.

- Creation of the visualisation tool has provided public and private sector players a means to understand the distribution of projects. Users are able to identify spatial trends at county level and country levels. This information can be used to for strategic planning of future CDM and other sustainable development projects.

- The general public is also able to access data on sustainable greenhouse gas reducing projects in an interactive manner through query pop-ups.

- The development of the web-based GIS platform will be beneficial in supporting smarter and well-informed decisions on climate change in Kenya. It can also assist the Kenyan government to monitor, verify and report on their greenhouse gas emissions.

5.2   Recommendations

In order to improve the policy decision-making of sustainable projects such as the CDM, the project would recommend:

- Utilisation of more web-based geospatial tools to understand the spatial aspects of sustainable projects especially one which can include search addresses. This would especially useful for the government and private developers who are the most involved in these projects.

- The platform is available via desktop. Further studies need to be undertaken to make the web-GIS platform for CDM accessible via other mobile platforms as a step towards improving data access. Government agencies can therefore maximise on these platforms and raise awareness GIS and sustainable development.

- Additional research is suggested to discover a means to automate the addition or removal of projects from the database.

- Further research can be done to develop more customized data models for sustainable mapping.

- More geospatial information needs to be generated on the sustainable projects such as CDM which can eventually be integrated into a geoportal as in other successful cases of using geovisualisation tools.

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APPENDICES

Relations created for the object relational database

Tables 5.1-5.9 are the result of designing the schema and splitting the CDM data into various relations for querying with PostgreSQL. The relations were used to develop the project developer and Ministry of Environment views for the web-based GIS platform.

Table 5.1: CDM Projects relation

Ref_No	ID	Title	Classificatio n	DOE	latitude	longitude
1404	GTZHE2W51k	'35 MW Bagasse Based Cogeneration Project' by Mumia	LARGE	Asia Private Li	0.363115	34.503948
2975	WXRVBNKL72	Olkaria III Phase 2 Geothermal Expansion Project in Keny	LARGE	RWTÜV GmbH	-0.901667	36.35944
3206	YE02S9T76I1/	Aberdare Range/ Mt. Kenya Small Scale Reforestation In	SMALL	CO CDM CO., I	-0.611178	36.678227
3207	9Y99NTCW97	Aberdare Range / Mt. Kenya Small Scale Reforestation Ir	SMALL	CO CDM CO., I	0.112172	37.539363
3773	2QUT4ANVKI	Olkaria II Geothermal Expansion Project	LARGE	orske Veritas	-0.891388	36.295833
4513	XDVH1TUQ2(	Lake Turkana 310 MW Wind Power Project	LARGE	l Kingdom Lir	2.448889	36.814167
5023	YXYY9VZPV19	Redevelopment of Tana Hydro Power Station Project	LARGE	orske Veritas	-0.785550	37.265284
5336	HEQTOAUBR!	Efficient Cook Stove Programme: Kenya	SMALL	ertification Hc	0.406111	35.625833
5341	122550AOL4	Improved Cooking Stoves Programme of Activities in Afr	SMALL	r Lloyd Certifi	0.462056	37.863289
5585	J6T3ITRUGO(	Aberdare Range/ Mt. Kenya Small Scale Reforestation In	SMALL	CO CDM CO., I	0.119009	37.631208
5962	LTCC04FT77\	International water purification programme	SMALL	r Lloyd Certifi	0.066154	34.770701
6110	73WHR9REN	Barefoot Power Lighting Programme	SMALL	Consulting In	1.749982	40.056150
6549	YJRI2BN6D5T	Nairobi River Basin Biogas Project	SMALL	RWTÜV GmbH	1.245833	36.665278
6606	EPQD5D3KDV	KTDA Small Hydro Programme of Activities	SMALL	andardisatior	-0.500184	36.866693
6625	CK1MWH6RI	60 MW Kinangop Wind Park Project	LARGE	Consulting In	-0.828056	36.555278
7014	KE7Q5W6G8L	Improved Cook Stoves for East Africa (ICSEA)	SMALL	(China) Ltd. (1	-1.180675	36.825286

Table 5.2: Crediting Period relation

ID	Type	Start_Date	End_Date
8TC5R6O85VGTZHE2W51KHKWBPIELQ4	Fixed	01oct2008	30sep2018
FQPS83XTFZWXRVBNKL728AKPRY2CY7	Renewable	04mar2010	03mar2017
ZSPB3HG9LVE02S9T76I1ALEUK0DYGD	Renewable	01oct2007	30sep2027
P304X22CZY9Y99NTCW97VXFTC23OSE	Renewable	01apr2008	31mar2028
MJB6BSFVT42QUT4ANVKF2II6FZDAME	Renewable	04dec2010	03dec2017
TEN5AY8PV0XDVH1TUQ2C5JZ9Z993SH	Renewable	21may2013	20may2020
JJC8FIF12CPXYY9VZPV199KB1LCXA0	Fixed	11oct2011	10oct2021
UACW6CORMHEQTOAUBR5T6EVBL3E9L3	Renewable	21mar2012	20mar2019
TKUCI3AN3E122550AOL40YALO7IJWW	Renewable	06dec2012	05dec2019
MTK9T50DHU6T3ITRUGOGHBCLNLTVX0	Renewable	01apr2010	31mar2030
MGV8ZMW0TLTCC04FT77WU7848AC6A4	Renewable	16nov2012	15nov2019
K7ROA1D14773WHR9RENE7CS44SA5VL	Renewable	25jul2012	24jul2019
IGKKTRN9MYJRI2BN6D5TBQ7IIP24BS	Fixed	31dec2012	30dec2022
1QJW5NPCBSEPQD5D3KDWG8BDC6CEFR	Renewable	14sep2012	13sep2019
H0TS48F3GZ3CK1MWH6RDI8Q01NX0MF	Renewable	01oct2012	30sep2019
8M4PPYQK5DXE7Q5W6G8UMAHX9TVF14	Renewable	17aug2012	16aug2019
2Q6GWNY332XXRS81YOIEB6EW5G4U5Q	Renewable	30nov2012	29nov2019
DV2KE3HA21Y7XW6W4UIBSVZ25375N6	Renewable	05aug2013	04aug2020

Table 5.3: Monitoring Period relation

ID	Start_Date	End_Date
8TC5R6O85VGTZHE2W51KHKWBPIELQ4	.	.
FQPS83XTFZWXRVBNKL728AKPRY2CY7	.	.
ZSPB3HG9LVE02S9T76I1ALEUK0DYGD	.	.
P3O4X22CZY9Y99NTCW97VXFTC23OSE	.	.
MJB6BSFVT42QUT4ANVKF2II6FZDAME	04dec2010	30sep2014
TEN5AY8PV0XDVH1TUQ2C5JZ9Z993SH	.	.
JJC8FIF12CPXYY9VZPV199KB1LCXA0	11oct2011	31dec2012
UACW6CORMHEQTOAUBR5T6EVBL3E9L3	21mar2012	20mar2013
TKUCI3AN3E122550AOL40YALO7IJWW	15dec2012	31dec2015
MTK9T50DHU6T3ITRUGOGHBCLNLTVX0	.	.
MGV8ZMW0TLTCC04FT77WU7848AC6A4	01nov2013	30sep2015
K7ROA1D14773WHR9RENE7CS44SA5VL	.	.
IGKKTRN9MYJRI2BN6D5TBQ7IIP24BS	31dec2012	30dec2016
1QJW5NPCBSEPQD5D3KDWG8BDC6CEFR	.	.
H0TS48F3GZ3CK1MWH6RDI8Q01NX0MF	.	.
8M4PPYQK5DXE7Q5W6G8UMAHX9TVF14	15sep2012	14mar2013
2Q6GWNY332XXRS81YOIEB6EW5G4U5Q	.	.
DV2KE3HA21Y7XW6W4UIBSVZ25375N6	.	.
38GWYF0B0ZCXY239Z33CN5YNEEBTJ6	.	.
7RJXZ70OE5F8EXYLLLBLHOAW4H4LWM	.	.
LE362B1FKK3H1I84L6MEQVMWYYKDV3	.	.

Table 5.4: Status relation

ID	Simplified_Status	Website_Status
8TC5R6O85VGTZHE2W51KHKWBPIELQ4	End of crediting period	Registered
FQPS83XTFZWXRVBNKL728AKPRY2CY7	End of crediting period	Registered
ZSPB3HG9LVE02S9T76I1ALEUK0DYGD	Registered	Registered
P3O4X22CZY9Y99NTCW97VXFTC23OSE	Registered	Registered
MJB6BSFVT42QUT4ANVKF2II6FZDAME	End of crediting period	Registered
TEN5AY8PV0XDVH1TUQ2C5JZ9Z993SH	Registered	Registered
JJC8FIF12CPXYY9VZPV199KB1LCXA0	Registered with issuances	Registered
UACW6CORMHEQTOAUBR5T6EVBL3E9L3	Registered with issuances	Registered
TKUCI3AN3E122550AOL40YALO7IJWW	Registered with issuances	Registered
MTK9T50DHU6T3ITRUGOGHBCLNLTVX0	Registered	Registered
MGV8ZMW0TLTCC04FT77WU7848AC6A4	Registered with issuances	Registered
K7ROA1D14773WHR9RENE7CS44SA5VL	Registered	Registered
IGKKTRN9MYJRI2BN6D5TBQ7IIP24BS	Registered with issuances	Registered
1QJW5NPCBSEPQD5D3KDWG8BDC6CEFR	Registered	Registered
H0TS48F3GZ3CK1MWH6RDI8Q01NX0MF	Registered	Registered
8M4PPYQK5DXE7Q5W6G8UMAHX9TVF14	Registered with issuances	Registered
2Q6GWNY332XXRS81YOIEB6EW5G4U5Q	Registered with issuances	Registered
DV2KE3HA21Y7XW6W4UIBSVZ25375N6	Registered	Registered
38GWYF0B0ZCXY239Z33CN5YNEEBTJ6	Registered	Registered
7RJXZ70OE5F8EXYLLLBLHOAW4H4LWM	Registered	Registered
LE362B1FKK3H1I84L6MEQVMWYYKDV3	Registered	Registered

Table 5.5: Registration relation

ID	Date_of_EB_Decision	Registered_or_rejected
8TC5R6O85VGTZHE2W51KHKWBPIELQ4	13nov2008	03sep2008
FQPS83XTFZWXRVBNKL728AKPRY2CY7	04mar2010	04mar2010
ZSPB3HG9LVE02S9T76I1ALEUK0DYGD	13jun2011	11jun2011
P3O4X22CZY9Y99NTCW97VXFTC23OSE	03jan2012	05oct2011
MJB6BSFVT42QUT4ANVKF2II6FZDAME	06dec2010	04dec2010
TEN5AY8PV0XDVH1TUQ2C5JZ9Z993SH	23may2011	28feb2011
JJC8FIF12CPXYY9VZPV199KB1LCXA0	05mar2012	11oct2011
UACW6CORMHEQTOAUBR5T6EVBL3E9L3	01jun2012	21mar2012
TKUCI3AN3E122550AOL40YALO7IJWW	26feb2013	06dec2012
MTK9T50DHU6T3ITRUGOGHBCLNLTVX0	25may2012	06mar2012
MGV8ZMW0TLTCC04FT77WU7848AC6A4	21jan2013	16nov2012
K7ROA1D14773WHR9RENE7CS44SA5VL	22oct2012	25jul2012
IGKKTRN9MYJRI2BN6D5TBQ7IIP24BS	21sep2012	28jun2012
1QJW5NPCBSEPQD5D3KDWG8BDC6CEFR	27dec2012	14sep2012
H0TS48F3GZ3CK1MWH6RDI8Q01NX0MF	05oct2012	09jul2012
8M4PPYQK5DXE7Q5W6G8UMAHX9TVF14	05dec2012	17aug2012
2Q6GWNY332XXRS81YOIEB6EW5G4U5Q	18feb2013	30nov2012
DV2KE3HA21Y7XW6W4UIBSVZ25375N6	02oct2013	05aug2013
38GWYF0B0ZCXY239Z33CN5YNEEBTJ6	21dec2012	25sep2012
7RJXZ70OE5F8EXYLLLBLHOAW4H4LWM	04jan2013	03oct2012

Table 5.6: Credits relation

ID	Total_CERs_Issued	Count_of_issuances_of_credits
8TC5R6O85VGTZHE2W51KHKWBPIELQ4	0	0
FQPS83XTFZWXRVBNKL728AKPRY2CY7	0	0
ZSPB3HG9LVE02S9T76I1ALEUK0DYGD	0	0
P3O4X22CZY9Y99NTCW97VXFTC23OSE	0	0
MJB6BSFVT42QUT4ANVKF2II6FZDAME	345,628	4
TEN5AY8PV0XDVH1TUQ2C5JZ9Z993SH	0	0
JJC8FIF12CPXYY9VZPV199KB1LCXA0	18,677	1
UACW6CORMHEQTOAUBR5T6EVBL3E9L3	18,337	1
TKUCI3AN3E122550AOL40YALO7IJWW	215,663	3
MTK9T50DHU6T3ITRUGOGHBCLNLTVX0	0	0
MGV8ZMW0TLTCC04FT77WU7848AC6A4	51,172	3
K7ROA1D14773WHR9RENE7CS44SA5VL	0	0
IGKKTRN9MYJRI2BN6D5TBQ7IIP24BS	8,311	2
1QJW5NPCBSEPQD5D3KDWG8BDC6CEFR	0	0
H0TS48F3GZ3CK1MWH6RDI8Q01NX0MF	0	0
8M4PPYQK5DXE7Q5W6G8UMAHX9TVF14	4,052	1
2Q6GWNY332XXRS81YOIEB6EW5G4U5Q	117,714	0
DV2KE3HA21Y7XW6W4UIBSVZ25375N6	0	0
38GWYF0B0ZCXY239Z33CN5YNEEBTJ6	0	0
7RJXZ70OE5F8EXYLLLBLHOAW4H4LWM	0	0

Table 5.7: Type relation

ID	Type	Subtype
8TC5R6O85VGTZHE2W51KHKWBPIELQ4	Biomass energy	Bagasse power
FQPS83XTFZWXRVBNKL728AKPRY2CY7	Geothermal	Geothermal electricity
ZSPB3HG9LVE02S9T76I1ALEUK0DYGD	Reforestation	Reforestation
P3O4X22CZY9Y99NTCW97VXFTC23OSE	Reforestation	Reforestation
MJB6BSFVT42QUT4ANVKF2II6FZDAME	Geothermal	Geothermal electricity
TEN5AY8PV0XDVH1TUQ2C5JZ9Z993SH	Wind	Wind
JJC8FIF12CPXYY9VZPV199KB1LCXA0	Hydro	Existing dam
UACW6CORMHEQTOAUBR5T6EVBL3E9L3	EE households	Stoves
TKUCI3AN3E122550AOL40YALO7IJWW	EE households	Stoves
MTK9T50DHU6T3ITRUGOGHBCLNLTVX0	Reforestation	Reforestation
MGV8ZMW0TLTCC04FT77WU7848AC6A4	EE service	Water purification
K7ROA1D14773WHR9RENE7CS44SA5VL	Solar	Solar lamps
IGKKTRN9MYJRI2BN6D5TBQ7IIP24BS	Methane avoidance	Domestic manure
1QJW5NPCBSEPQD5D3KDWG8BDC6CEFR	Hydro	Run of river
H0TS48F3GZ3CK1MWH6RDI8Q01NX0MF	Wind	Wind
8M4PPYQK5DXE7Q5W6G8UMAHX9TVF14	EE households	Stoves
2Q6GWNY332XXRS81YOIEB6EW5G4U5Q	EE households	Stoves
DV2KE3HA21Y7XW6W4UIBSVZ25375N6	EE service	Lighting in service
38GWYF0B0ZCXY239Z33CN5YNEEBTJ6	Biomass energy	Biomass briquettes or pellets
7RJXZ70OE5F8EXYLLLBLHOAW4H4LWM	Solar	Solar lamps
LE362B1FKK3H1I84L6MEQVMWYYKDV3	Solar	Solar lamps

Table 5.8: Project developer view

Ref_No	ID	latitude	longitude	Title	Registered_or_rejected	Total_CERs_issued	Type
1404	GTZHE2W51k	0.363115	34.503948	'35 MW Bagasse Based Cogener	03sep2008	0	iomass energ
2975	WXRVBNKL72	-0.901667	36.35944	Olkaria III Phase 2 Geothermal	04mar2010	0	Geothermal
3206	YE02S9T76I1/	-0.611178	36.678227	Aberdare Range/ Mt. Kenya Sm	11jun2011	0	Reforestation
3207	9Y99NTCW97	0.112172	37.539363	Aberdare Range / Mt. Kenya Sm	05oct2011	0	Reforestation
3773	2QUT4ANVKl	-0.891388	36.295833	Olkaria II Geothermal Expansior	04dec2010	345,628	Geothermal
4513	XDVH1TUQ2(	2.448889	36.814167	Lake Turkana 310 MW Wind Pc	28feb2011	0	Wind
5023	'XYY9VZPV19	-0.785550	37.265284	Redevelopment of Tana Hydro	11oct2011	18,677	Hydro
5336	HEQTOAUBR!	0.406111	35.625833	Efficient Cook Stove Programm	21mar2012	18,337	EE households
5341	122550AOL4	0.462056	37.863289	Improved Cooking Stoves Progr	06dec2012	215,663	EE households
5585	J6T3ITRUGO(	0.119009	37.631208	Aberdare Range/ Mt. Kenya Sm	06mar2012	0	Reforestation
5962	LTCC04FT77\	0.066154	34.770701	International water purification	16nov2012	51,172	EE service
6110	73WHR9REN	1.749982	40.056150	Barefoot Power Lighting Progra	25jul2012	0	Solar
6549	YJRI2BN6D5°	1.245833	36.665278	Nairobi River Basin Biogas Proje	28jun2012	8,311	thane avoidar
6606	EPQD5D3KDV	-0.500184	36.866693	KTDA Small Hydro Programme	14sep2012	0	Hydro
6625	CK1MWH6RI	-0.828056	36.555278	60 MW Kinangop Wind Park Pr	09jul2012	0	Wind

Table 5.9: Ministry of Environment view

Ref_No	ID	latitude	longitude	Title	Registered_or_rejected	Total_CERs_issued	Type	Classification	DOE	Simplified_Status
1404	GTZHE2W51k	0.363115	34.503948	'35 MW Bag	03sep2008	0	iomass energ	LARGE	sia Private L	bf crediting pe
2975	WXRVBNKL72	-0.901667	36.35944	Olkaria III Ph	04mar2010	0	Geothermal	LARGE	RWTÜV Gmbl	bf crediting pe
3206	YE02S9T76I1/	-0.611178	36.678227	Aberdare Ra	11jun2011	0	Reforestatior	SMALL	O CDM CO.,	Registered
3207	9Y99NTCW97	0.112172	37.539363	Aberdare Ra	05oct2011	0	Reforestatior	SMALL	O CDM CO.,	Registered
3773	2QUT4ANVKl	-0.891388	36.295833	Olkaria II Ge	04dec2010	345,628	Geothermal	LARGE	orske Veritas	f crediting pe
4513	XDVH1TUQ2	2.448889	36.814167	Lake Turkan	28feb2011	0	Wind	LARGE	I Kingdom Lir	Registered
5023	'XYY9VZPV19	-0.785550	37.265284	Redevelopm	11oct2011	18,677	Hydro	LARGE	orske Veritas	red with issu
5336	HEQTOAUBR	0.406111	35.625833	Efficient Coc	21mar2012	18,337	EE household	SMALL	rtification He	red with issu
5341	122550AOL4(	0.462056	37.863289	Improved Co	06dec2012	215,663	EE household	SMALL	r Lloyd Certif	red with issu
5585	6T3ITRUGO(	0.119009	37.631208	Aberdare Ra	06mar2012	0	Reforestatior	SMALL	O CDM CO.,	Registered
5962	LTCC04FT77\	0.066154	34.770701	Internationa	16nov2012	51,172	EE service	SMALL	r Lloyd Certif	red with issu
6110	73WHR9REN	1.749982	40.056150	Barefoot Pov	25jul2012	0	Solar	SMALL	Consulting In	Registered
6549	YJRI2BN6D5°	1.245833	36.665278	Nairobi Rive	28jun2012	8,311	thane avoida	SMALL	RWTÜV Gmbl	red with issu
6606	EPQD5D3KDV	-0.500184	36.866693	KTDA Small	14sep2012	0	Hydro	SMALL	ndardisation	Registered
6625	CK1MWH6RI	-0.828056	36.555278	60 MW Kina	09jul2012	0	Wind	LARGE	Consulting In	Registered
7014	KE7Q5W6G8(	-1.180675	36.825286	Improved Co	17aug2012	4,052	EE household	SMALL	(China) Ltd. (	red with issu

Source code for web-based GIS platform

JavaScript code

```javascript
//OpenLayers.ProxyHost = "/cgi-bin/proxy.cgi?url=";

/*set the extent of the map*/

var extents = new OpenLayers.Bounds(3717536, -540160.89, 5153002.29, 608108.79);


/*load the controls to the map*/

var control, controls = [];


function init() {

  var map = new OpenLayers.Map("map" /*this map is the div id in the html code*/, {

    controls: [

      new OpenLayers.Control.Navigation(),

      new OpenLayers.Control.ArgParser(),

      new OpenLayers.Control.Attribution(),

      new OpenLayers.Control.LayerSwitcher({'div':OpenLayers.Util.getElement('dropdown-content')}),

      new OpenLayers.Control.MousePosition(),

      new OpenLayers.Control.PanZoomBar(),

       //new OpenLayers.Control.Zoom(),

      new OpenLayers.Control.KeyboardDefaults(),

      // new scalebar

      new OpenLayers.Control.ScaleLine(),

      new OpenLayers.Control.OverviewMap()

    ],

    maxExtent: extents,
```

```
      minExtent: "auto",

     // restrictedExtent: extents /*one cannot pan outside the specified extent*/

   },

      {projection: new OpenLayers.Projection("EPSG:900913")}, /*specify the projection*/


      {units: 'm'},

      {allOverlays: true} /* basemap will appear below overlays*/

      );
var OSM = new OpenLayers.Layer.OSM("OpenStreetMap");  /*loading the OSM basemap*/


   //Load data layers as WMS into webmap
var counties = new OpenLayers.Layer.WMS(

      "Counties",

      "http://localhost:8080/geoserver/cdm/wms",

      {layers:"cdm:counties",transparent: true, format: "image/png"},

      {visibility: false},

      {'displayInLayerSwitcher':true},

      {attribution:"KODI"}

);


var roads = new OpenLayers.Layer.WMS(

      "Major Roads",

      "http://localhost:8080/geoserver/cdm/wms",

      {layers:"cdm:ke_major-roads",transparent: true, format: "image/png"},

      {visibility: false},
```

```
          {'displayInLayerSwitcher':true}

);

 var protected_areas = new OpenLayers.Layer.WMS(

      "Protected-Areas",

      "http://localhost:8080/geoserver/cdm/wms",

      {layers:"cdm:ke_protected-areas",transparent: true, format: "image/png"},

      {visibility: false},

      {'displayInLayerSwitcher':true}

);

 var ProjDev_CDM_view = new OpenLayers.Layer.WMS(

      "CDM projects project developer view",

      "http://localhost:8080/geoserver/cdm/wms",

      {layers:"cdm:projdev_cdm_view",transparent: true, format: "image/png"},

      {visibility: true},

      {'displayInLayerSwitcher':true}

);

 var MoE_CDM_view = new OpenLayers.Layer.WMS(

      "CDM projects Ministry of Environment view",

      "http://localhost:8080/geoserver/cdm/wms",

      {layers:"cdm:moe_cdm_view",transparent: true, format: "image/png"},

      {visibility: false},

      {'displayInLayerSwitcher':true}

);

/*add the data to the map object*/

map.addLayers([OSM,counties,roads,protected_areas,ProjDev_CDM_view,MoE_CDM_view]);
```

```
//adding a popup control for wms layers

info = new OpenLayers.Control.WMSGetFeatureInfo({

        url: 'http://localhost:8080/geoserver/cdm/wms',

        title: 'Identify features by clicking',

        queryVisible: true,

        eventListeners: {

          getfeatureinfo: function(event) {

            map.addPopup(new OpenLayers.Popup.FramedCloud(

              "cdm",

              map.getLonLatFromPixel(event.xy),

              null,

              event.text,

              null,

              true

            ));

          }

        }

    });

map.addControl(info);

info.activate();

/*define the center of the map and a zoom level of 11*/

map.setCenter(new OpenLayers.LonLat(4182273.27, 56773.69),6 );


}
```

HTML

```html
<!DOCTYPE html>

<html lang="en">

        <head>

                <title>CDM Web-Map</title>

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

                <meta name="viewport" content="width=device-width, initial-scale=1.0,minimal-
ui">

                <!-- loading the stylesheet for the application -->

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

                <!-- loading the style for the OpenLayers --> <!-- versions of OpenLayers can be
downloaded from the OpenLayers website --><!-- this is version 2 of OpenLayers being used  --
>

                <link rel="stylesheet" type="text/css"
href="OpenLayers/theme/default/style.css"/>

                <!-- loading the OpenLayers javaScript file -->

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

    </head>

    <body onload="init()">

        <!-- the div holding the CDM map -->

        <div id="map">

                <!-- loading the javaScript file containing the properties of the webmap -->

                <script type="text/javascript" src="cdm.js"></script>


        <!-- style width and height for map-->

    <style>

  #map{ width: 1300px; height: 620px; }
```

```
  </style>

                </div>

      </body>

</html>
```

CSS

```css
#map {

   position: absolute;

}


#map{

  border: 2px solid #c8a88e;

   bottom: 2px;

   left: 10;

   min-width: 1024px;

   position: absolute;

   top: 0px;

   width: 99%;

   height:790px;

}
```