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System Documentation Manual

Consultancy Services on the Design and Development of a Geo-Platform and Configuration of Open Data Cube for the Kenya Space Agency

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TABLE OF CONTENTS

LIST OF ABBREVIATIONS

DBMS	Database Management system
FSD	Financial Sector Deepening
GIS	Geospatial Information System
ICT	Information and Communications Technology
KSA	Kenya Space Agency
MVCC	Multi-Version Concurrency Control
ODC	Open Data Cube
OGC	Open Geospatial Consortium
OSL	Oakar Services Limited
PCs	Personal Computers
RDBMS	Relational Database Management system
SQL	Structured Query Language

1 INTRODUCTION

1.1 Background Information

The Kenya Space Agency intended to design and develop a Geo-Platform to facilitate the dissemination of geospatial data and maps. In line with the Kenya Space Agency mandate, the objective of this consultancy was to design and develop a Geo-Platform and configure an Open Data Cube. Following the contract signed on **14th January 2022**, Oakar Services committed to undertake the consultancy to design and develop a geo-platform and configure an instance of Open Data Cube for Kenya Space Agency taking advantage of industry-standard technologies.

This documentation details the components, data, and technologies used to develop the KSA Geo-Platform. The documentation also contains exercises and tutorials for capacity building of the system administrators and users.

1.2 Report Organization

The remaining parts of this documentation are organized as follows. Chapter two (2) focuses on technologies while Chapter three (3) details the specifications of the Geo-Platform, and Chapter four details information on Capacity Building on of use and administration of the system.

2 SYSTEM MANAGEMENT

2.1 Overview

This consultancy has successfully developed a Geo-Platform for the Kenya Space Agency. This chapter details the technologies used, steps taken, data utilized, and the results obtained. Various technologies have been employed to develop the Geo-Platform. These technologies build on some of the existing software and other custom-developed applications. Components of the Geo-Platform include:

a) A geodatabase based on PostgreSQL 12.8 and PostGIS 3.1;
b) A GIS server based on GeoServer 2.20;
c) Open Data Cube; and
d) Geospatial Portal (Admin and Public portal).

The first step of the development process involved undertaking project mobilization including initial meetings with the client and the user to gain insights into the project. An inception report was then compiled and shared with the user and presented on 3rd February 2022. Comments from the user were then incorporated and the final inception report was shared. The following few sections give details on the reaming steps and technologies used to develop the Geo-Platform.

2.2 System Architecture

The developed Geo-platform contains the following software components, as shown in Figure 2.1:

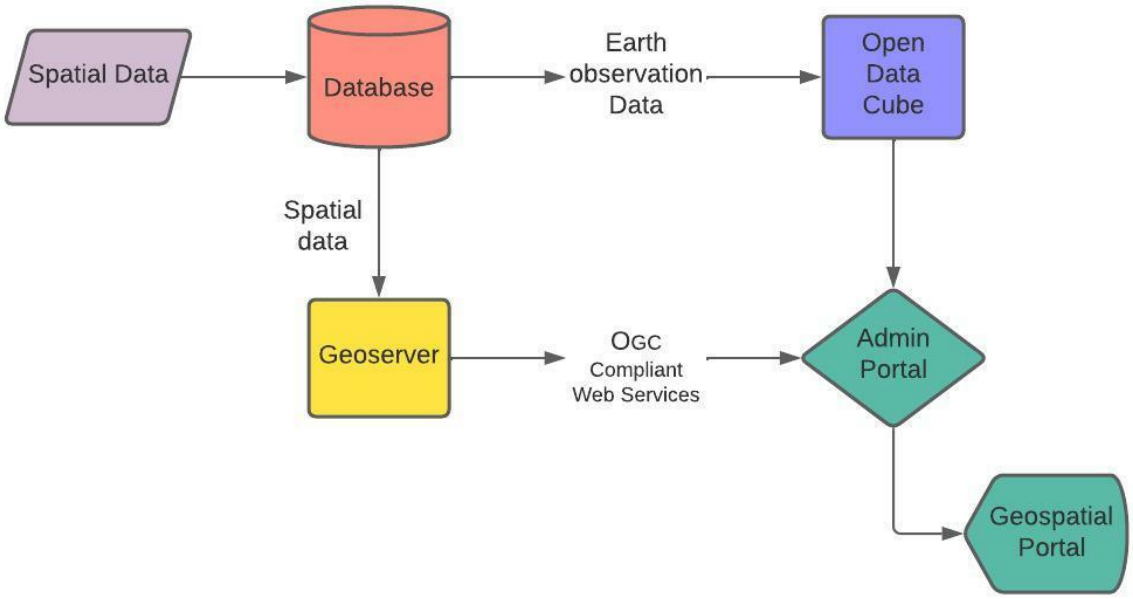
a) A geodatabase based on PostgreSQL 12.8 and PostGIS 3.1;
b) A GIS server based on GeoServer 2.20;
c) Open Data Cube; and
d) A Custom-developed Geospatial portal (Pubic Portal and Admin Portal).

The geodatabase has been configured to support both spatial data and non-spatial data including the user accounts and user feedback such as messages and comments. The GIS server is responsible for retrieving raw data from the geodatabase and publishing the same as OGC compliant web services for consumption by the geospatial portal. The Open Data Cube has been configured to manage and analyze earth observation data.

The Geospatial Portal acts as an interface between the **end-user** and the **GeoServer**. It also provides an easy to configure Admin Portal for configuring the client-facing Geospatial portal including managing users, defining data sources, styling, and configuring predefined analysis.

The Geospatial portal allows for web-based visualization, querying, analytics, and management of the published spatial data. Figure 2.1 shows the system architecture.

Figure 2.1: System Architecture



2.3 Technologies

The technologies implemented in the KSA Geoplatform are as described in the following sections:

2.3.1 Database

The database development phase involved planning, requirement gathering, conceptual design, logical design, physical design, construction, implementation, and rollout. The database was created in PostgreSQL by using pgAdmin, which is a web-based, Open Source management tool for PostgreSQL. This was purposely meant for hosting all the data and other information for easy development of the Geo-platform.

PostgreSQL[1] 12 database has been installed and configured with PostGIS 3.1 spatial extension to store spatial data and all the attributive information. Other data stored in the database include authentication of users, messages, and comments. The database name is **KSA_DB.** The geodatabase offers an efficient way of handling large amounts of both spatial and non-spatial data for the Kenya Space Agency.

PostgreSQL implements multi-version concurrency control (MVCC) feature, which allows the KSA to enjoy versioned data and hence a point-in-time consistent views of data. The geodatabase also allows the KSA to add custom functions developed using different programming languages such as C/C++, Java, etc. In addition, KSA can define custom data types, index types, functional languages, etc. The data has been organized in tables to allow for easy management. Table 2.1 shows a summary of the tables in the KSA_DB database.

[1] PostgreSQL is a general-purpose and object-relational database management system, the most advanced open-source database system. It was developed based on POSTGRES 4.2 at Berkeley Computer Science Department, University of California. PostgreSQL was designed to run on UNIX-like platforms. However, it was then designed to be portable so that it could run on various platforms such as Mac OS X, Solaris, and Windows.

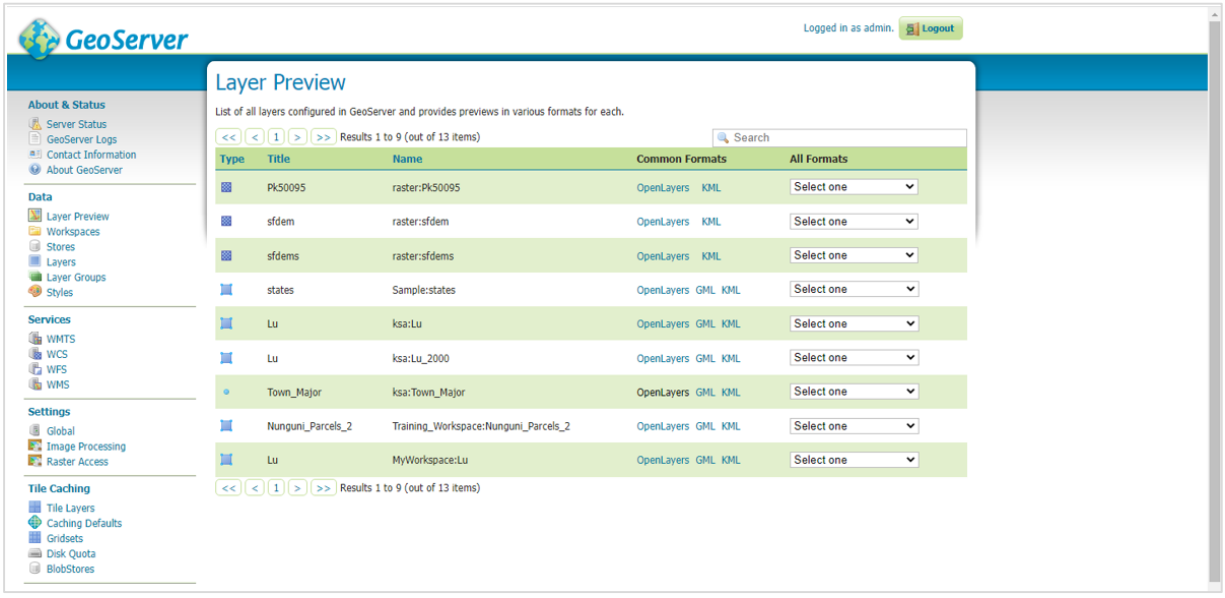
Table 2.1: KSA_DB Database Tables

No	Table	Description
1	Auths	A table containing credentials of user accounts of the admin portal.
2	Users	A table containing credentials of user accounts of the public portal.
3	Events	A table containing events reported and displayed in the Geo-Platform
4	GIS	A table containing GIS data and maps displayed in the Geo-Platform
5	Comments	A table containing user comments in the Geo-Platform
6	Comments Replies	A table containing replies to comments in the Geo-Platform
7	Messages	A table containing information on all communication between the user and administrator in the Geo-Platform
8	Messages Replies	A table containing replies to messages in the Geo-Platform

2.3.2 Geoserver Configuration

GeoServer is an open-source software server written in Java that allows users to share and edit geospatial data. Designed for interoperability, it publishes data from any major spatial data source using open standards. The GeoServer allows for easy publishing of OGC compliant web services and sophisticated visualization and analysis within an interactive web mapping application. GeoServer has been configured as the core GIS server supporting both publishings of GIS data (PostgreSQL database) as feature and web services (WFS and WMS). The GeoServer has been used to publish GIS data from the KSA_DB database as a Web Feature Service (WFS) for consumption on the data portal. Figure 2.2 shows an interface of the GeoServer.

Figure 2.2: KSA Geoserver Interface

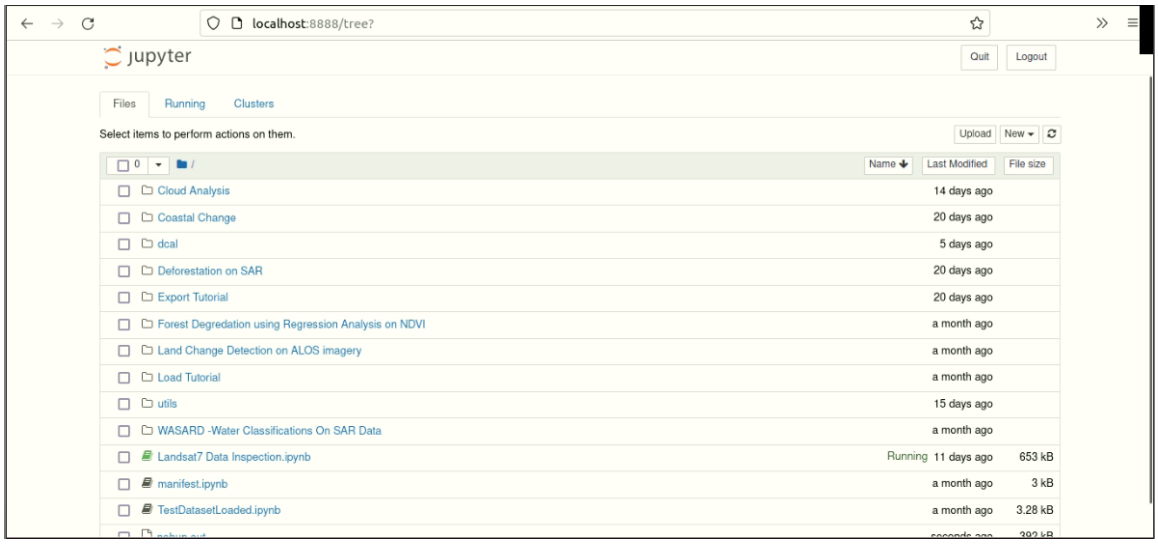


2.3.3 Open Data Cube Configuration

The consultancy has installed and configured an instance of Open Data Cube (ODC) for the Kenya Space Agency as per the provisions of the contract for this project. The Open Data Cube is an open-source solution for managing satellite data backed by a multitude of Python libraries. We have used the proposed geodatabase, PostgreSQL, as the core database for the ODC. This will provide an easy database-level integration between the ODC and Geo-Platform since they all share a common geodatabase.

ODC is primarily built for the analysis of satellite data with a major focus on temporally-rich data. Some of the datatypes that will be supported by the ODC instance include Landsat Images, Sentinel Images, elevation models, and interpolated surfaces. KSA will benefit from the ability that ODC provides flexibility in hosting. As such, the ODC instance is hosted following the client's select hosting environment. ODC is both a cloud-based hosting environment and an on-premises hosting environment. It can catalog large amounts of Earth Observation data as well as a python based API to allow for advanced querying and data access. Figure 2.3 shows the interface of Open Data Cube.

Figure 2.3: Open Data Cube Interface



Open Data Cube contains rich functionalities for analysis of imagery. KSA will be able to do various analyses on Earth Observation data/images using Jupyter Notebooks. Sample Cloud Analysis on an image is as shown in Figures 2.4, 2.5, 2.6 and 2.7.

Figure 2.4: Importing the Image

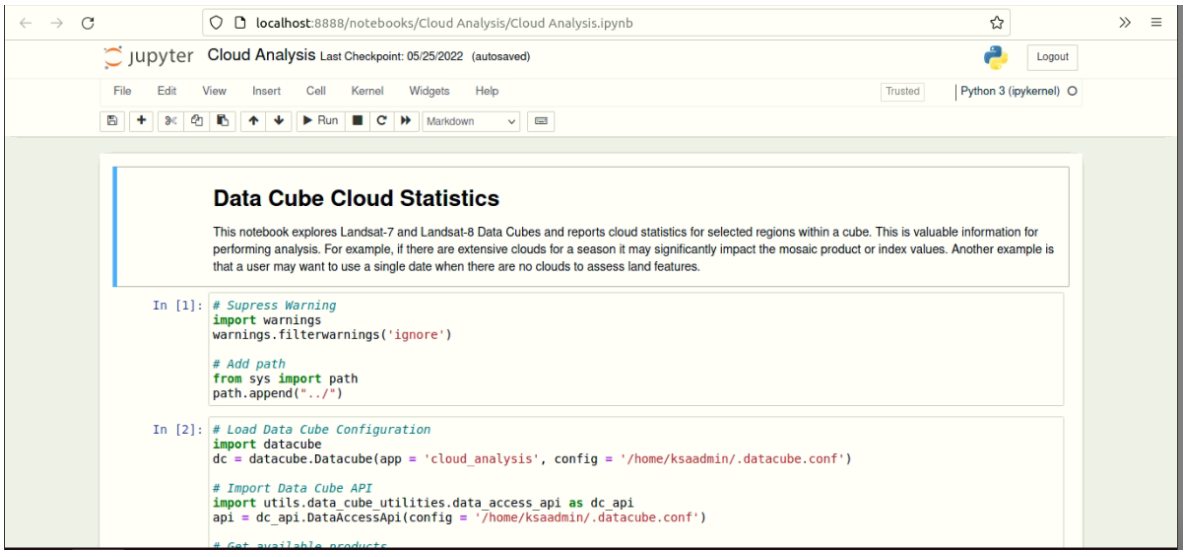


Figure 2.5: Obtaining Extends

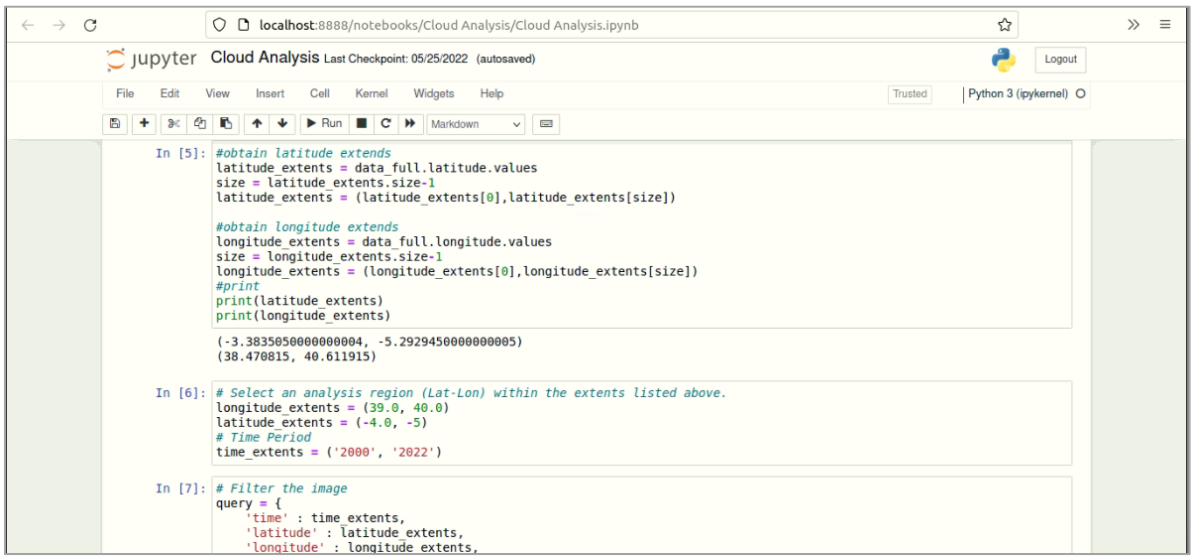


Figure 2.6: Masking

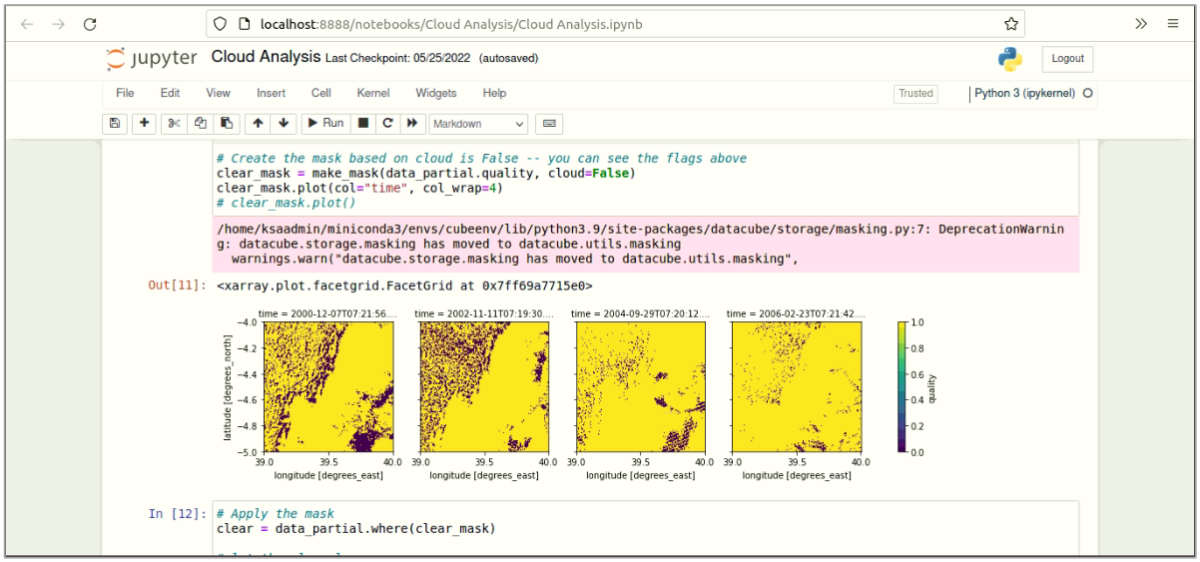
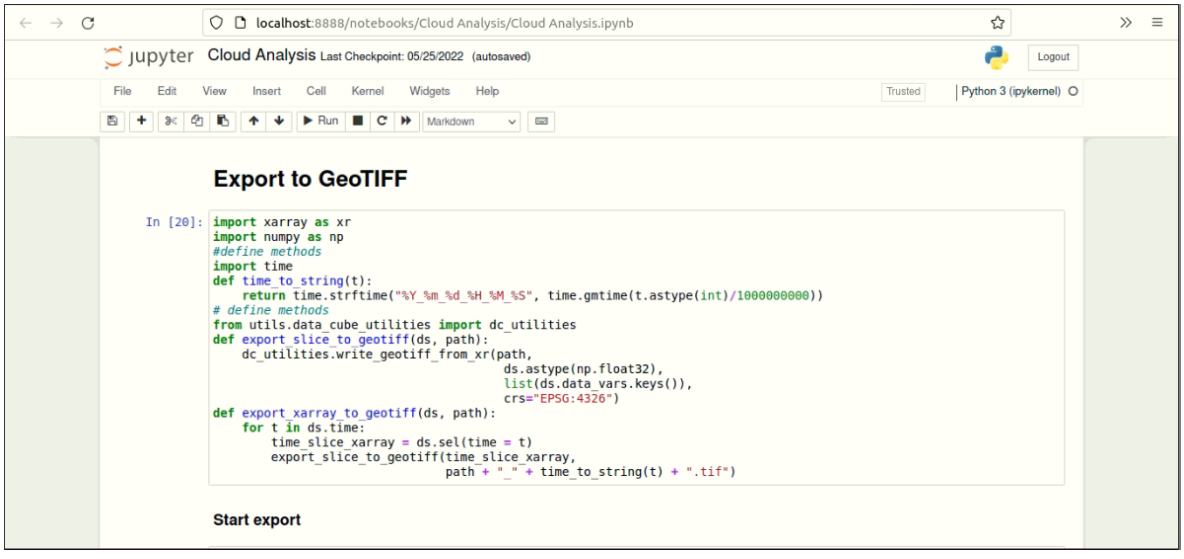


Figure 2.7: Exporting Results to GeoTIFF



2.3.4 Geo-Platform API

The consultancy has developed an Application Programming Interface (API), which acts as a bridge between the Geo-Platform and the GIS-enabled database through a PostgreSQL extension called PostGIS. This allows for the development of an integrated Geo-Platform that is scalable and easy to maintain. The API is responsible for managing spatial and non-spatial data and as well manage access to various components of the Geo-Platform system through the assigned user roles and permissions.

The consultancy has used Node JS, a powerful JavaScript framework for building web applications, to develop an API to support the proposed Geo-Platform. Node JS utilizes an event-driven, non-blocking I/O model that makes it lightweight and efficient, making it an ideal choice for building fast, highly scalable, data-intensive, and real-time backend devices that power the client applications running across distributed devices. Node JS can be combined with a browser, a database that supports JSON data such as PostgreSQL and JSON for a unified JavaScript development stack. Node JS also allows the reuse of the same model and service interface between the client-side and server-side. Node JS has in-built security features such as ORM/ODM that validates every access to the API database. Node JS API provides regular monitoring of the performance and it is highly extensible.

2.3.5 Web Application Development (Geospatial Portal)

The consultancy has successfully developed the Geo-Platform while taking advantage of modern cutting-edge technologies featuring fast and reliable server technologies and responsive user interface designs. In terms of the development technology, the consultant used React JS, a powerful platform for developing responsive web applications with the use of TypeScript and HTML. React is a free and open-source front-end JavaScript library for building user interfaces based on UI components. It is maintained by Meta and a community of individual developers and companies. React can be used as a base in the development of single-page or mobile applications.

The consultancy employed the following six main steps in the development of the Geo-Platform:

a) User Needs Assessment;
b) Definition of Features and Functionality;
c) UI/UX Design;
d) System Development;
e) Piloting and Testing; and
f) System Deployment and Commissioning.

The first step was conducting a small survey to understand the most important aspects and the Geo-Platform system goals. The second step involved the definition of the platform's layout and the core functionality mainly by creating a sitemap[2] of the website and a wireframe of the proposed Geo-Platform.

The wireframe formed the basis of the User Interface (UI) design, which was the third step in the development. The user interface took into consideration colors and branding as specified by KSA whilst employing modern UI/UX design best practices to ensure a good user experience.

The fourth step in the development of the Geo-Platform involved defining and developing functional components to meet the technical specifications as defined by KSA. On approval of the proposed UI/UX design and the website content, the consultancy worked hand-in-hand with the client to refine the features and functionalities of the Geo-Platform.

OpenLayers was used as the main mapping library to extend the Geospatial capabilities of the Geo-Platform. OpenLayers is an open-source JavaScript library for displaying map data in web browsers. OpenLayers provides an API for building rich web-based GIS applications. OpenLayers supports the main GIS data formats used in web applications, which include GeoRSS, Keyhole Markup Language (KML), Geographic Markup Language (GML), GeoJSON, and map data from any OGC compliant web service. Some of the most common OGC compliant web services include Web Feature Service (WFS), Web Map Service (WMS), and Web Map Tile Service (WMTS).

The Geo-Platform utilizes GIS data stored in the KSA_DB database in three main data formats that include Web Feature Service (WFS) from Geoserver; Web Map Tile Service (WMTS) from Geoserver, and GeoJSON from PostGIS data conversion functions. The WFS contains utility network feature data that users of the Geo-Platform can query and visualize. On the other hand, the WMTS contains styled map data that is used as a base map and/or for visualization purposes; whereas the GeoJSON data format is used to fetch data directly from the PostGIS database for visualization and analytics on the proposed Geo-Platform. The Geo-Platform has been developed following the terms of reference for this tender

[2] A sitemap is a birds-eye view of the proposed Geo-Platform and is used to identify the list of pages, their placement, and their relationship on the website. A wireframe on the other hand is a layout of each page of the proposed website.

The Geospatial Portal is comprised of both the public and admin portal. The public portal is the core web-based data visualization and analysis solution and can be accessed by public users at different access levels. The admin portal allows private users to manage the entire Geo-Platform and users of the public portal. The Geospatial portal will have the following real-world benefits for KSA:

a) Bring the power of geospatial processing to the web;
b) Maximize the value of GIS data and more specifically astronomy data, weather data, and thematic maps;
c) Give users fast and easy access to data disseminated by KSA;
d) Access and analyze data and maps and any other related information anywhere and anytime;
e) Capture and update data, report events, and publish maps from a user-friendly web application;
f) Improve productivity; and
g) Enjoy the benefits of a customized application with industry standards and proven performance scalability.

2.4 Personnel

The Geo-Platform has been designed as a critical tool for managing the spatial and non-spatial data for The Kenya Space Agency. The users of the geodatabase will therefore need specific skills in data capture, data editing, data manipulation, and database management to be able to maximize the potential benefits of the platform. Continued training and capacity development will hence be crucial for the successful implementation of the Geo-Platform. In general, a user of the geodatabase will need to have at the minimum:

- Basic training in GIS;
- Experience with Geoserver and PostgreSQL;
- Basic experience with Open Data Cube;
- A conceptual understanding of GIS and relational database management;
- An understanding of spatial and non-spatial data; and
- Familiarity with KSA data.

2.5 Geo-Platform Data Dictionary

KSA Geo-Platform Data Dictionary is a set of metadata that contains definitions and representations of data elements used in the KSA geodatabase. It describes the data objects or items used in the data model for the benefit of those who may need to refer to them. This data dictionary can be consulted to understand where a data item fits in the data structure,

what values it may contain, and basically what the data items mean in real-world terms. All present and subsequent coding in the geodatabase should comply with this Data Dictionary. However, additional attributes with their definition and description can be added to the dictionary when the need arises. In this data dictionary the terms in Table 2.2 are used and have specified meanings as below:

Table 2.2: Description of Terminologies

Item	Description
Schema	A schema is used to group related data and contains all the relevant database objects such as tables, views, indexes, data types, functions, stored procedures, and operators
Table	A table is a structure with a bunch of rows (aka "tuples"), each of which has the attributes defined by the schema
Geodatabase	A geographic data model that represents real-world geographic features as objects in an object-relational database.
Geometry	Describes the geometric shape of a feature i.e. point, line, or polygon.
Location	Describes where the feature classes are located e.g. File Geodatabase.
Source	Refers to the source of the data i.e. Data digitization, Scanning, or GPS Survey

The attribute table is made up of standard fields for storing feature shapes and ID numbers. In addition to these are the user-defined fields.

2.5.1 Description of Data

The Geo-Platform has been configured to use two databases, one for running the backend of the platform and the other for storing data published in the platform. The geodatabase that stores spatial data, maps, and images for the platform is referred to as **KSA_Data_DB** while the one running the platform's backend is **KSA_DB**.

2.5.1.1 KSA_DB

This database has been configured to run the backend of the Geo-platform. It is purely controlled and managed by the Geo-Platforms Application Programming Interface (API) which is responsible for creating the tables, retrieving data, editing data, and deleting data. The operations performed on this database result from the user activities on the Geo-platform. Therefore, a user or the admin cannot manually create tables or add data to tables in KSA_DB using the Graphic User Interface of PostgreSQL.

Functionalities of the platform that are facilitated by KSA_DB include:

1. User Account Creation – User details of accounts created to access the Geo-Platform are stored in the database. These details include the personal details of the user and the login credentials to the platform.
2. User Account Management- KSA_DB stores details that enable the admin and users to manage accounts edit their details and passwords and also to delete accounts
3. Login and Logout- This database facilitates access to the functionalities of the platform by storing the login credentials of the admin and users and the authentication tokens
4. View Reports – KSA_DB enables the admin to view reports and portal statistics such as the number of users logged in, and number of downloads made among others
5. Track Payments – KSA_DB stores details of payments made by users for access or download of data.

KSA_DB has been configured to contain only the **public schema** which contains the tables as shown in Table 2.1

Table 2.1: Tables in KSA_DB

No	Table	Description
1	Auths	A table containing credentials of user accounts of the admin portal.
2	Users	A table containing credentials of user accounts of the public portal.
3	Events	A table containing events reported and displayed in the Geo-Platform
4	GIS	A table containing GIS data and maps displayed in the Geo-Platform
5	Comments	A table containing user comments in the Geo-Platform
6	Comments Replies	A table containing replies to comments in the Geo-Platform
7	Messages	A table containing information on all communication between the user and administrator in the Geo-Platform
8	Messages Replies	A table containing replies to messages in the Geo-Platform

All tables contain standardized data arranged in rows and columns; where the columns store related data and the rows represent independent records.

a) Auths Table

The Auths table contains personal details and login credentials of user accounts of the admin portal. Users of the admin portal include the system administrators, KSA Users, and admin portal guests. These users are controlled by a role-based authentication system whereby a user will only access the functionalities of the admin portal based on the type of account. The Auths table contains the columns as shown in Table 2.2.

Table 2.2: Columns in Auths Table

No	Name	Data Type	Description
1	UserID	Integer	Unique Identification of the user
2	Name	Character Varying	Name of the Account User
3	Phone	Integer	Phone Number of Account User
4	Email	Character Varying	Email Address of Account User
5	Position	Character Varying	Designation of Account User at Kenya Space Agency
6	Department	Character Varying	Department of Account User at Kenya Space Agency
7	Password	Character Varying	Encrypted password to use for login to the admin portal
8	Role	Character Varying	Role of the account user e.g admin, regular user, guest
9	Status	Boolean	Whether the user is logged in to the system or not
10	CreatedAt	Character Varying	Date when the user account was created
11	UpdatedAt	Character Varying	Date when the user account was updated

Types of a user account for the KSA Geo-Platform are shown in Table 2.3

b) Users Table

The Auths table contains personal details and login credentials of user accounts of the public portal. Unlike the Auths Table, this table only contains credentials of public, regular, and guest users of the public portal. The size of this table will always increase as public users of the Geo-Platform increase. Columns for the Users table are as shown in Table 2.4

c) Events Table

This table stores events reported and displayed in the Geo-Platform. The Geo-Platform supports users to report and display events such as forest fires, landslides, natural calamities, etc. The events table contains columns as shown in Table 2.5

d) GIS Table

Table 2.6 contains GIS data and maps displayed in the Geo-Platform.

Table 2.3: Types of User Accounts

Role	Portal	Available Pages	Functionalities
Portal Admin	Admin Portal	Home Page	Access to all functionalities of the Home Page
		Instances	Publish instances to the Geo-platform View a list of published instances Edit Published Instances Delete Published Instances
		Portal Statistics	View Portals Statistics like number of users logged in, number of downloads, number of published instances, etc. Analyze payment statistics for downloaded data
		Feedback Section	Receive and respond to messages from public users Receive and respond to comments on published instances from the public users. Delete messages and comments from public users.
		Users Page	Create users of the admin portal. Disable and Enable user accounts Delete users of admin and public portal
	Public Portal	All	Access to all Functionalities
KSA User	Admin Portal	Home Page	Access to all functionalities of the Home Page
		Instances	Publish instances to the Geo-platform View a list of published instances Edit Published Instances Delete Published Instances
		Feedback Section	Receive and respond to comments on published instances from the public users.
	Public Portal	All	Access to all Functionalities
Public User	Public Portal	All	Access to all Functionalities
Guest	Public Portal	All	Access to all Functionalities except downloading and sharing data

Table 2.4: Columns in Users Table

No	Name	Data Type	Description
1	UserID	Integer	Unique Identification of the user
2	Name	Character Varying	Name of the Account User
3	Phone	Integer	Phone Number of Account User
4	Email	Character Varying	Email Address of Account User
5	Password	Character Varying	Encrypted password to use for login to the public portal
6	Status	Boolean	Whether a user is logged in to the system or not
7	CreatedAt	Character Varying	Date when a user account was created
8	UpdatedAt	Character Varying	Date when a user account was updated

Table 2.5: Columns in Events Table

No	Name	Data Type	Description
1	ID	Integer	Unique Identification of the event instance
2	Category	Character Varying	Type of Event e.g. forest fire, landslide
3	Title	Character Varying	Name of the event e.g. Fire at Karura Forest
4	Description	Character Varying	Summarised information about the event
5	X	Geometry	Longitude geometry of the event
6	Y	Geometry	Latitude geometry of the event
7	Thumbnail	Character Varying	Small Identification photo of the event
8	Pictures	Character Varying	Several photos of the event
9	Date	Date	Date when the event occurred
10	CreatedAt	Character Varying	Date when the event was reported to the Geo-Platform
11	UpdatedAt	Character Varying	Date when event details were updated in the Geo-Platform

Table 2.6: Columns in GIS Table

No	Name	Data Type	Description
1	ID	Integer	Unique Identification of the instance
2	Category	Character Varying	Category of the instance e.g. world map, thematic data, cadastral map
3	Title	Character Varying	Name of the instance e.g. Map of Kenya
4	Description	Character Varying	Summarised information about the instance
5	Thumbnail	Character Varying	Small Identification photo of the instance
6	Dataset	Character Varying	Name of the dataset
7	Keywords	Character Varying	Keywords to use for searching the instance
8	Owner	Character Varying	Owner of the dataset contained in the instance
9	Type	Text	Type of spatial data e.g. Raster, vector
10	URL	Character Varying	Geoserver workspace and layer name containing the data
11	Column	Character Varying	The column that will pick the default style when the instance is published
12	Classification	Character Varying	
13	Style	Character Varying	Style applied to the dataset when publishing
14	Status	Boolean	Whether an instance is activated or disabled for display in the public portal
10	CreatedAt	Character Varying	Date when the event was reported to the Geo-Platform
11	UpdatedAt	Character Varying	Date when event details were updated in the Geo-Platform

e) Comments Table

This table contains user comments in the Geo-Platform. User comments are feedback by the platform users on data, maps, and events published in the Geo-Platform. The Comments Table provides for the interactive feedback mechanism of the Geo-Platform. These comments are displayed to the system administrator in the admin portal.

Table 2.7: Columns in Comments Table

No	Name	Data Type	Description
1	CommentID	Integer	Unique Identification of a comment
2	To	Character Varying	The user that the comment is directed to.
3	From	Integer	The ID of the user making the comment
4	Subject	Character Varying	The subject of the comment
5	Content	Character Varying	Body of the comment
6	Status	Boolean	Whether a comment has been replied to or not
7	CreatedAt	Character Varying	Date when the comment was created
8	UpdatedAt	Character Varying	Date when the comment was edited

f) Comments Reply Table

This table contains replies to comments made by users in the Geo-Platform. Replies to comments can be from the system administrator and from users who are responding to the replies from administrators. This table serves both the public and the admin portal. The

Comments Replies Table 2.8 provides for the interactive feedback mechanism of the Geo-Platform.

Table 2.8: Columns in Comments Replies Table

No	Name	Data Type	Description
1	ReplyID	Integer	Unique Identification of a comment reply
2	CommentID	Integer	The ID of the comment upon which the reply is based.
3	UserID	Integer	The ID of the user who made the comment
5	Content	Character Varying	Body of the comment reply
6	CreatedAt	Character Varying	Date when comment reply was created
7	UpdatedAt	Character Varying	Date when comment reply was updated

g) Messages Table

The Messages table contains information on all communication between the user and administrator in the Geo-Platform. This communication is facilitated by the 'Contact Us Page' of the public portal. The table serves the data to the system administrator through the 'Messages Page' of the admin portal. The Messages table contains the columns illustrated in Table 2.9.

Table 2.9: Columns in Comments Table

No	Name	Data Type	Description
1	MessageID	Integer	Unique Identification of a message
2	To	Character Varying	The user to that the message is directed.
3	From	Integer	The ID of the user sending the message
4	Subject	Character Varying	The subject of the message
5	Content	Character Varying	Body of the message
6	Status	Boolean	Whether the message has been replied to or not
7	CreatedAt	Character Varying	Date when the message was sent
8	UpdatedAt	Character Varying	Date when the message was updated

h) Messages Replies Table

A table containing replies to messages in the Geo-Platform. These are replies that the administrator makes to messages sent by the user through the 'Contact Us Page'. The Messages Replies Table contains the columns illustrated in Table 2.10.

Table 2.10: Columns in Messages Replies Table

No	Name	Data Type	Description
1	ReplyID	Integer	Unique Identification of a message reply
2	MessageID	Integer	The ID of the message upon which the reply is based.
3	UserID	Integer	The ID of the user who sent the message
5	Content	Character Varying	Body of the message reply
6	CreatedAt	Character Varying	Date when message reply was created
7	UpdatedAt	Character Varying	Date when message reply was updated

The Comments, Comments Replies, Messages, and Message Replies tables provide for the interactive feedback mechanism of the KSA Geo-Platform.

2.5.1.2 KSA_Data_DB

The KSA_Data_DB is a database that contains all the spatial data that is to be displayed, disseminated, and/or downloaded from the KSA Geo-Platform. The spatial capabilities of this database are provided by the **PostGIS extension** for PostgreSQL. Therefore, if the administrator needs to create another database to contain the Platform's spatial data, it must be configured with the PostGIS database. This database has been configured to contain only the **public schema**.

The tables of the KSA_Data_DB are unlimited depending on the amount of data stored in it. Unlike the KSA_DB, the systems administrators can create tables in KSA_Data_DB manually by creating tables either through the PostGIS shapefile Import/Export Wizard or through a desktop GIS software like QGIS.

The database has capabilities to store the following types of data:

i. Spatial Data
ii. Thematic data
iii. Cadastral Maps
iv. Topographical Maps
v. Satellite Images
vi. Aerial Images
vii. Topographical Images etc.

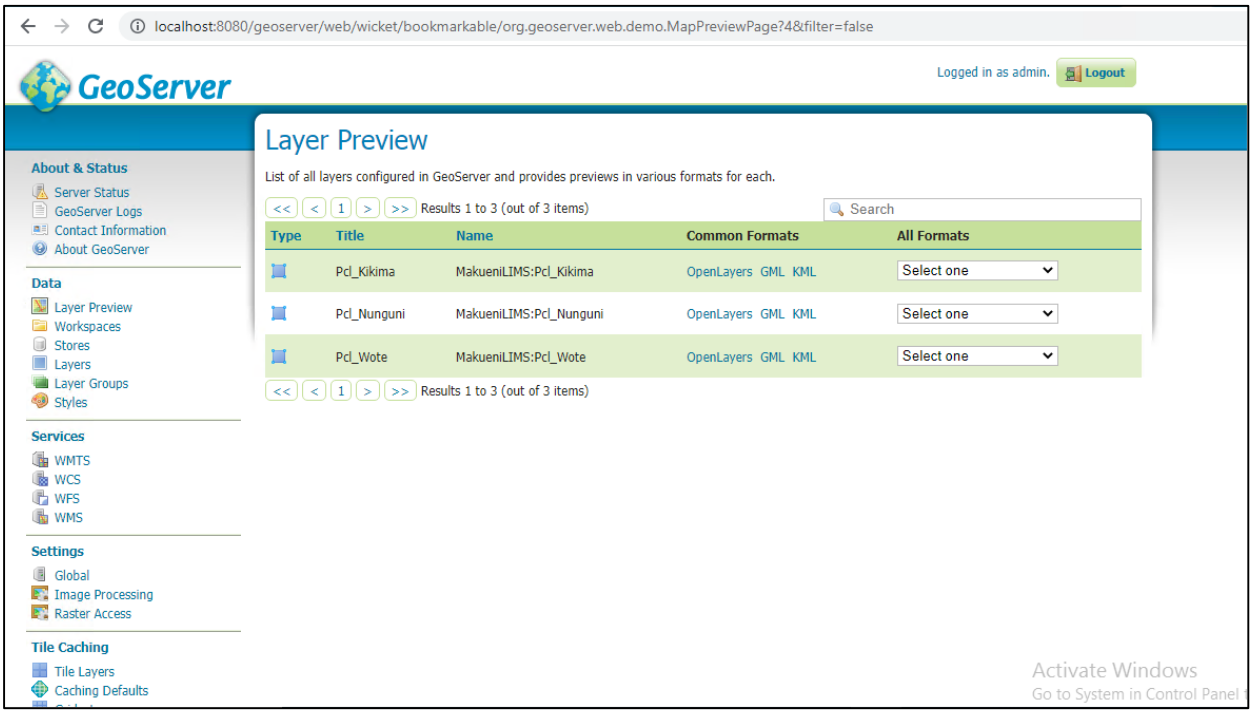
The columns of the table in KSA_Data_DB depend on the attributive information of the data.

2.5.2 Geoserver Data

The system us using **Geoserver** as the main GIS server and is responsible for retrieving raw data from the **KSA_Data_DB** and publishing the same as OGC compliant web services for consumption by the geospatial portal.

To publish data from the geodatabase to Geoserver, the administrator must ensure the data is transformed from its Native coordinate system to **EPSG 4326 SRS**. This transformation is done through Geoserver Graphical Interface and therefore the native coordinate system of the data in the geodatabase is not affected. Figure 2.3 shows some of the imported layers in GeoServer. Note: the layers correspond to the tables contained in the KSA_Data_DB.

Figure 2.3: Imported Geoserver Layers



The layers imported in Geoserver can then be published to the Geo-Platform through the Admin Portal for it to be accessible to public users through the public portal.

2.5.3 Open Data Cube Data

Open Data Cube will be used for processing and analyzing Earth Observation data that will be disseminated in the Geo-Platform. Earth Observation data includes:

i. Landsat Images
ii. Sentinel images
iii. Aerial Images

The satellite images will be stored locally according to the user's preferance. To publish processed E.O to the Geo-Platform, the administrator will first add the data to Geoserver just like the other spatial data and then publish it to the platform through the Admin Portal.

NOTE: The SRS of the EO data has to be transformed to **EPSG 4326** when publishing to Geoserver.

2.6 Spatial Reference

Spatial reference refers to a collection of properties that define the coordinates used to store feature geometry. The spatial reference employed by the PostGIS extension of PostgreSQL to store and organize data is based on the Projected Coordinate System specifically Spherical Mercator for Transformation EPSG 3857. However, the data can be published to the database using any other suitable coordinate system.

The spatial reference employed by the KSA-GeoPlatform to display data is WGS 84 EPSG 4326. Therefore all the data has to be transformed to EPSG 4326 when being published to Geoserver for it to display in the Geo-Platform.

3 KSA GEO-PLATFORM

The Kenya Space Agency Geo-Platform has been developed using industry-standard technologies and development tools enabling universal accessibility through the internet. The development has incorporated a user-friendly interface with logically organized navigation controls for easy accessibility of the different pages and functionalities. The notable functionalities of the Geo-Platform are:

a) **Controlled access**: Access to the system has been secured through a role-based authentication system. Public users are required to create an account through which they can use to access functionalities of the public portal. The system administrator can create accounts for users of the admin portal with a default password that can be changed by the users. Additionally, the administrator, through the admin portal, can manage public users.

b) **Visualization:** Users of the system can visualize the spatial location of the different types of data consumed in the application in various supported formats. A user can zoom in and out and pan features.

c) **Feature Attributes:** Capability to display the Feature Info window showing all the attribute information associated with a selected feature by using the available identification icon.

d) **Query Capabilities.** The system has capabilities for users to build custom queries to retrieve information from custom data sources. A user can build queries using in build operators, unique values and keywords.

e) **Analysis:** The system contains tools to perform various simple to complex analyses for all the data availed to the geospatial portal by GeoServer.

f) **Measurements:** The system supports the measurement of distances or an area of features displayed on a map and returns the coordinates of a given point. The feature is designed to improve the ease of use for end-users.

g) **Print Engine:** The system supports the printing of map-based reports either on Chrome, Internet Explorer, or PhantomJS browsers.

The system has also been customized to include an admin and a public portal as described in the following few sections.

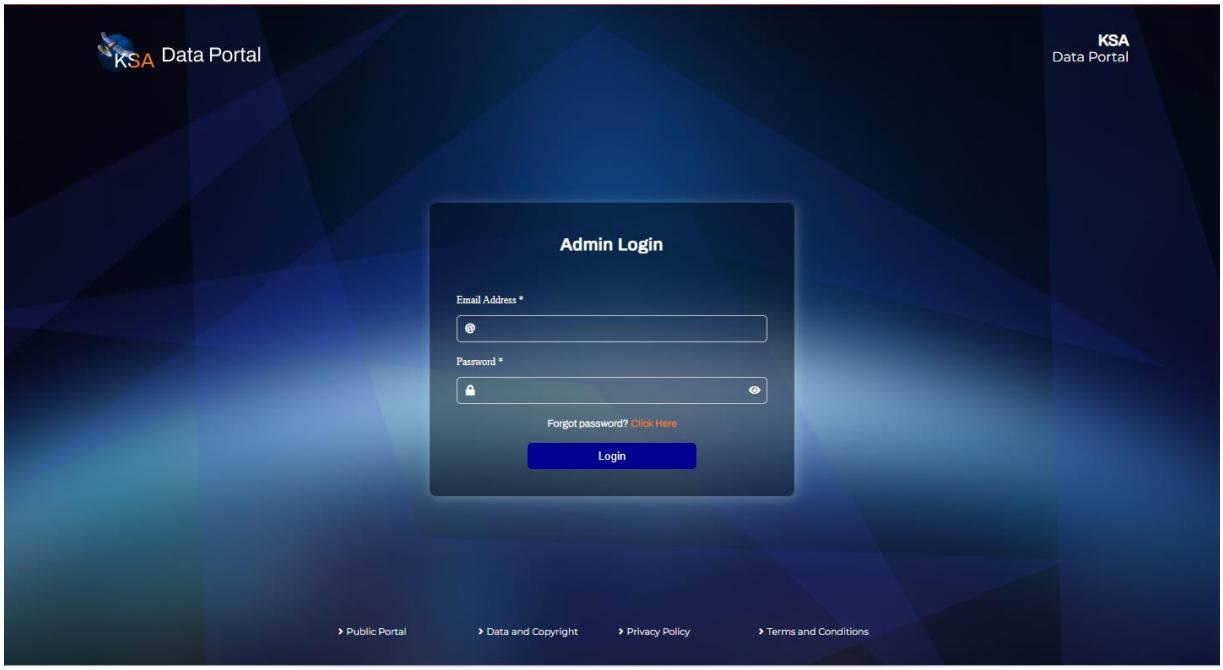
3.1 Admin Portal

The admin portal acts as a backend for the data portal. It provides functionalities to manage the data displayed in the public portal. The admin portal also manages users of the public portal by providing functionalities to create users, disable accounts, and delete accounts. Additionally, the admin portal can be used to define the roles available to different types of users. The admin portal comprises the following pages: Login, Home, Valuation Roll, Searches, Transfers, Services, Billing, Users, and Settings.

3.1.1 Login Page

The admin portal can be accessed by KSA staff at different role levels. The creation of accounts to access the admin portal has been restricted to only the administrator of the system. Therefore, only the system administrator can create login accounts with a default password, which the users are required to change.

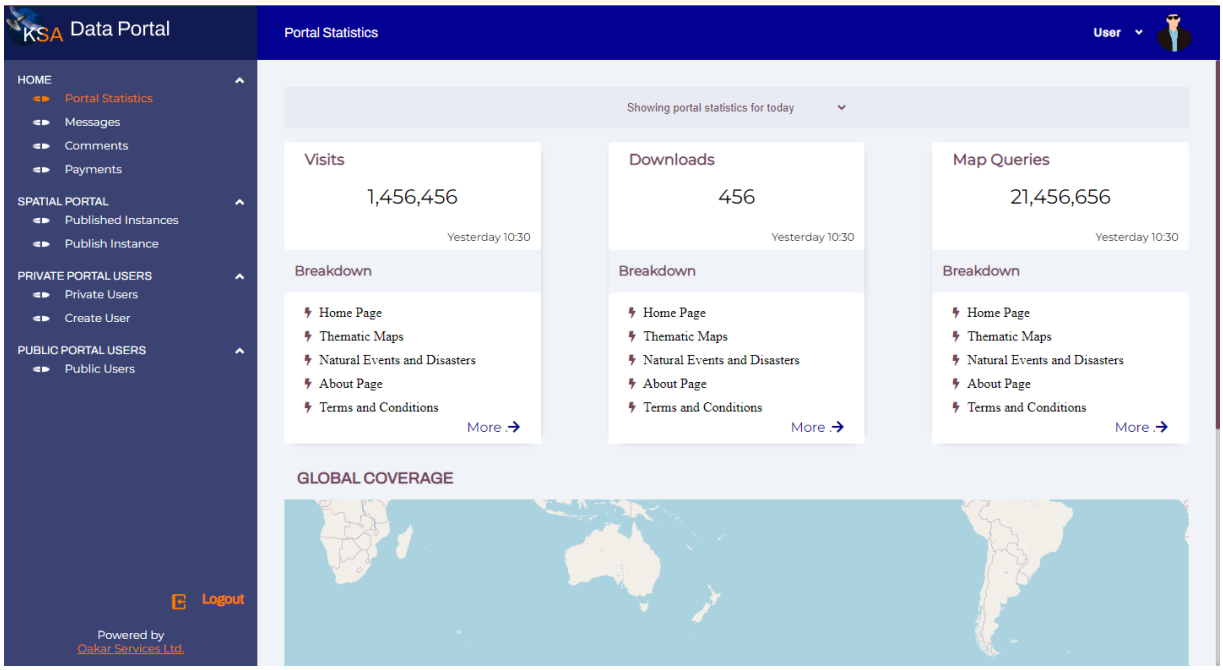
Figure 3.1: Admin Portal Login Page



3.1.2 Home Section

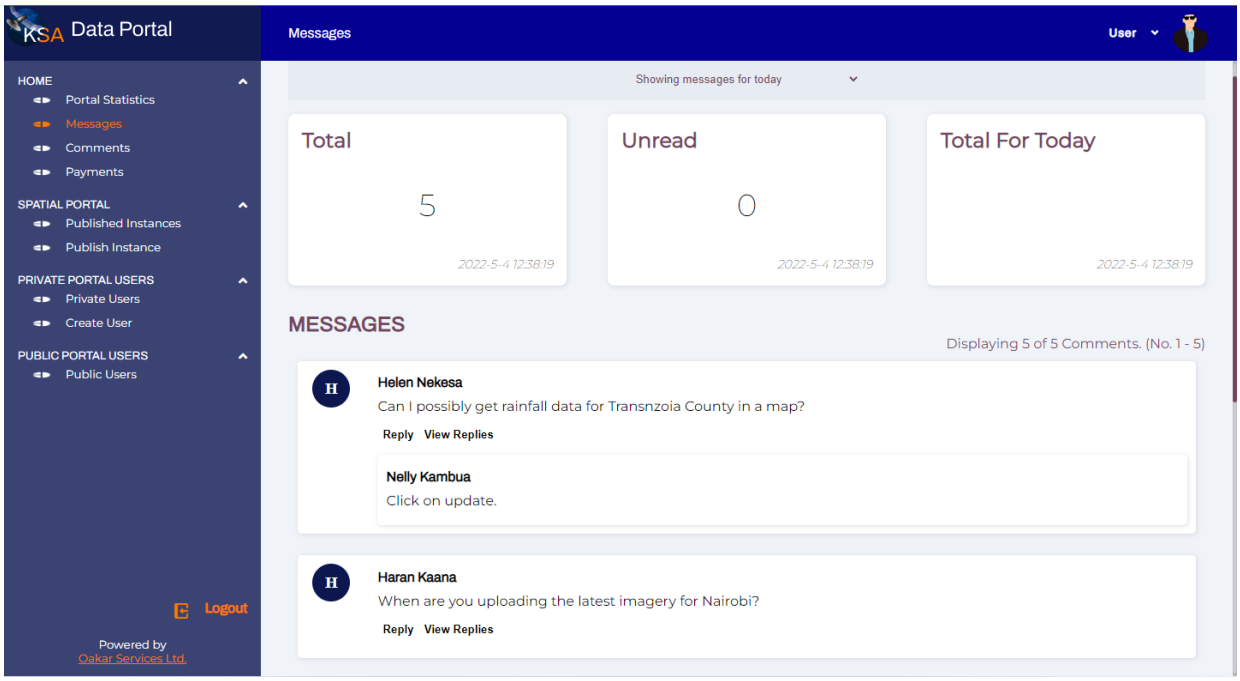
For the Admin Portal, the home section contains the portal statistics page, messages page, comments page, and the payments page. The portal statistics show the number of visits to the public portal, the number of downloads, and map queries performed in the public side as shown in Figure 3.2.

Figure 3.2: Admin Portal Home Page



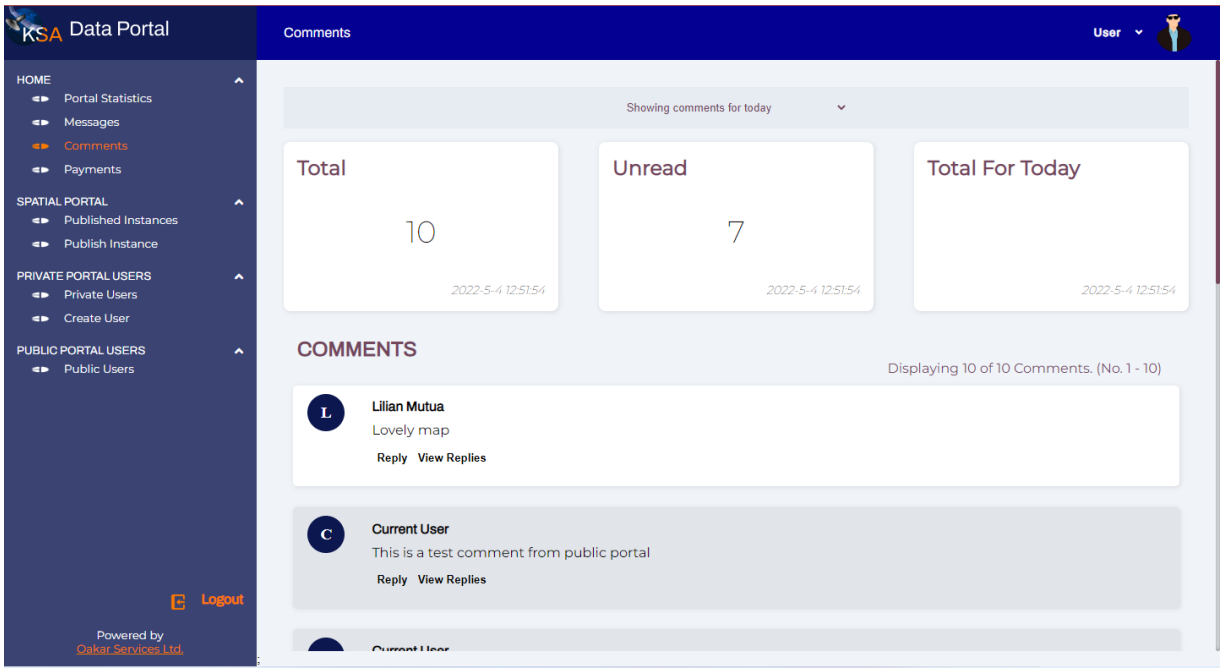
The Messages page is as shown in Figure 3.3 and displays messages from the public users. A summary of the Total Messages, Unread Messages, and Messages of a Particular date is displayed in the head section. The admin can view messages from public users and send replies. This feedback mechanism enables interaction between the public users and the system administrators.

Figure 3.3: Portal Statistics Page



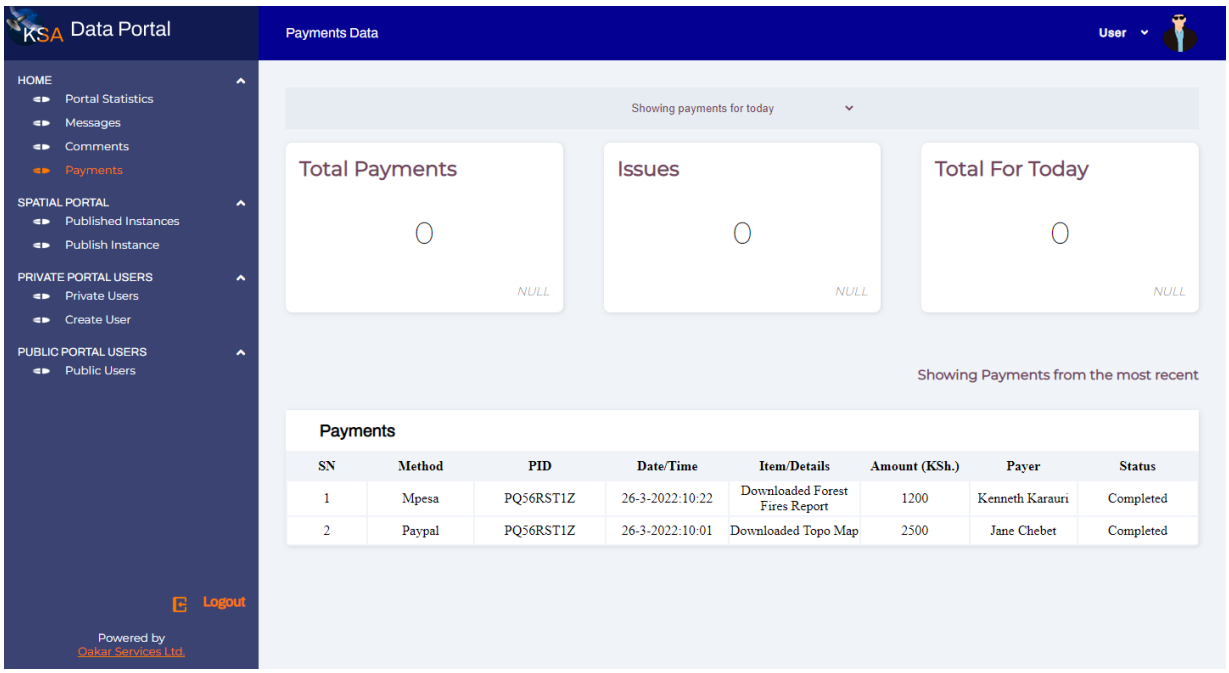
The Comments page is as shown in Figure 3.4 and displays comments from the public users. Unlike Messages, the Comments page shows a user's feedback specific to a published instance. The admin can view and reply to the comments.

Figure 3.4: Comments Page



The payments page is as shown in Figure 3.5 and displays data on payments made by public users for downloads of data and/or maps.

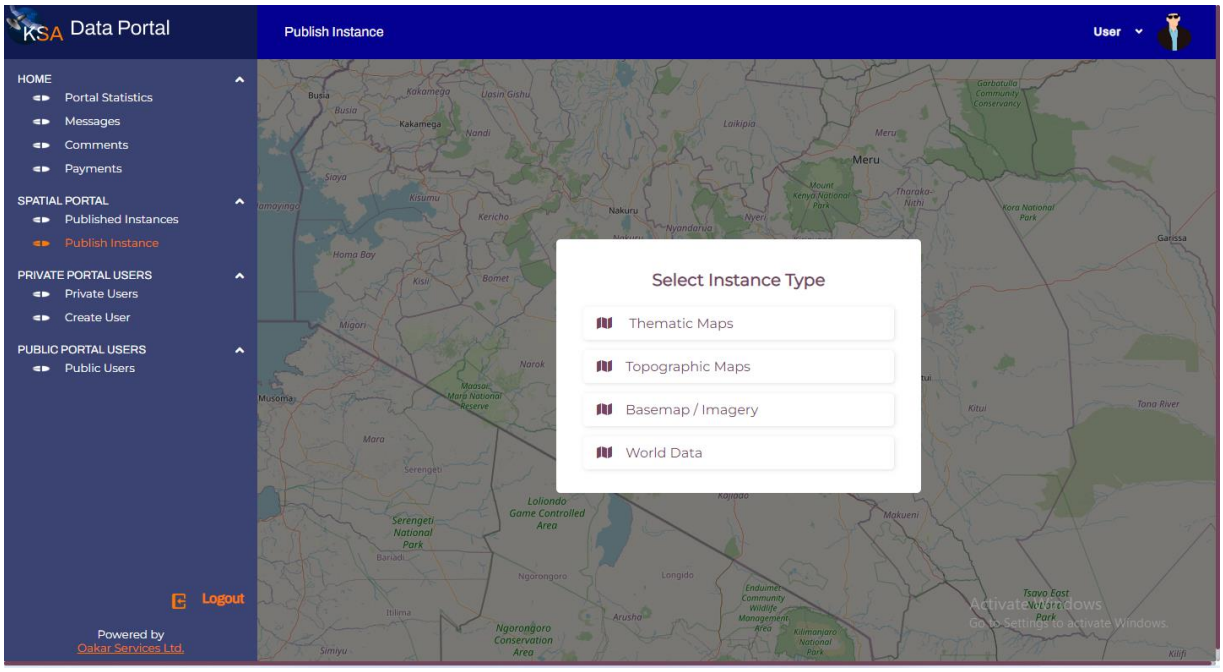
Figure 3.5: Payments Page



3.1.3 Spatial Portal Section

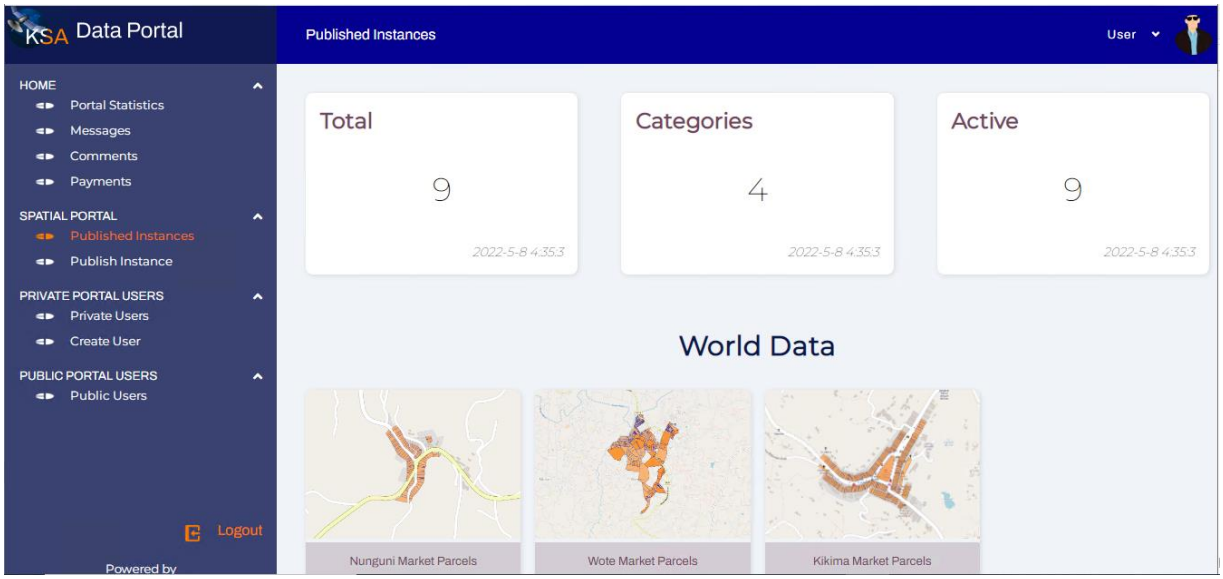
This section enables the administrator and other users of the admin portal to manage the instances published in the public portal. Instances include maps and data. The Administrator can publish Thematic Maps, Topographical Maps, Basemaps/Imagery, and World Data to the public portal as shown in Figure 3.6.

Figure 3.6: Publish Instance



Users of the admin portal are also able to see all the published instances with the options to Preview, Delete and Edit as shown in Figure 3.7.

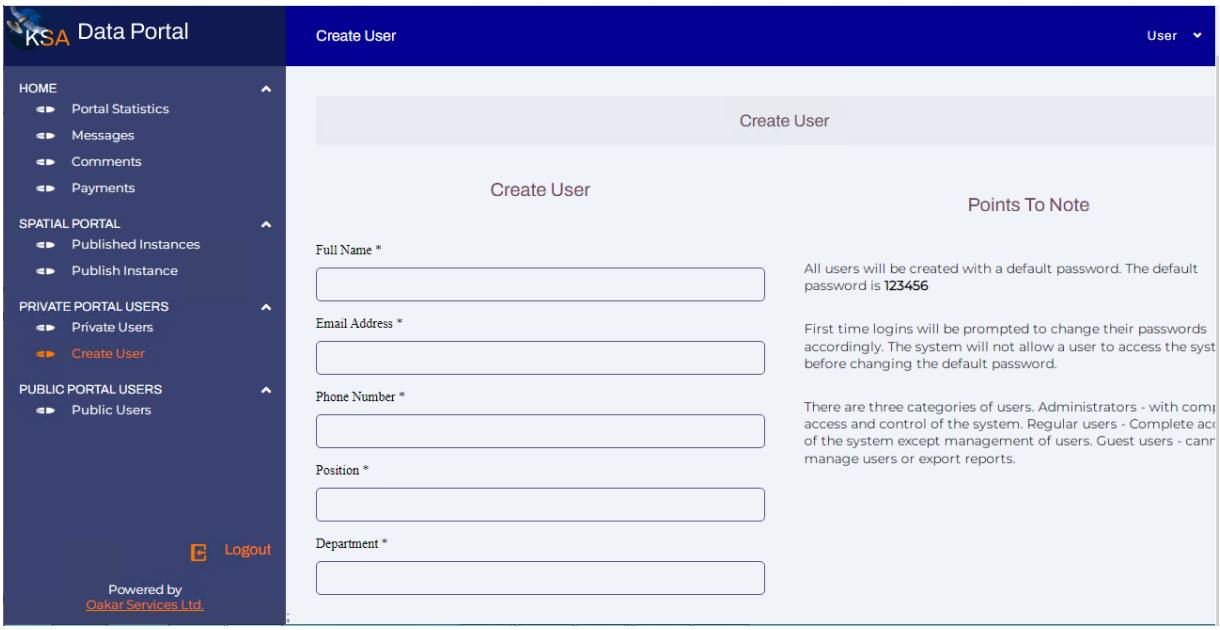
Figure 3.7: Published Instances



3.1.4 Users Section

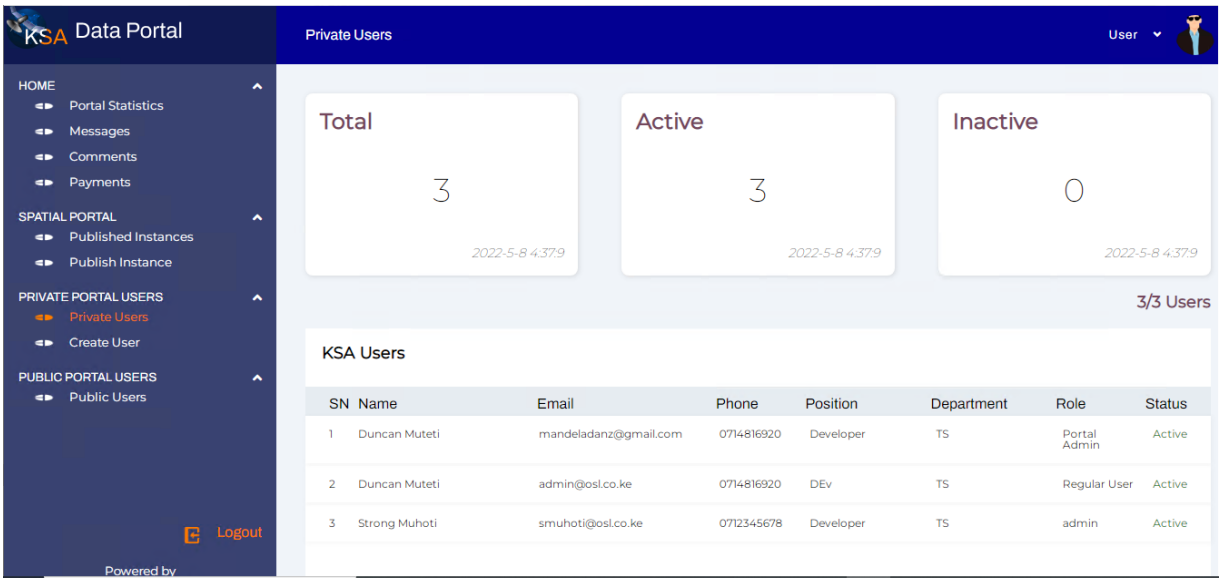
This section enables the system administrator to manage users of the Geo-Platform. Access to the user section is restricted to only the administrator accounts of the admin portal. The administrator can create users of the admin portal as shown in Figure 3.8.

Figure 3.8: Create User Page



The administrator can also disable, enable and delete user accounts of both the public and admin portal as shown in Figure 3.9

Figure 3.9: Delete User Page



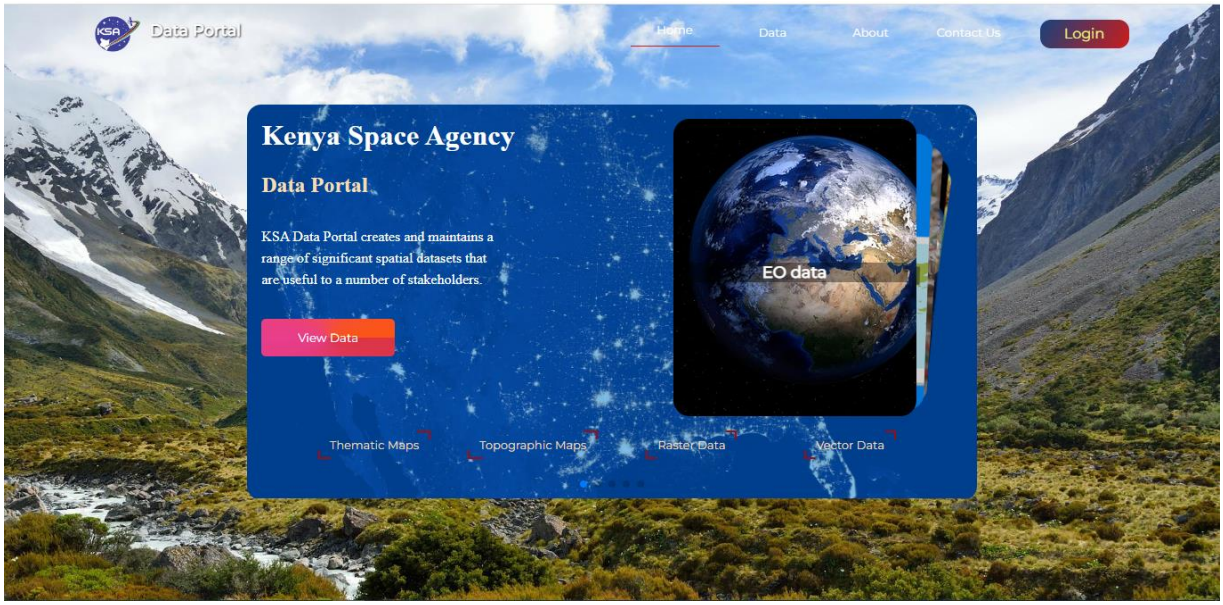
3.2 Public Portal

The main aim of the public portal is to enable KSA to disseminate data and maps to the general public. The public portal is accessible to all members of the public with and without login credentials. The Portal enables KSA to disseminate Thematic data, Topographic Maps, Base Maps and World Data. The data can be downloaded in different formats or shared as OGC compliant web services. The public portal is accessible to the public and contains the following pages; Register Login, Home, Data, About, and Contact Us.

3.2.1 Home Page

Figure 3.10 shows the home page of the public portal. A user is able to access functionalities of the Data Portal. However, some functionalities will require the user to be logged in. The Home page displays a brief description of the data portal, available pages and a categorization of the all the data instances.

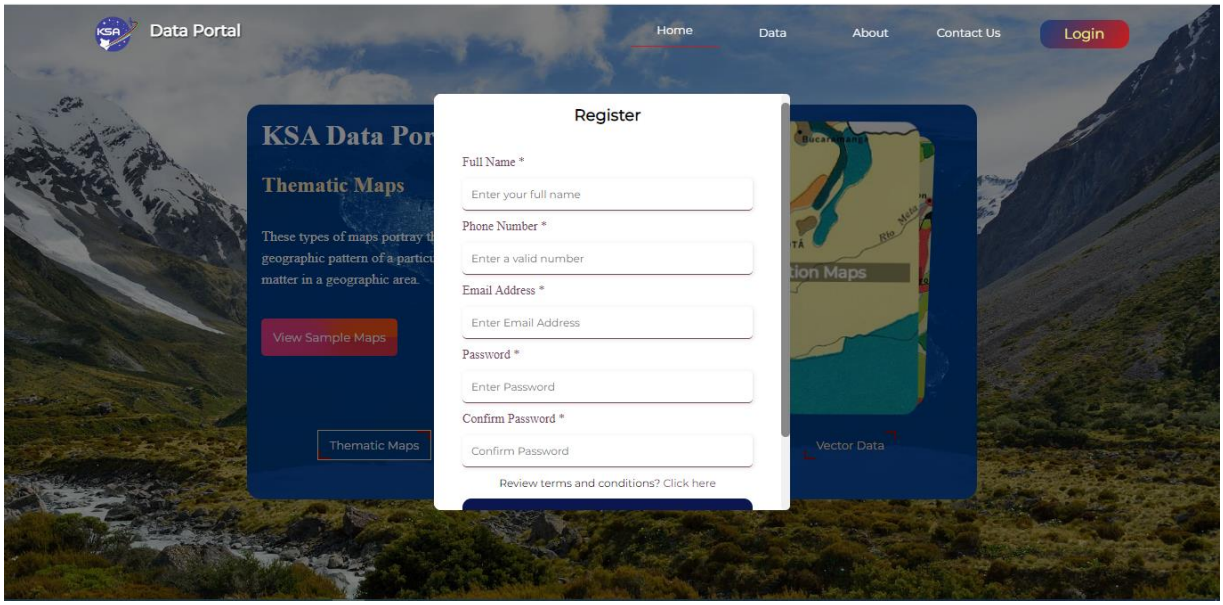
Figure 3.10: Public Portal Home Page



3.2.2 Accessing the Public Portal

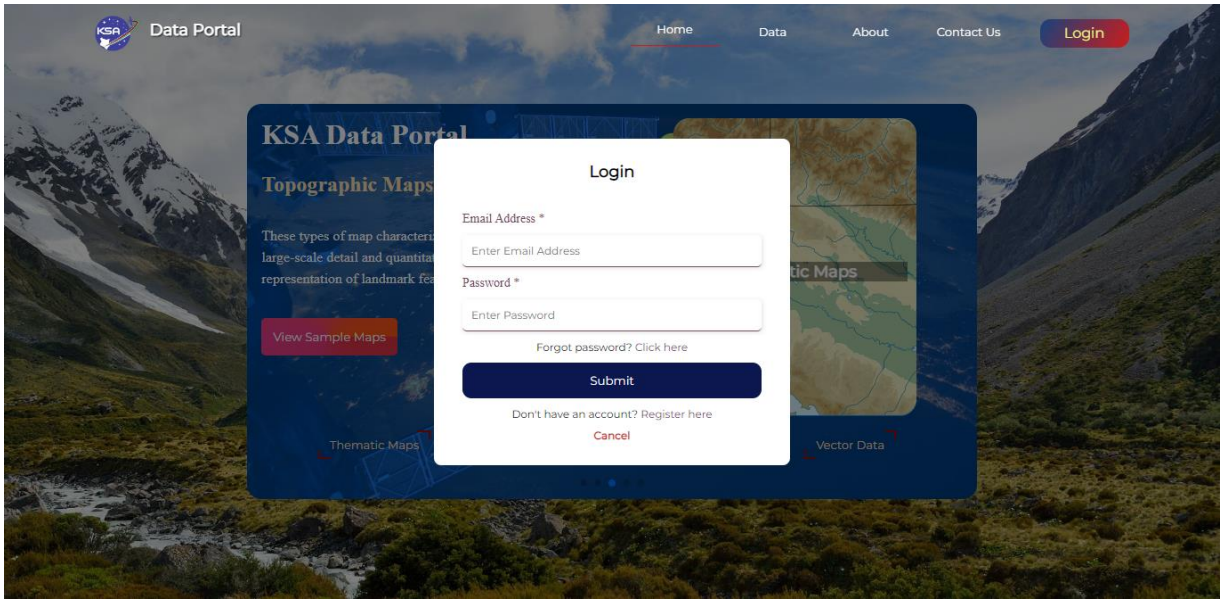
Public users can register as users of the public portal by creating an account. Unlike the Admin portal, the public portal allows users to create their accounts and manage their passwords as shown in Figure 3.11

Figure 3.11: Public Portal Register Page



To login to the public portal, a user needs an email address and the password created during registration as shown in Figure 3.12. A user can change password.

Figure 3.12: Public Portal Login Page

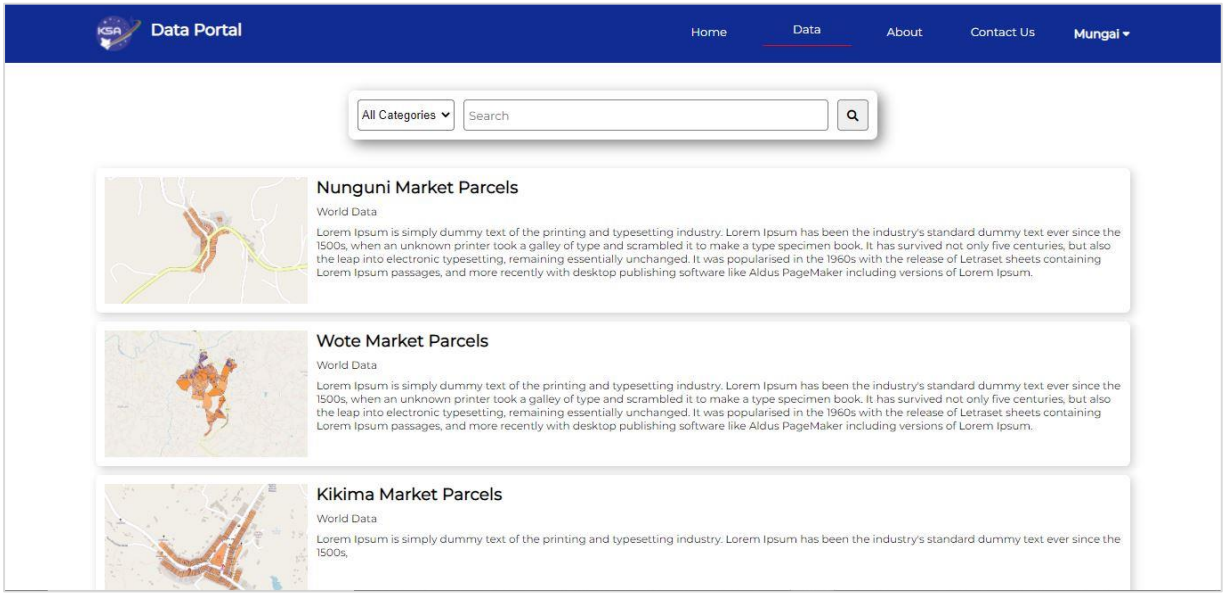


3.2.3 Accessing Data

The data page shows all the data published in the public portal by the administrator through the admin portal. The data has been categorized into Thematic Data, Topographical Maps, Base Maps and World Data.

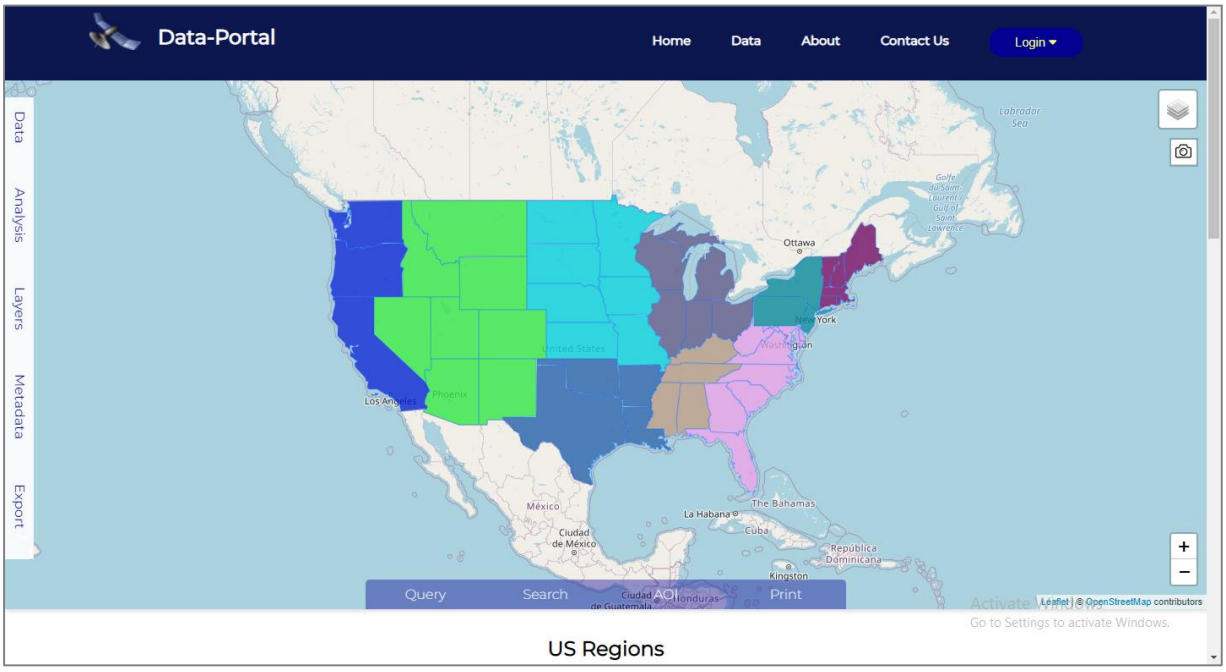
Users can search based on the titles and keywords as shown in Figure 3.13.

Figure 3.13: Public Portal Data Page



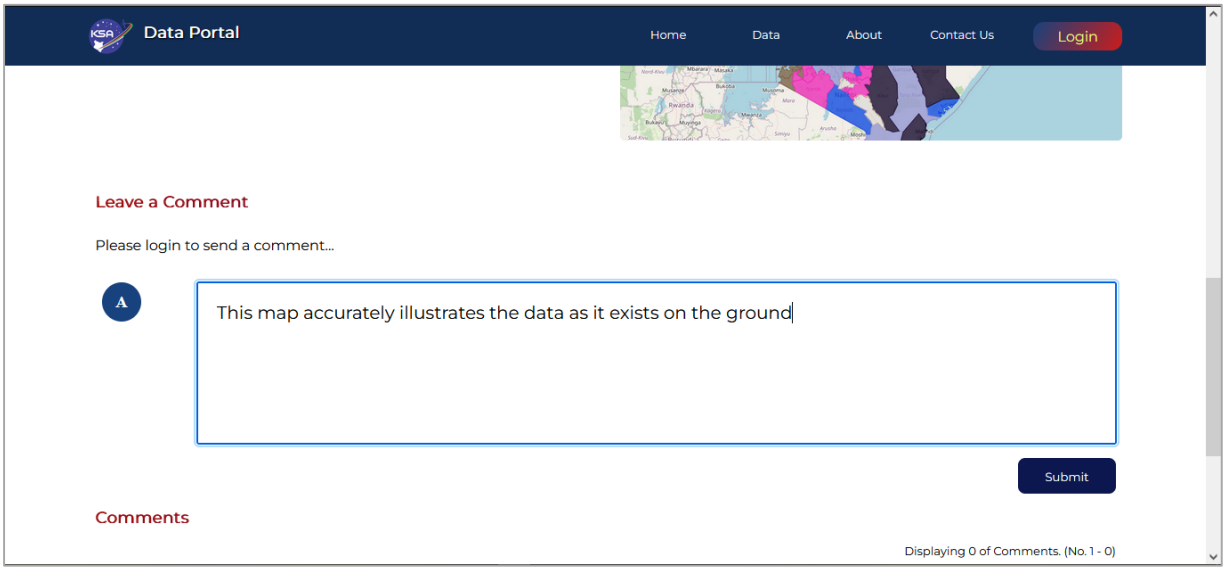
A user can view single instances of published data as shown in Figure 3.14.

Figure 3.14: Zoomed In View of Single Instances



Users can make comments on the quality of maps, type of data and ask various questions regarding the published instance. The system administrator will receive, view and respond to the comments through the Comments Page of the Admin Portal. Users can also get a reply on the comments through email address.

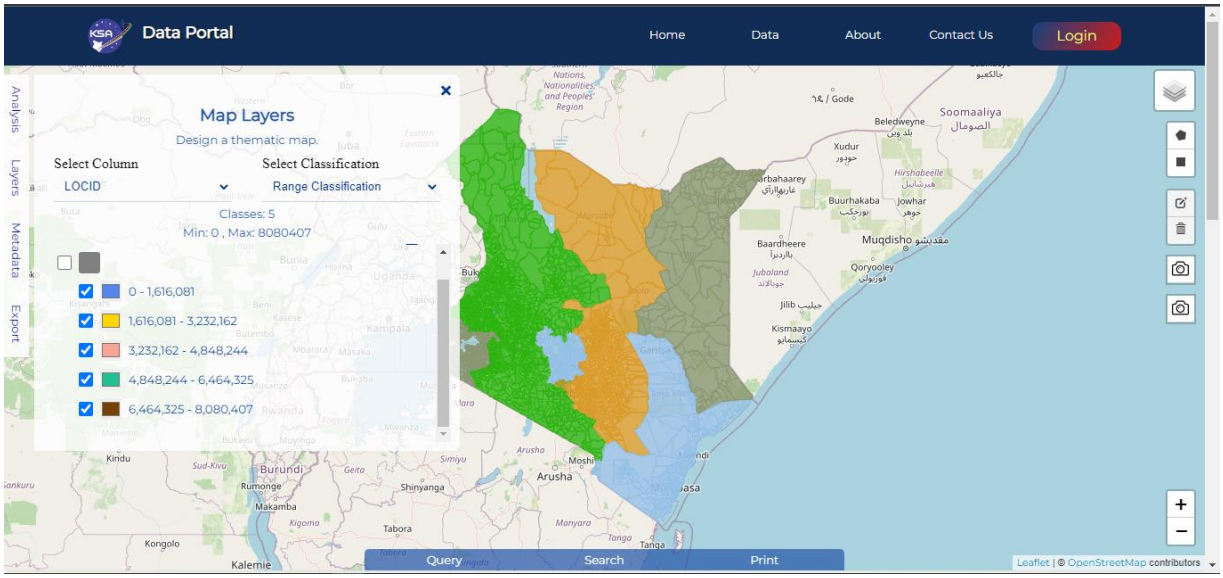
Figure 3.15: Zoomed In View of Single Instances



3.2.4 Simple Analysis

Users can perform simple analyses on the data using the Layers Tab. The analysis allows users to visualize the different attributes of the data in a color coded schema. The portal also allows users to query the data using the query builder and filter data using the search tool.

Figure 3.16: Zoomed In View of Single Instances



3.2.5 Building Queries

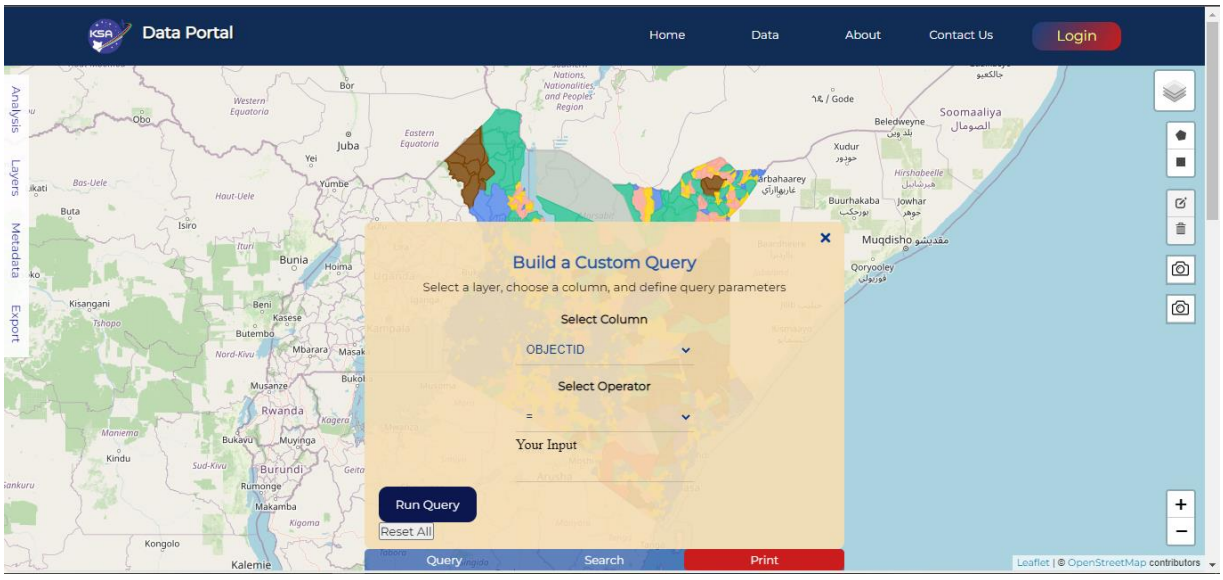
The Query Builder allows users to search and retrieve data by creating simple queries. To buld a query in the Public Portal, a user selects the column to search data from, the operatoe to use and the input to search. The user input can be informed by the type of operator selected. The Query tool has been enriched to provide users with various operators as shown in Table 3.1.

Table 3.1: Operators for Building Queries

Symbol	Label	Description
=	Equals to	The data to be retrieved is equal to the user input
<	Less than	The data to be retrieved is less than the user input
>	Greater than	The data to be retrieved is greater than the user input
iLike	Similar to	The data to be retrieved has key words, characters or values similar to the user input
<=	Less or equals to	The data to be retrieved is less or equal to the user input
>=	Greater or equal to	The data to be retrieved is greater or equal to the user input
<>	Not equals to	The data to be retrieved is not equal to the user input

The results of the query are immediately displayed on the map as ahown in Figure 3.17.

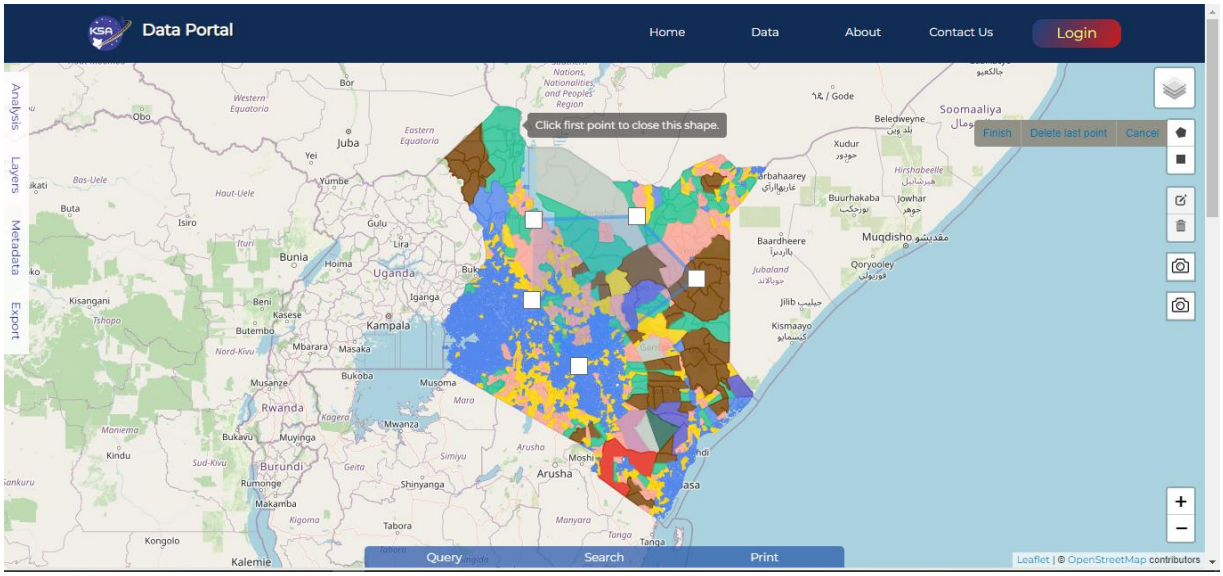
Figure 3.17: Zoomed In View of Single Instances



3.2.6 Defining Area of Interest (AOI)

The AOI tool enable users to define custom Areas on Interest by drawing polygons on the map. The user can then base their analysis on the defined area.

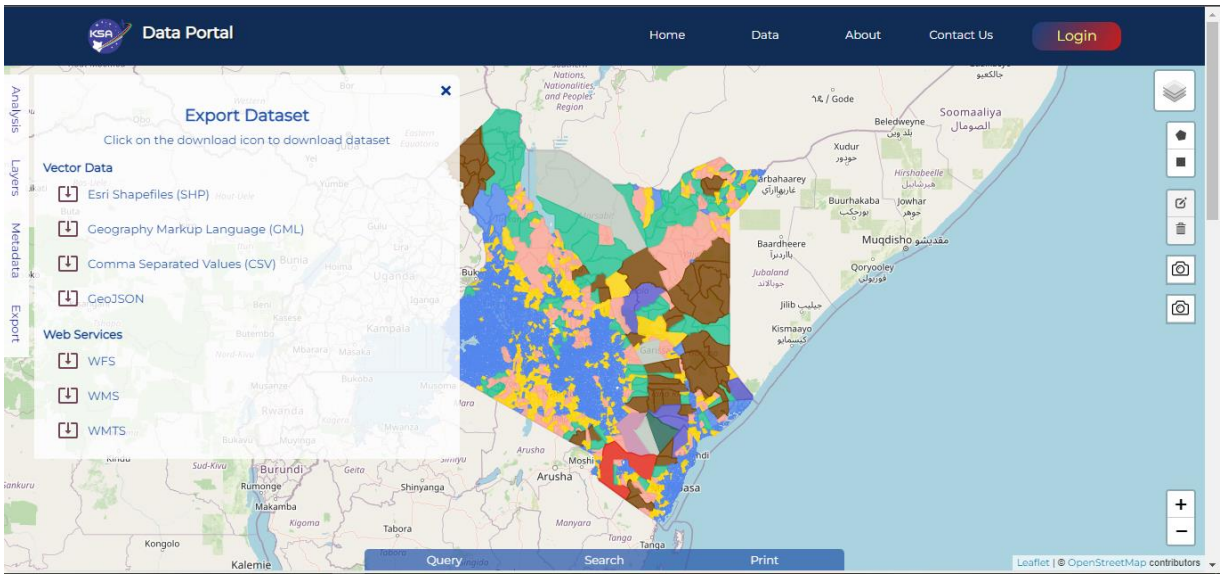
Figure 3.18: Zoomed In View of Single Instances



3.2.7 Downloading Data

Users can also share data in OGC Compliant webs services such as WFS, WMS, WMTS and WCS.

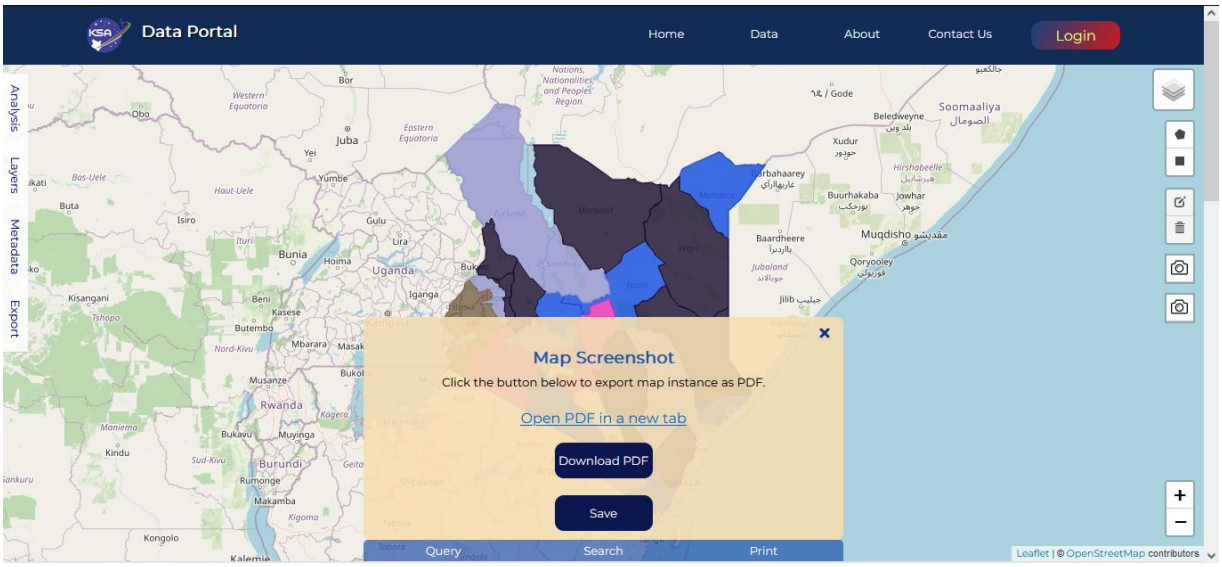
Figure 3.19: Zoomed In View of Single Instances



3.2.8 Exporting Maps

Analyzed maps can be exported in PDF formats containing the title of the map, a brief description, a legend and a preview of the analysis.

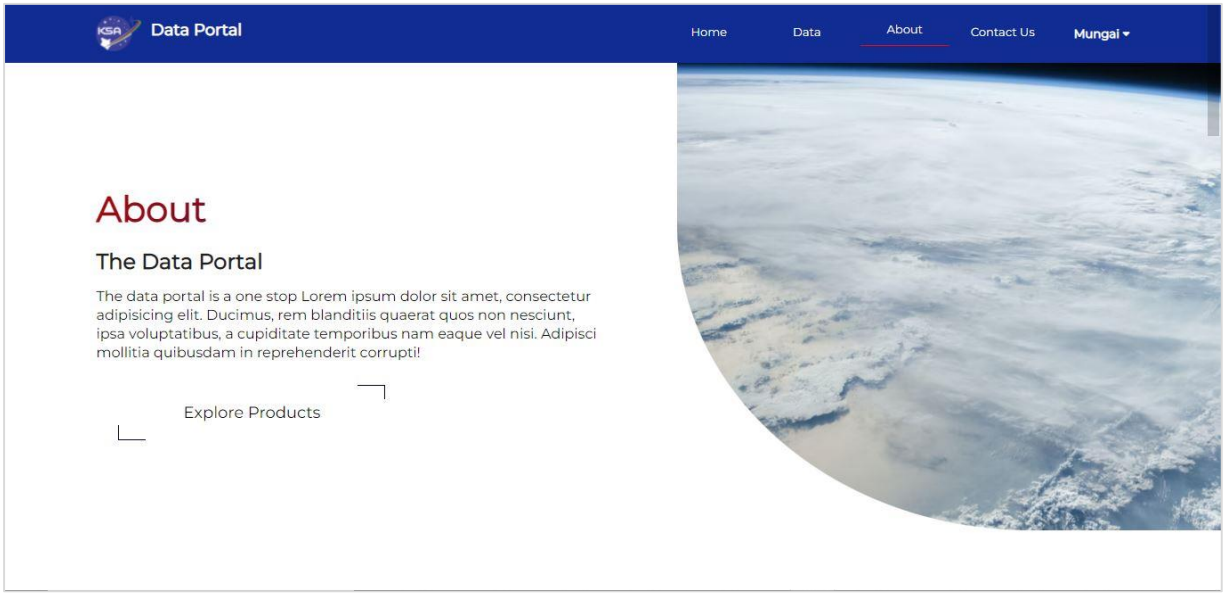
Figure 3.20: Zoomed In View of Single Instances



3.2.9 About Page

The About Page contains information about the entire Data Portalas shown in Figure 3.21

Figure 3.21: Public Portal About Page

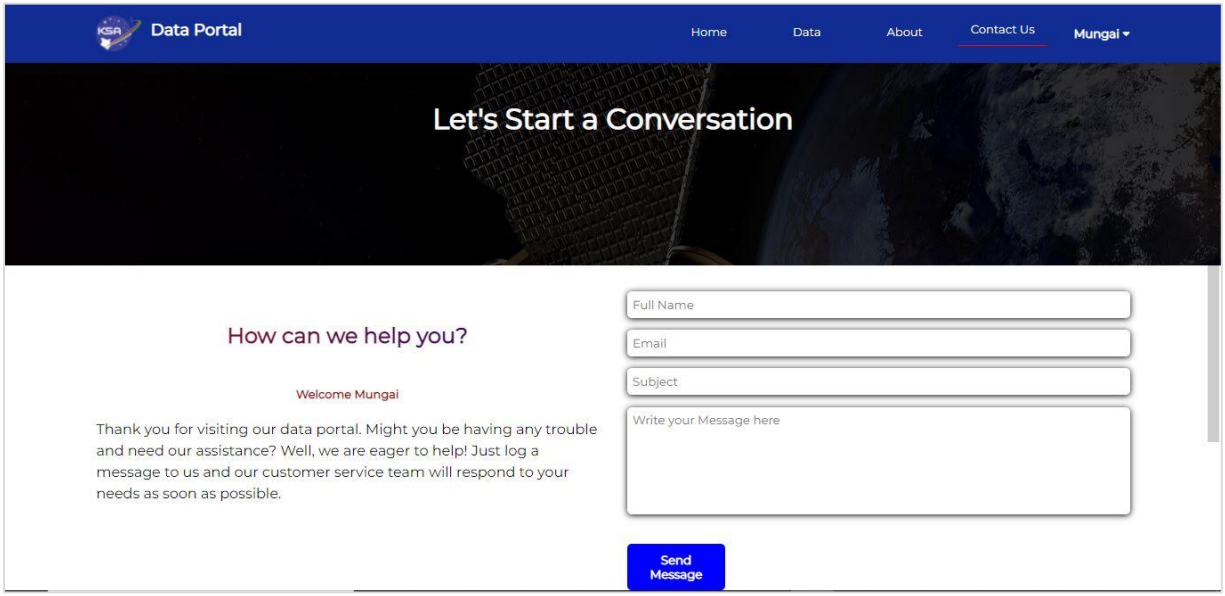


3.2.10 Contact Us Page

This Page contains provides an interactive feedback mechanism that provides functionalities for the user to communicate with the system administrator. A user can type messages and send them directly to the administrator as shown in Figure 3.22. The administrator receives the message through the messages page of the admin portal and can respond.

The Contact Us page also contains contact details for The Kenya Space Agency including phone numbers, email addresses, and postal addresses.

Figure 3.22: Public Portal Contact Us Page



Generally, the public portal enables users of the Data Portal to:

1. Access data for different thematic layers and base maps (high-resolution satellite images, topographic maps, and hybrid maps) that are disseminated by KSA.
2. Perform spatial analysis of thematic data layers such as buffer analysis and proximity analysis.
3. Build custom queries on thematic data.
4. Report and update events such as forest fires, floods, landslides, and natural calamities along with photograph storage.
5. Access cadastral maps that have been availed by the Kenya Space Agency.
6. Access and prepare a digital atlas for administrators, planners, or resource managers.

4 EXERCISES AND TUTORIALS

In this chapter, the user is guided through the entire system via a set of tutorial exercises. These exercises are complementary to training courses on the specific technologies implemented in the system i.e. Fundamentals of PostgreSQL Databases, Web Mapping using Geoserver, and Open Data Cube. The following exercises show the basic functionalities that are deemed relevant for a user of The KSA Geo-Platform. It is assumed that the user has installed PostgreSQL, Geoserver, and Open Data Cube.

4.1 Adding Data to PostgreSQL

This chapter involves using PostGIS, for PostgreSQL. It will also dwell on the PostGIS features as well as writing spatial queries and analysis. PostGIS is a spatial database extender for PostgreSQL object-relational database. It adds support for geographic objects allowing location queries to be run in SQL. In addition to basic location awareness, PostGIS offers many features[3] rarely found in other competing spatial databases such as Oracle Locator/Spatial and SQL Server.

This exercise assumes that the user has already Installed PostgreSQL and PostGIS extension as it is part of the system.

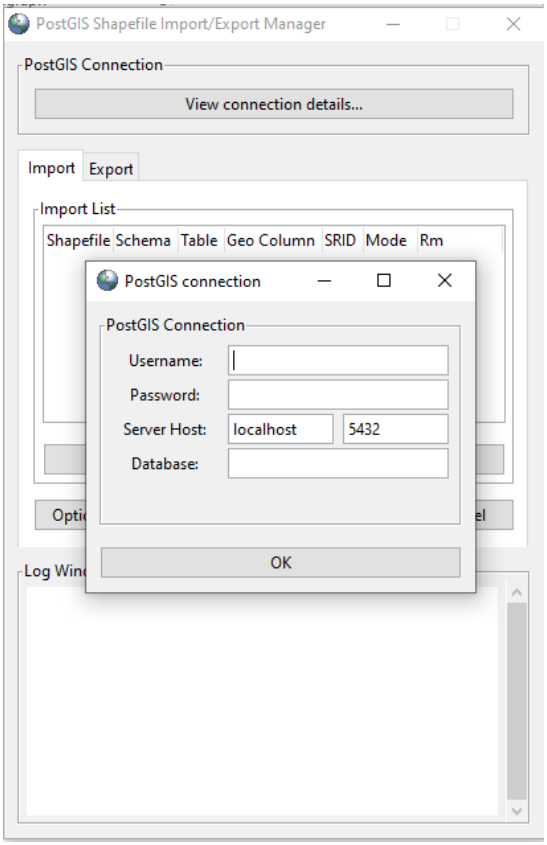
[3] POSTGIS features

a) Processing and analytic functions for both vector and raster data for splicing, dicing, morphing, reclassifying, and collecting/unioning with the power of SQL
b) raster map algebra for fine-grained raster processing
c) Spatial reprojection SQL callable functions for both vector and raster data
d) Support for importing / exporting ESRI shapefiles vector data via both command line and GUI packaged tools and support for more formats via other 3rd-party Open Source tools
e) Packaged command-line for importing raster data from many standard formats: GeoTIFF, NetCDF, PNG, JPG to name a few
f) Rendering and importing vector data support functions for standard textual formats such as KML, GML, GeoJSON, GeoHash and WKT using SQL
g) Rendering raster data in various standard formats GeoTIFF, PNG, JPG, NetCDF, to name a few using SQL
h) Seamless raster/vector SQL callable functions for extrusion of pixel values by geometric region, running stats by region, clipping raster by a geometry, and vectorising raster
i) 3D object support, spatial index, and functions
j) Network Topology support
k) Packaged Tiger Loader / Geocoder/ Reverse Geocoder / utilizing US Census Tiger data

4.1.1 Loading Data using PostGIS Import/Export Wizard

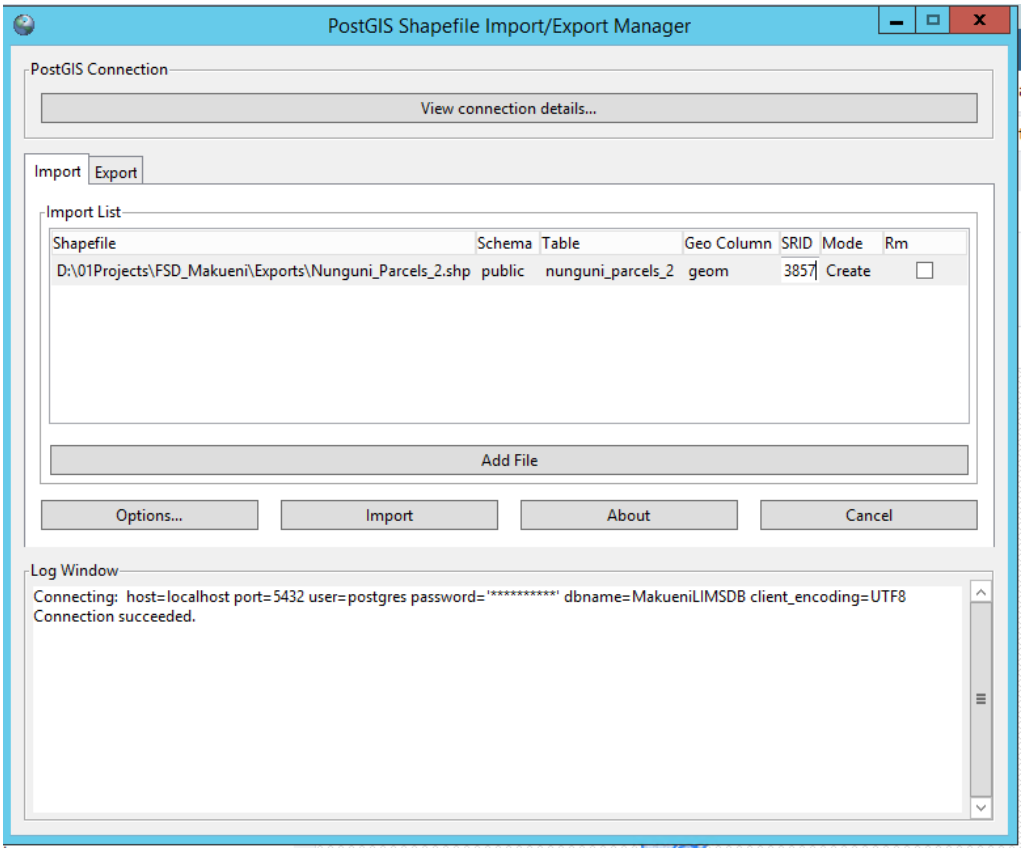
From Windows Programs, Open PostGIS Shapefile Import/Export Wizard.

- Click on 'View Connection Details' to connect to the database as shown below.
- Enter the connection parameters of the database to connect to and click OK.



- Now, click on the Add File button and browse to the shapefile containing the data. The tool doesn't recognize the SRS contained in the prj file.
- Set the value of the field to 3857 to any other EPSG code value of the coordinate system of your choice.

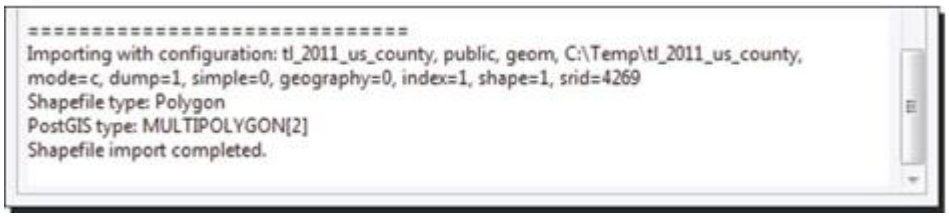
NOTE: We recommend using either EPSG 3857 or 4326 to publish data to PostGIS.



- Click on the Import button:

Wait while the loader transforms your data and inserts them into a new PostGIS table. Eventually, you should see a success message in the log textbox.

- Click on Cancel to dismiss the loader utility:



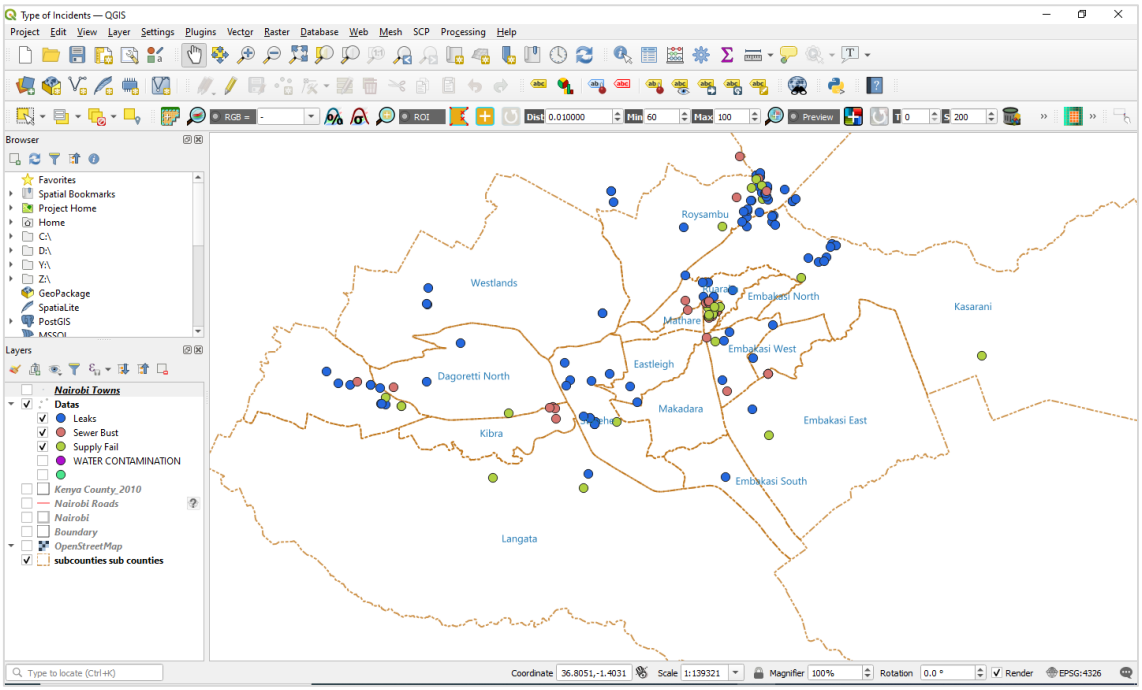
You have now saved the shapefile as a table in PostGIS.

- To display all the features in the table we have just imported, run the following query in the 'Query Tool'

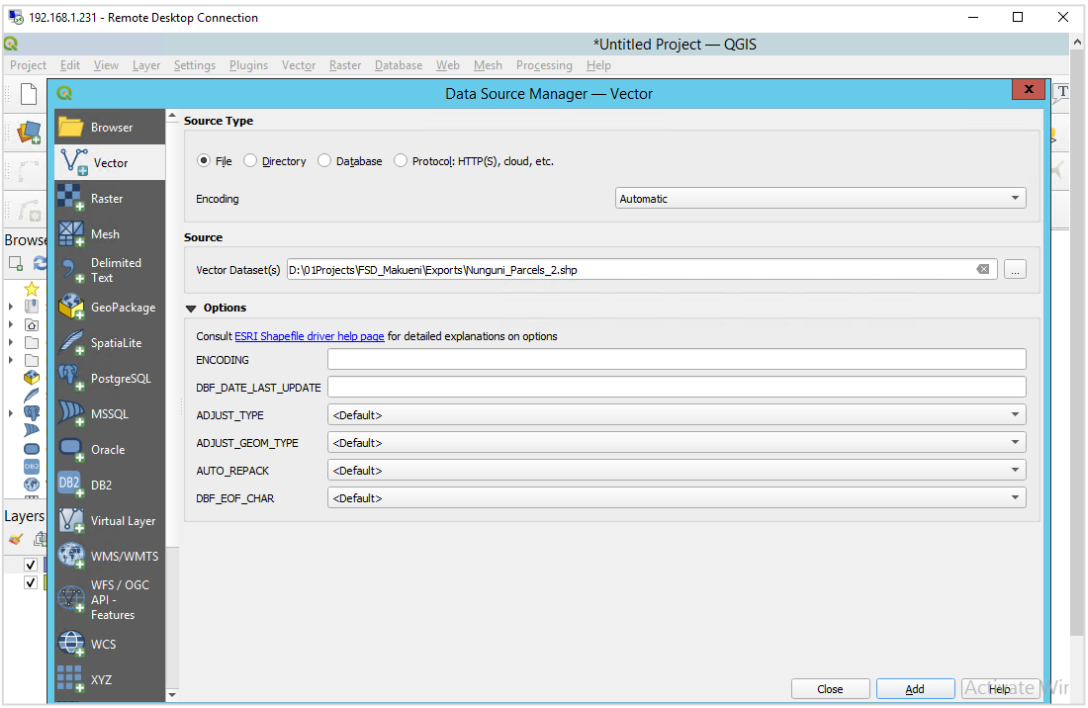
```
SELECT * FROM table_name
```

4.1.2 Loading Data to Database from QGIS

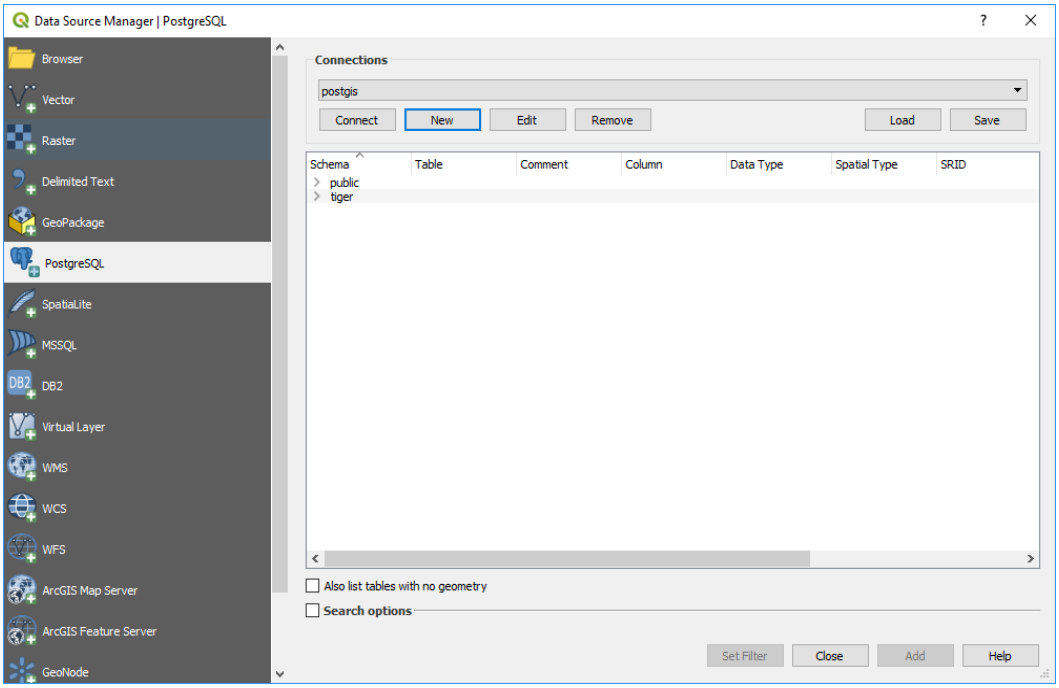
This exercise assumes that you have already displayed your data in QGIS software as shown in the example below.



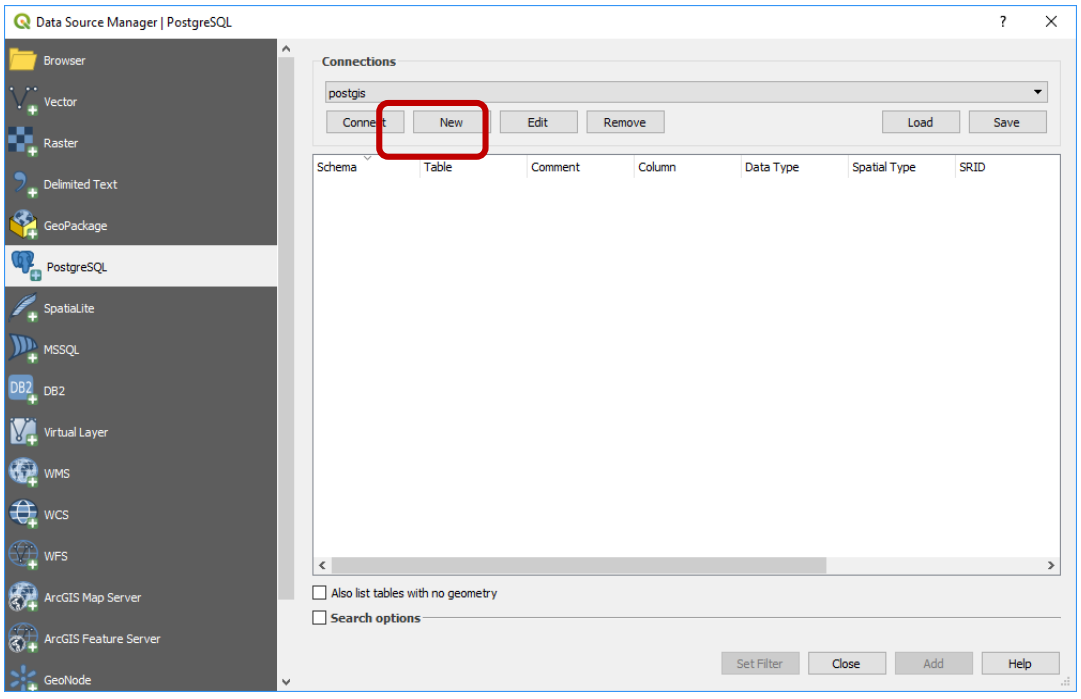
- On the layer's menu click on **Data Source Manager**. The Data Source Manager Window is displayed



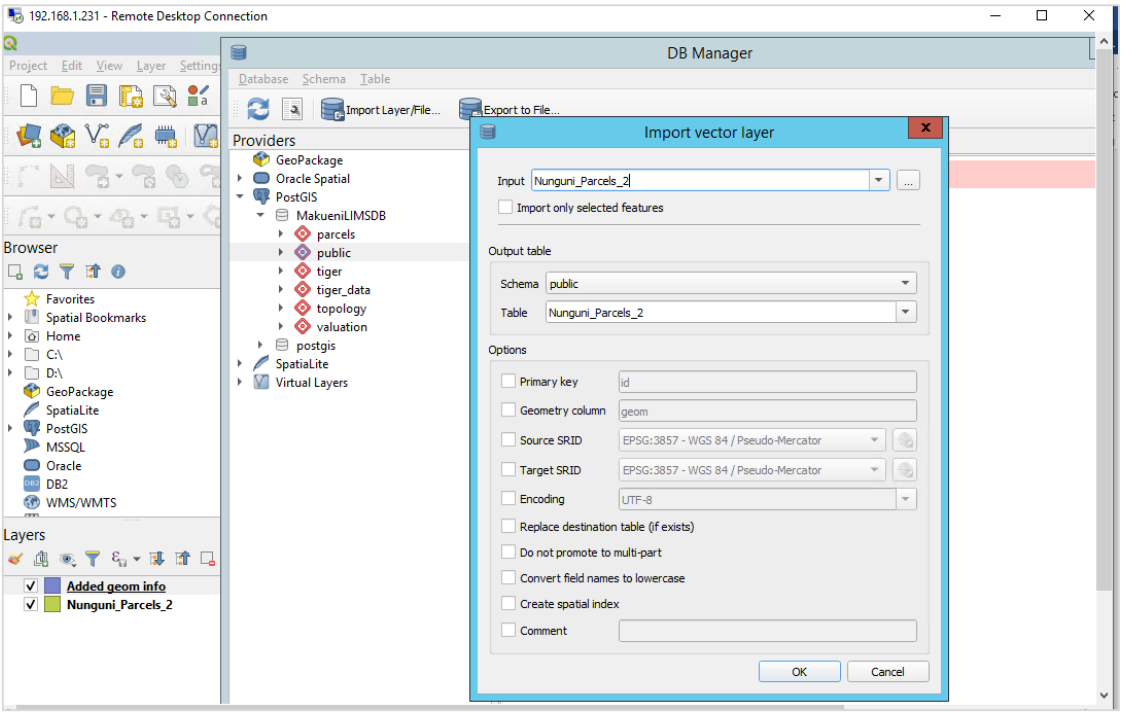
- On the data source manager, click on the **PostgreSQL** tab.



- Select **New Connection...**. Enter your credentials for your database



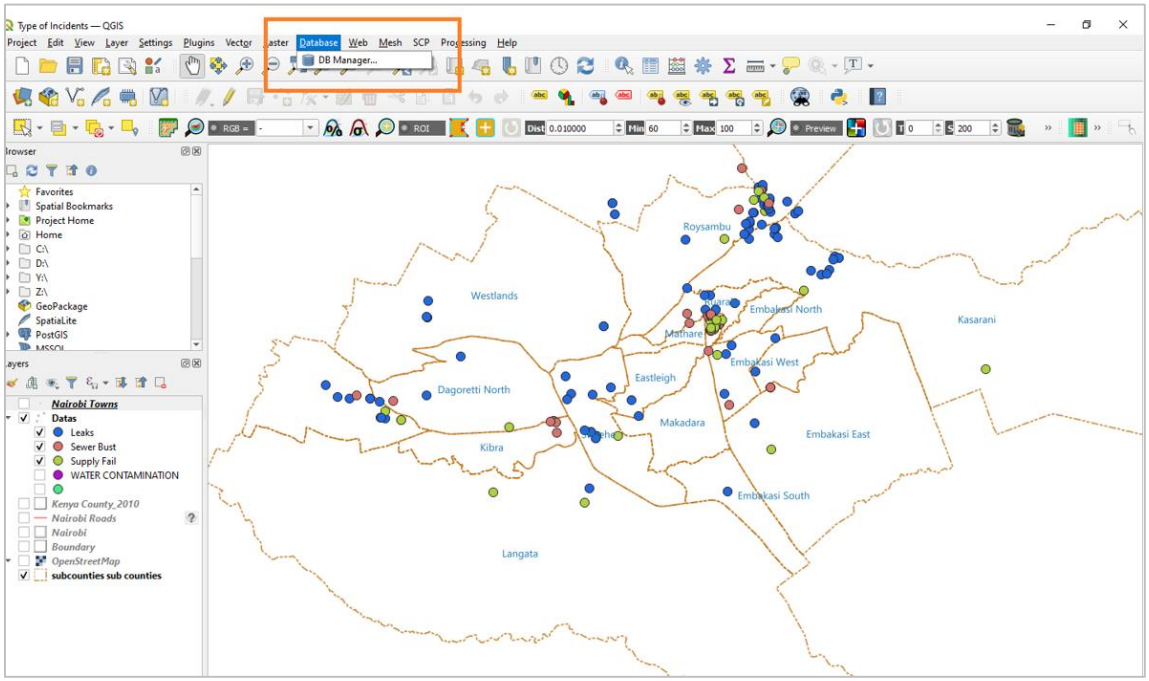
- Fill the resulting dialogue box as follows.

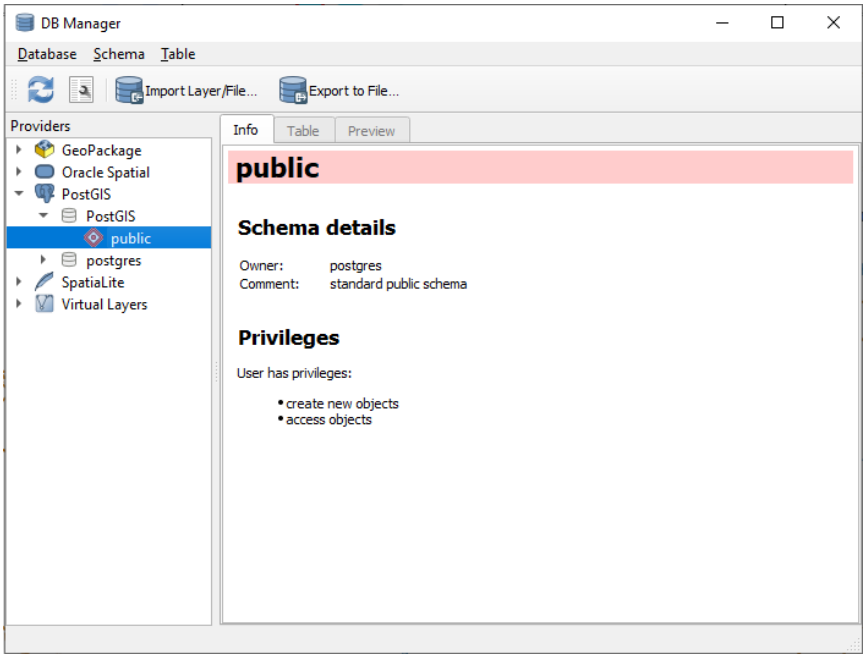


- *Test your Connection, and click OK.*

The next step is to add the data to PostGIS as a table.

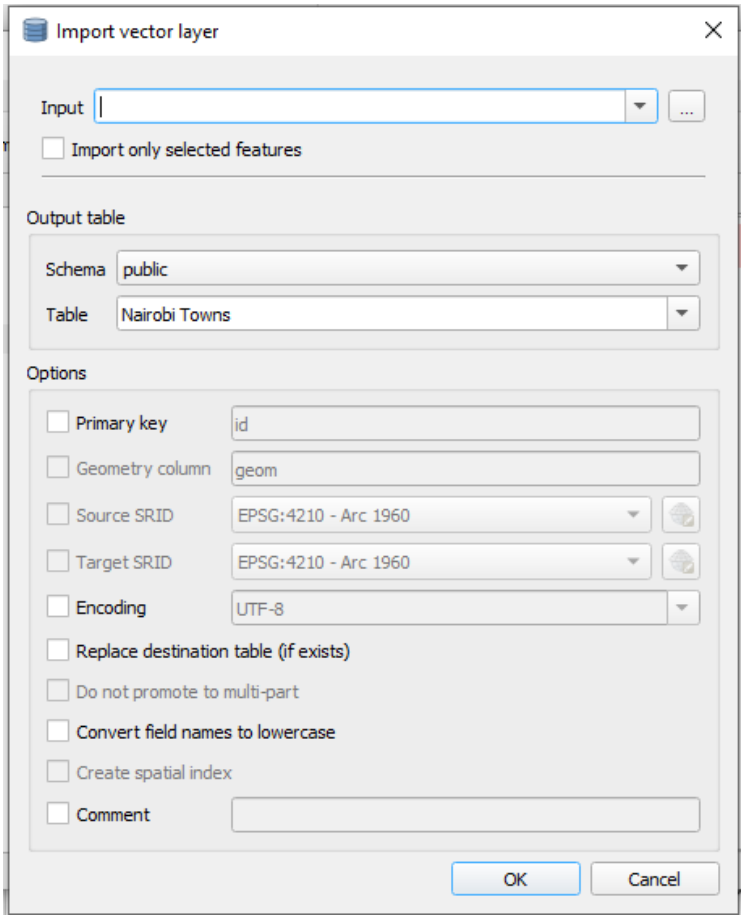
- From QGIS main tabs, Click on the 'Database' tab and select 'DB Manager' as shown below.





The DB Manager displays as shown above.

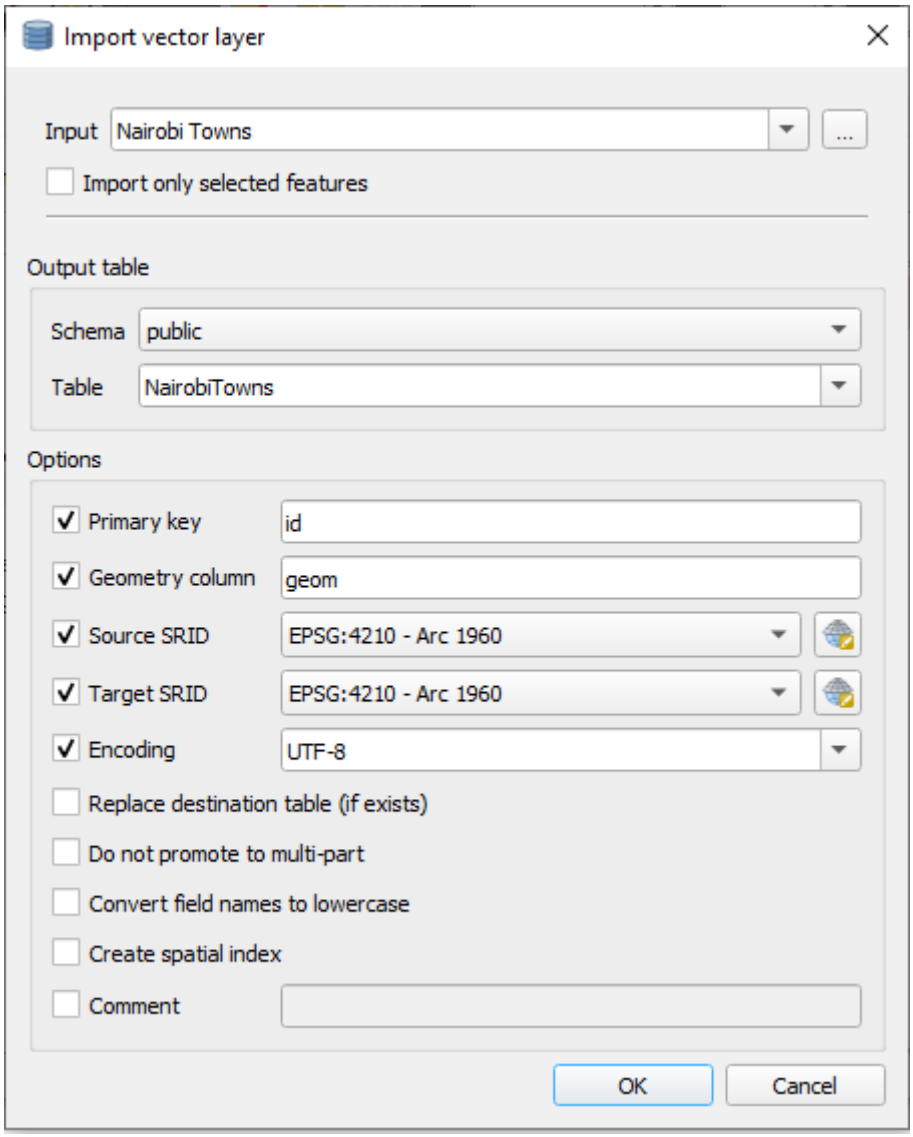
- Click on the drop-down arrow next to PostGIS to select the name of your database.
- Click on 'Import Layer/File' to open the Import dialog box and fill in the details as shown below.



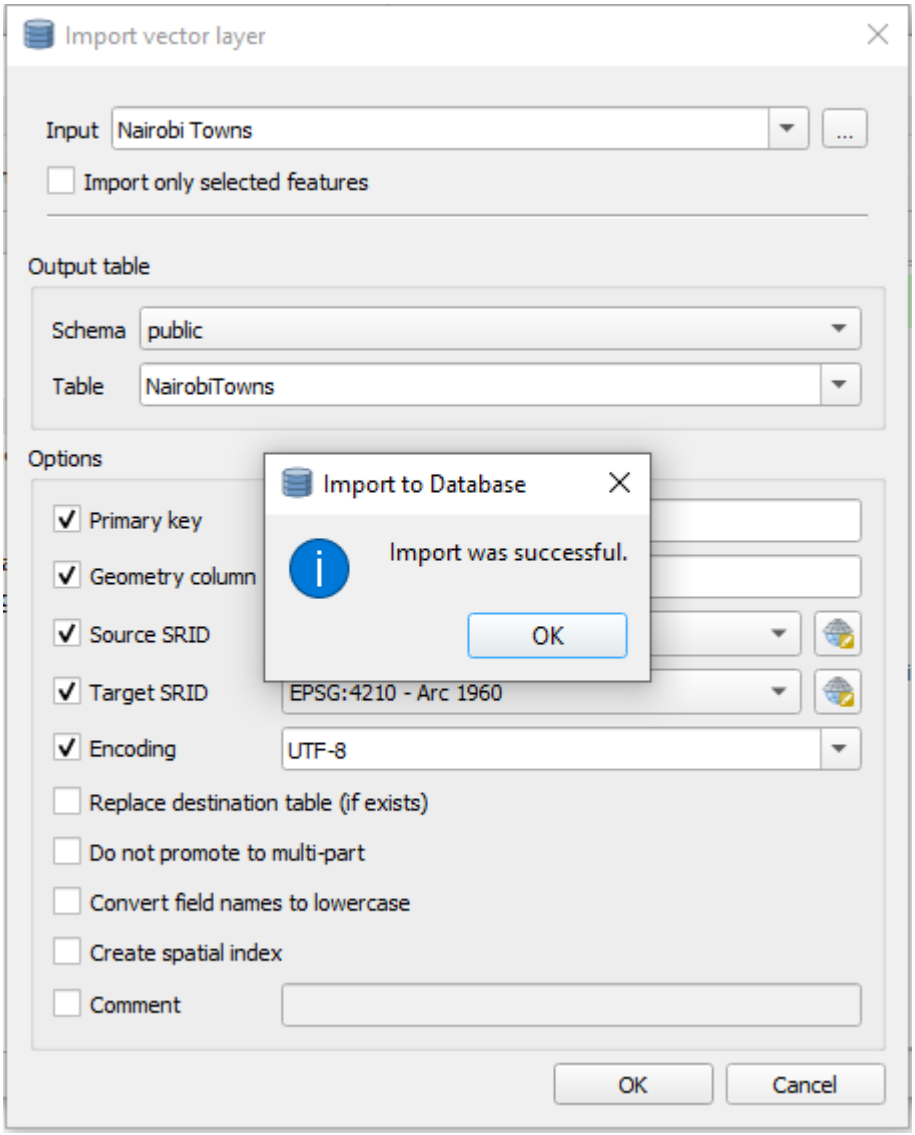
- In the Input Field, Select the Layer to be published to PostGIS. Select the schema using the drop-down arrow.

- Input the name of the Table that will be created in PostGIS to hold the data. It is advisable to use short names for the table and avoid spaces.

- In the Options section, check the Primary key, geometry column, Source SRID, Target SRID, and Encoding.



- Click 'OK' to Import the table to PostGIS.



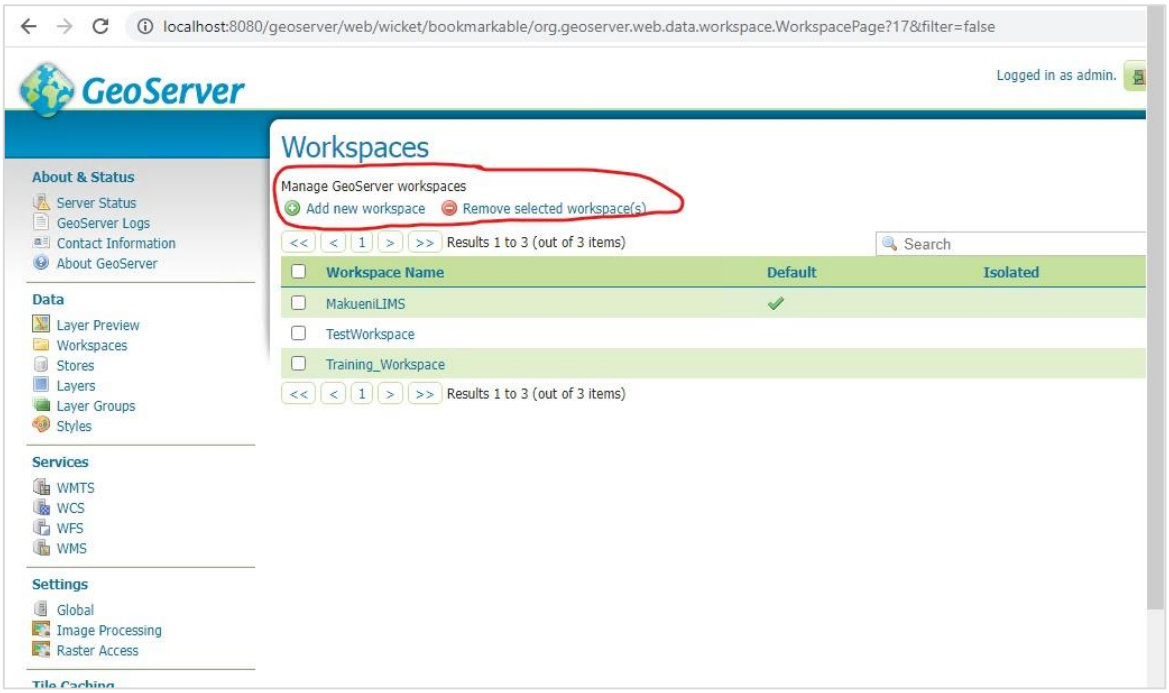
You have successfully added the data to PostGIS as a table! The next step is to publish the data added to PostGIS to Geoserver.

4.2 Adding Data to Geoserver

In this section, we will look at how to add data to Geoserver. KSA Geo-Platform pulls data from Geoserver. Therefore any data that has to be displayed in the application should first be added to Geoserver. There are different ways to add spatial data to Geoserver. For this exercise, we shall explore the following two ways:

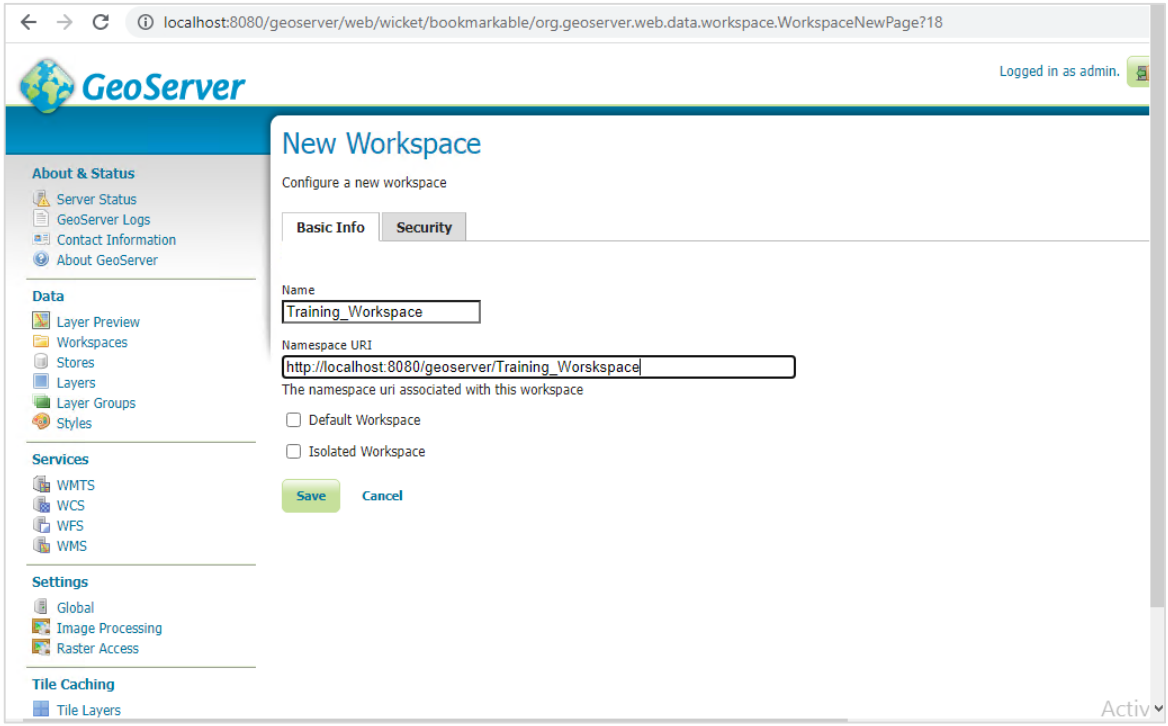
i. Adding data to Geoserver from PostGIS Database
ii. Adding data to Geoserver from a shapefile.

The first step in working with Geoserver is to create a Workspace. Workspaces enable a user to organize their data, layers, stores, etc. It is the working environment of a user in Geoserver.

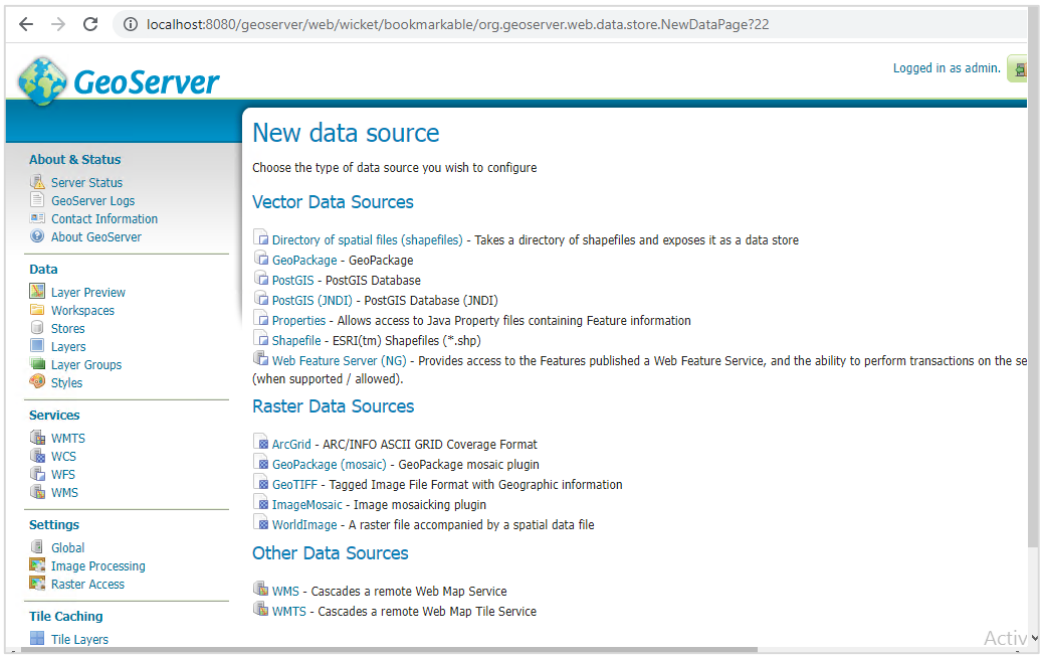


Exercise 1: To create a workspace for this exercise

- Go to the 'Data' Section and Click on 'Workspace'.
- On the Open window, click on 'Add New Workspace'



- In the resulting window, type the Name of the workspace as '**Training_Workspace'**.
- On the Link to the workspace add 'http://localhost:8080/geoserver/Training_Worskspace' and click 'Save''

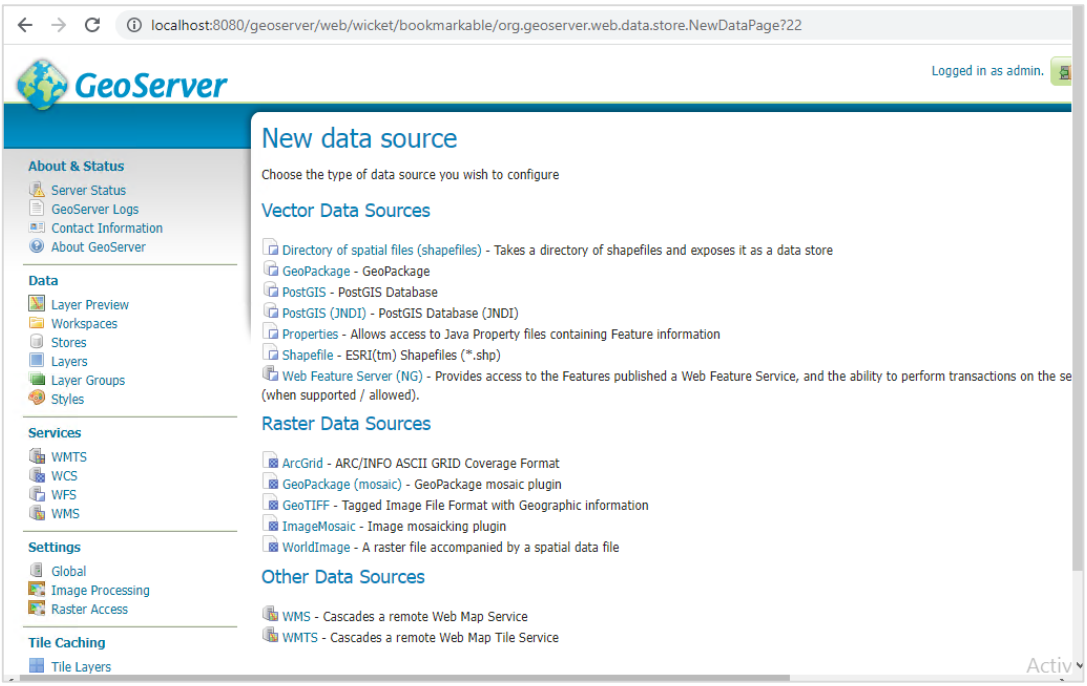


The workspace is successfully created and added to the list of existing workspaces. We will work with this workspace for the entire exercise.

4.2.1 Adding shapefiles

You can add shapefiles to GeoServer with two data sources. With the first, you configure a folder containing a set of shapefiles and you can add new ones after the data source is created. The other data source works the same way as the shapefile directory store, except you provide a path to a different data source (PostGIS). We will use the following steps to add a shapefile to Geoserver from a folder:

- Go to the 'Data' section and click on 'Stores'
  A store is a folder that organizes data in Geoserver. It is the equivalent of a warehouse in GeoMedia Desktop.
- Click on Add New Store.
  The resulting window displays some data source types that are supported by Geoserver as shown in the figure below.

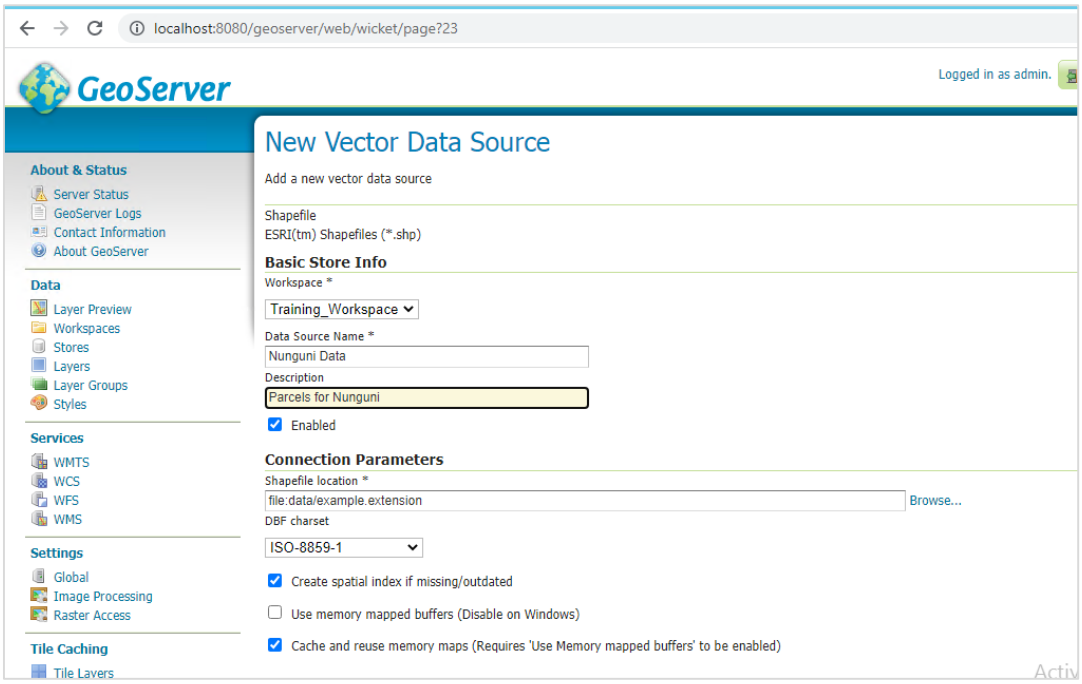


In this exercise, we are adding a Vector Data Source specifically a shapefile.

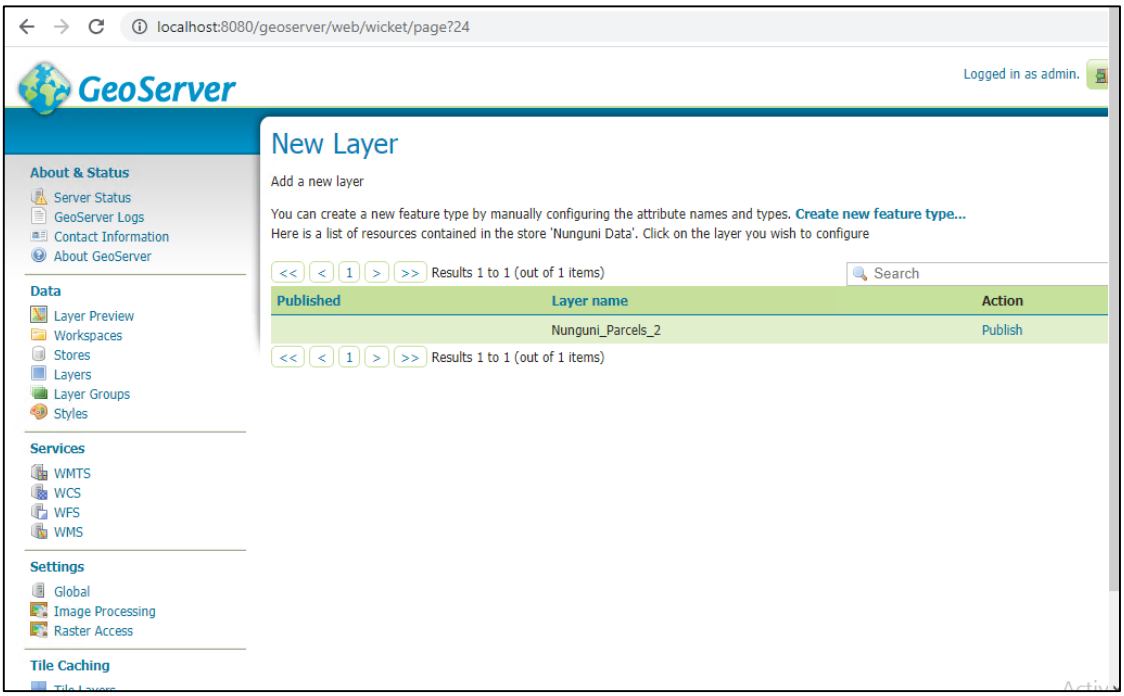
- Click on ‘Shapefile’
- For Workspace, select Training_Workspace
- For Data Source Name, type ‘Nunguni Data’. This will be the label of the shapefile we are adding in Geoserver.

You can also add a description just to provide an overview of your data.

The ‘Connection Parameters’ section connects to the root folder containing the data in the local drive.



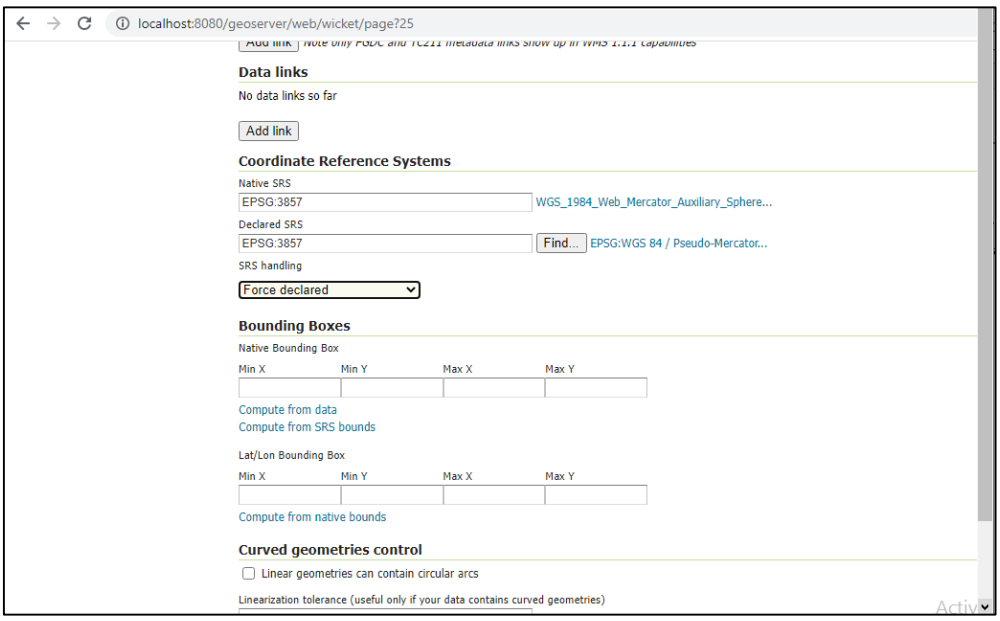
- Click on ‘Browse’. And navigate to the folder containing the shapefile i.e. Nunguni.shp
- Leave the other options as defaults and click ‘Save’
- On the next screen, click on Publish to start the process of creating a layer:



You have to complete some information in the form.

- Scroll down to the Coordinate Reference Systems and confirm that both the Native SRS and Declared SRS is EPSG 3857. If not, manually type EPSG 3857.

- Click on Compute from data and Compute from native bounds in the Bounding Boxes section:



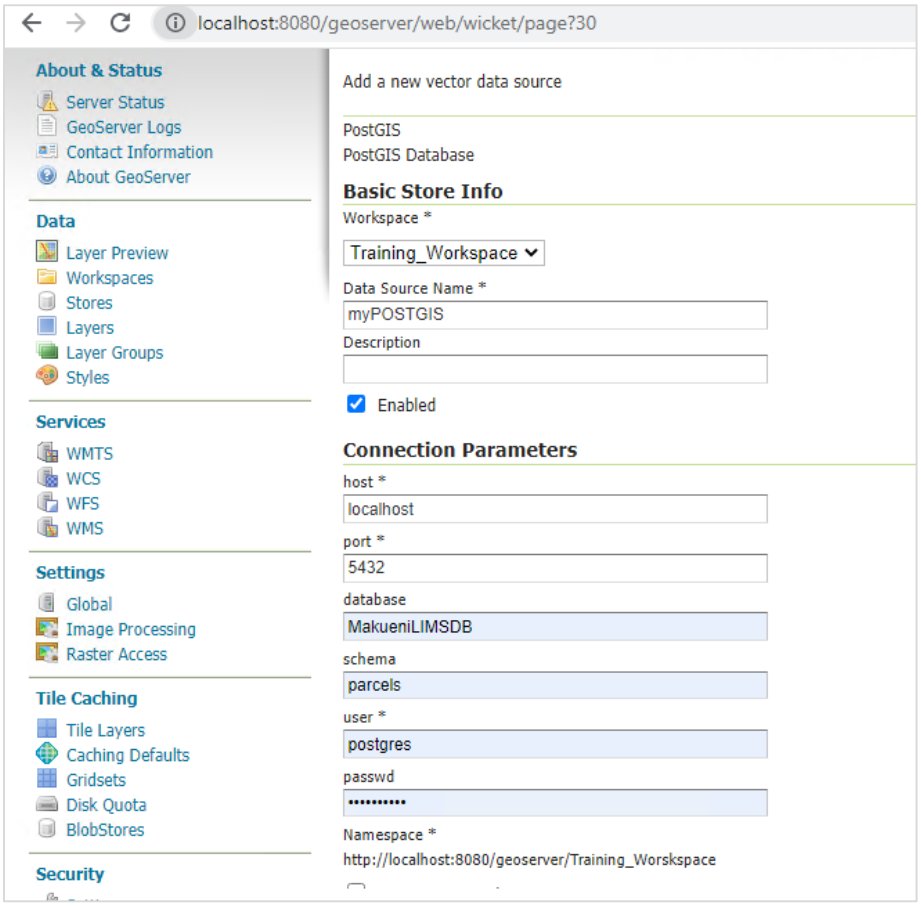
- Click on Save.

You have successfully added a shapefile to Geoserver. We will then add a table from PostGIS Database to Geoserver.

4.2.2 Adding Data from PostGIS Table

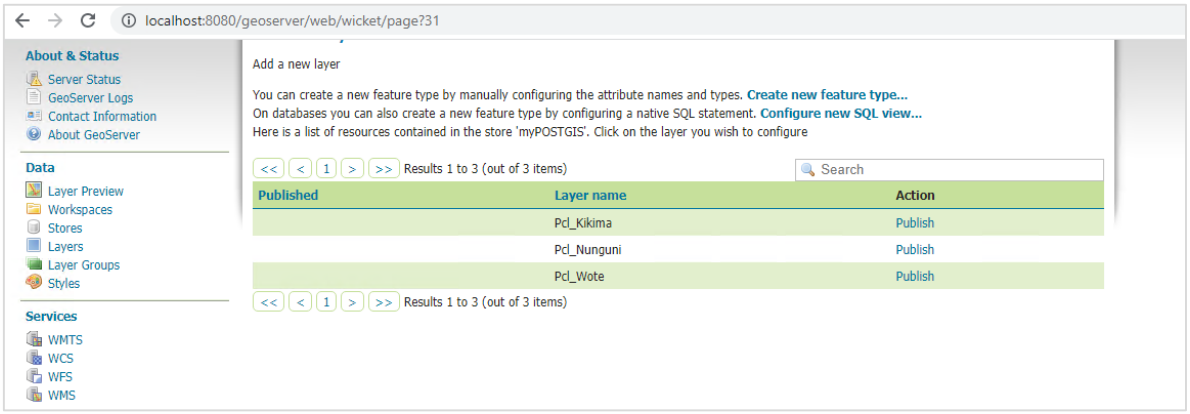
The next step is to add data to Geoserver from PostGIS Database. PostGIS is an extension of PostgreSQL database that provides capabilities for handling geometry features.

- Open the GeoServer administration interface, go to the Data | Stores section, and click on Add new store | PostGIS.
- Select 'Training_Workspace' for Workspace.
- Set Data Source Name and Description as myPostGIS.
- For Connection Parameters, you need to insert the same values you used with the loader. For your simple database, you don't need to play with the other settings; go with default values and click on Save:



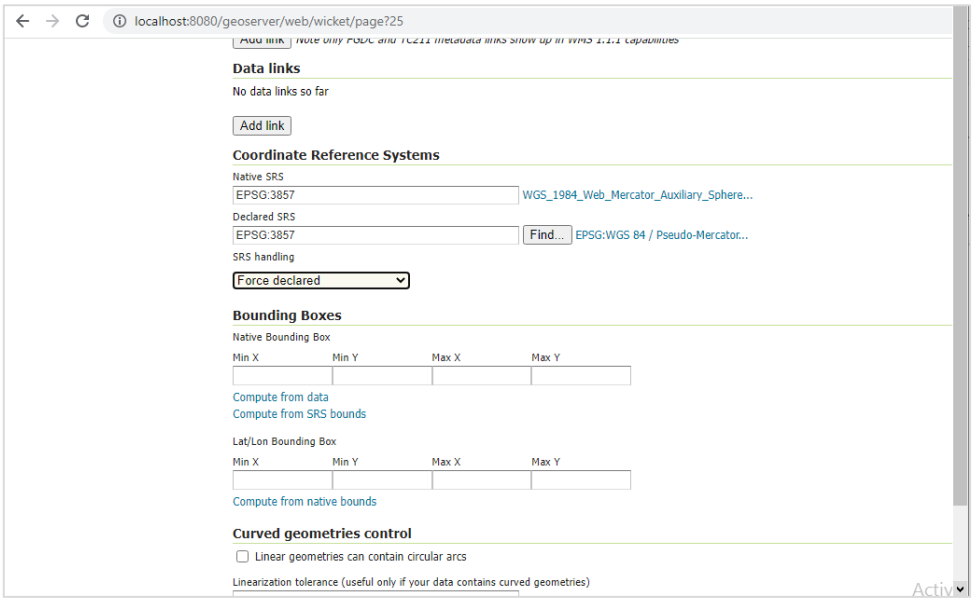
GeoServer will connect to PostGIS and present you a list with all tables containing spatial features.

- Click on the Publish link to the right of the table you added to PostGIS.

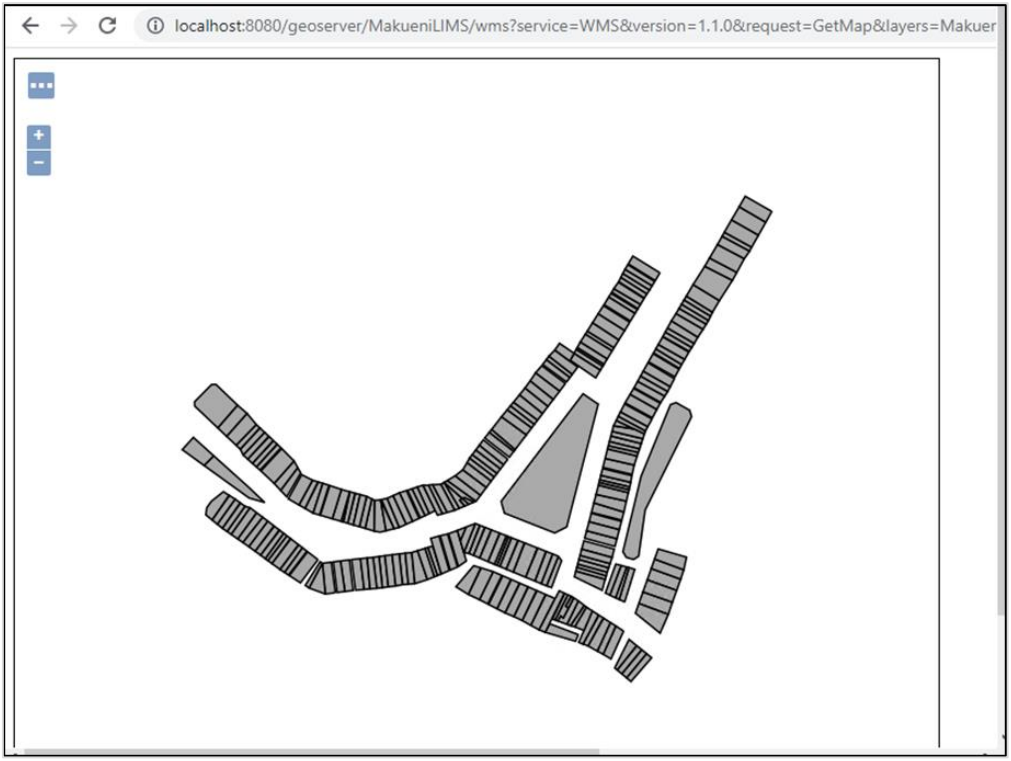


You now have the same publishing form we used for the shapefile. Note that this time GeoServer recognizes the native SRID for data.

- Click on Compute from data and Compute from native bounds in the Bounding Boxes section.



- Click on Save and your data is published. You can now see a preview on Layer Preview | OpenLayers next to Nunguni Parcels.



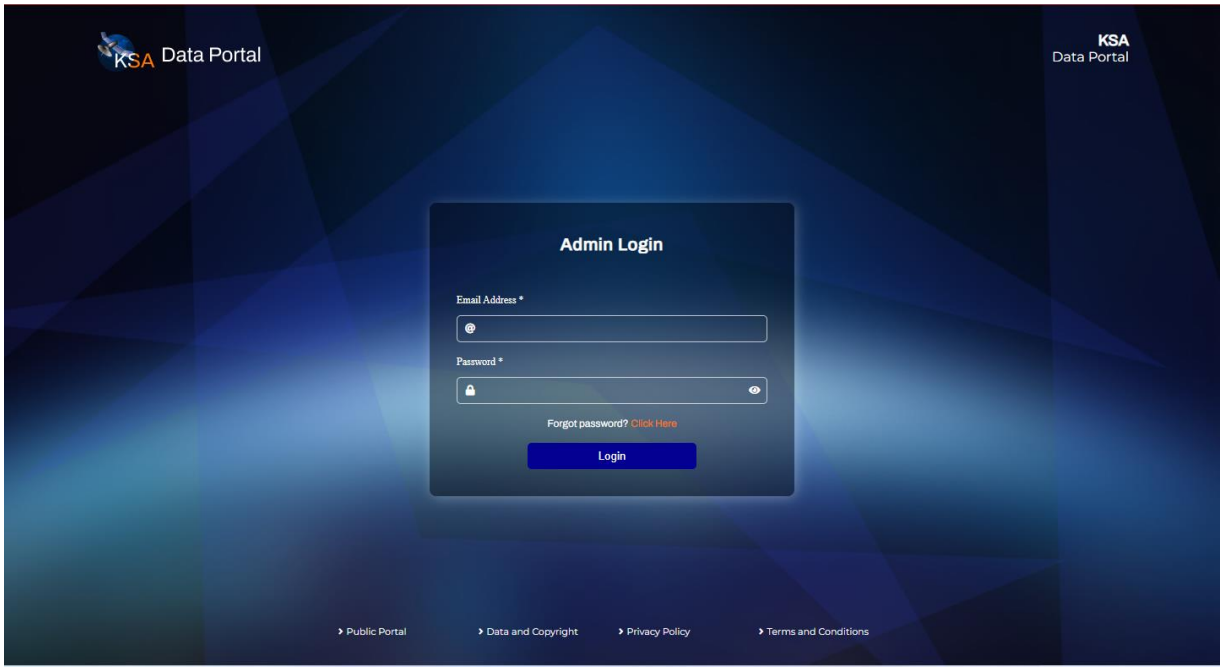
You are now able to work with PostGIS and Geoserver.

The END!

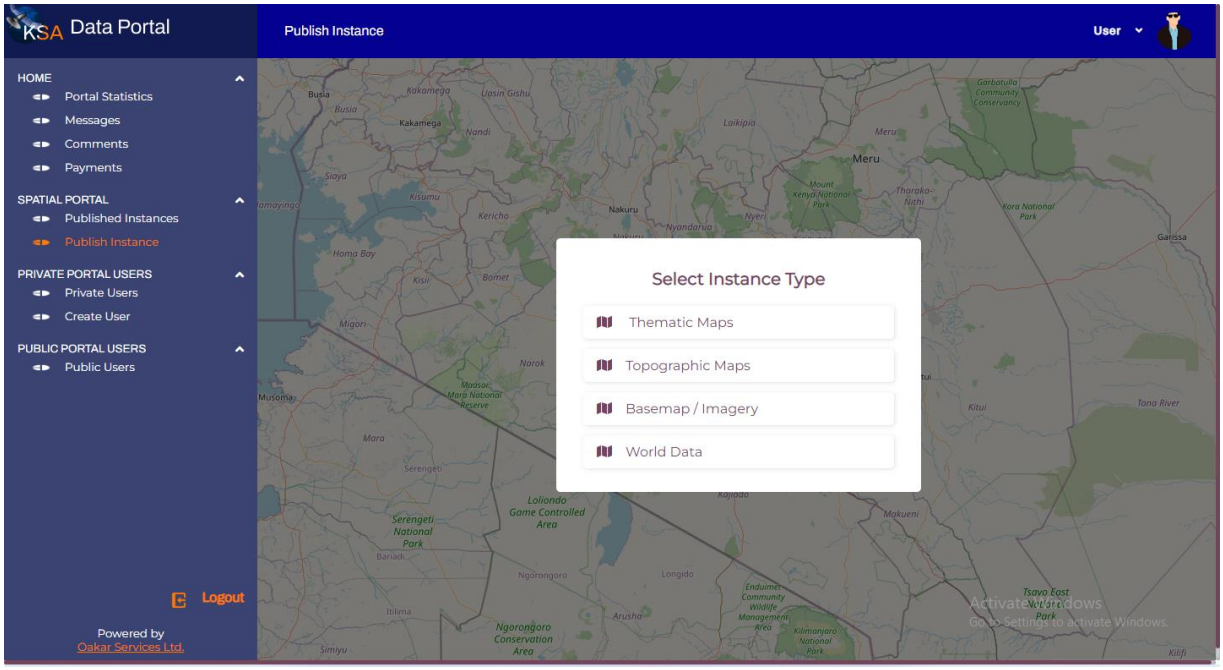
4.3 Publishing Data to KSA Data Portal

The admin portal is used by the administrator to add data to the KSA Geo-Platform.

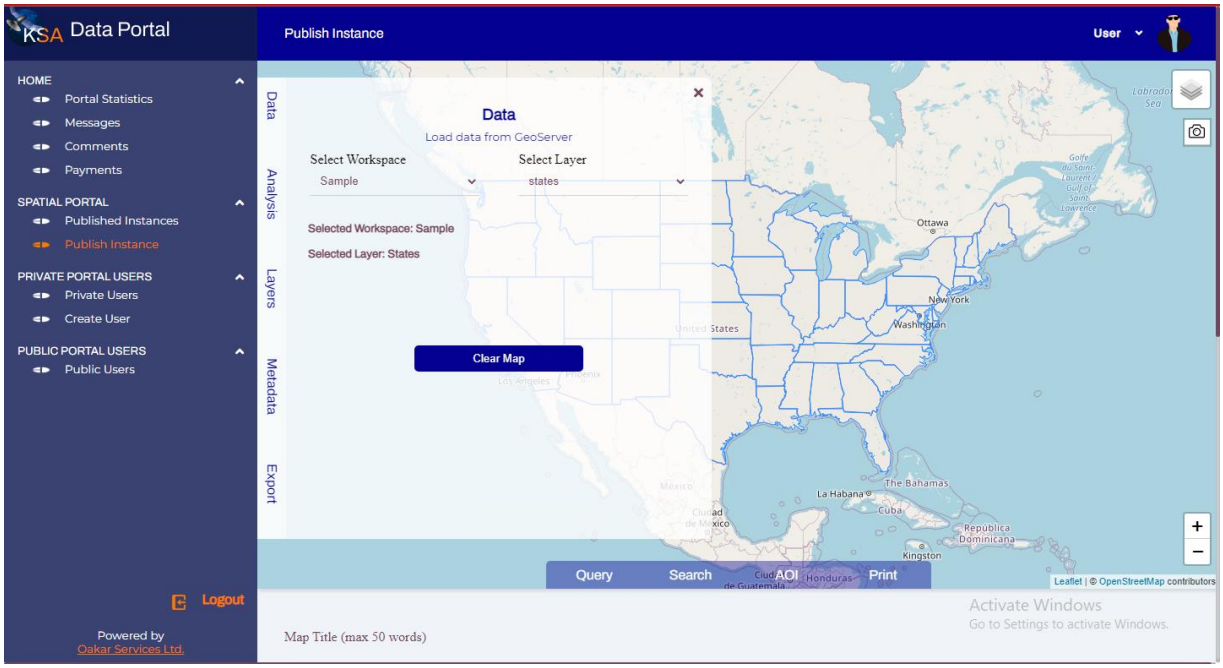
- Login to the KSA Geo-Platform Admin Portal as administrator.



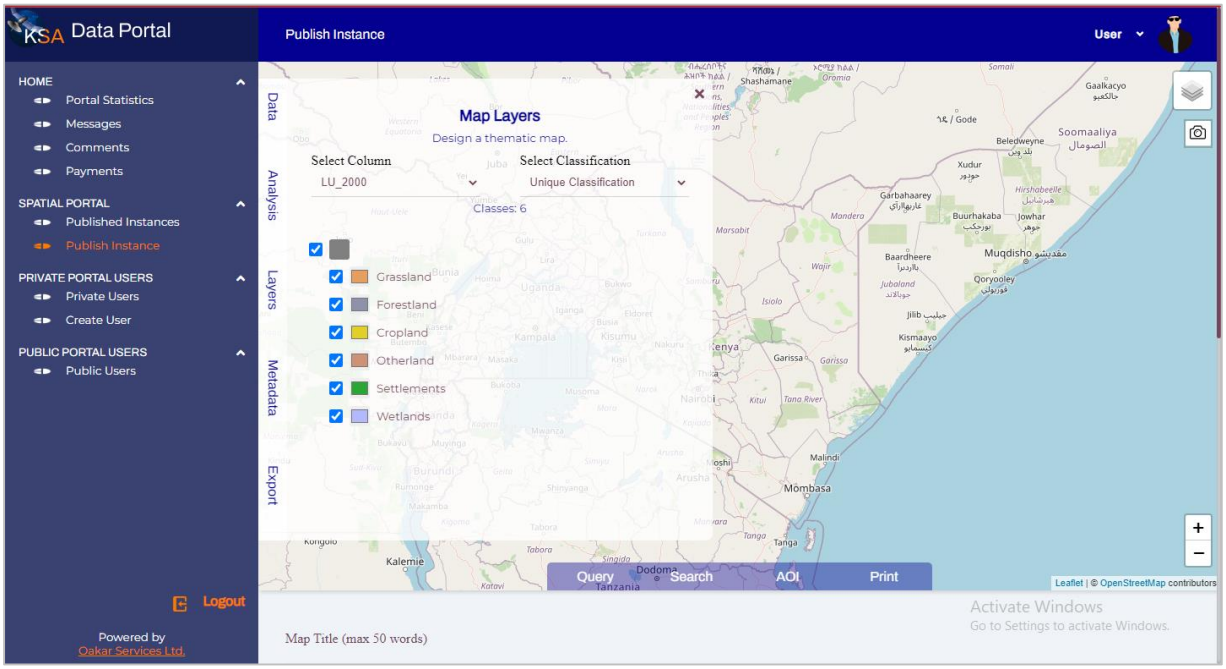
- Click on Publish Instance to add data to the Data Portal.



- Select the Instance Type to Publish from the popup window e.g Thematic Maps, then click on Data.



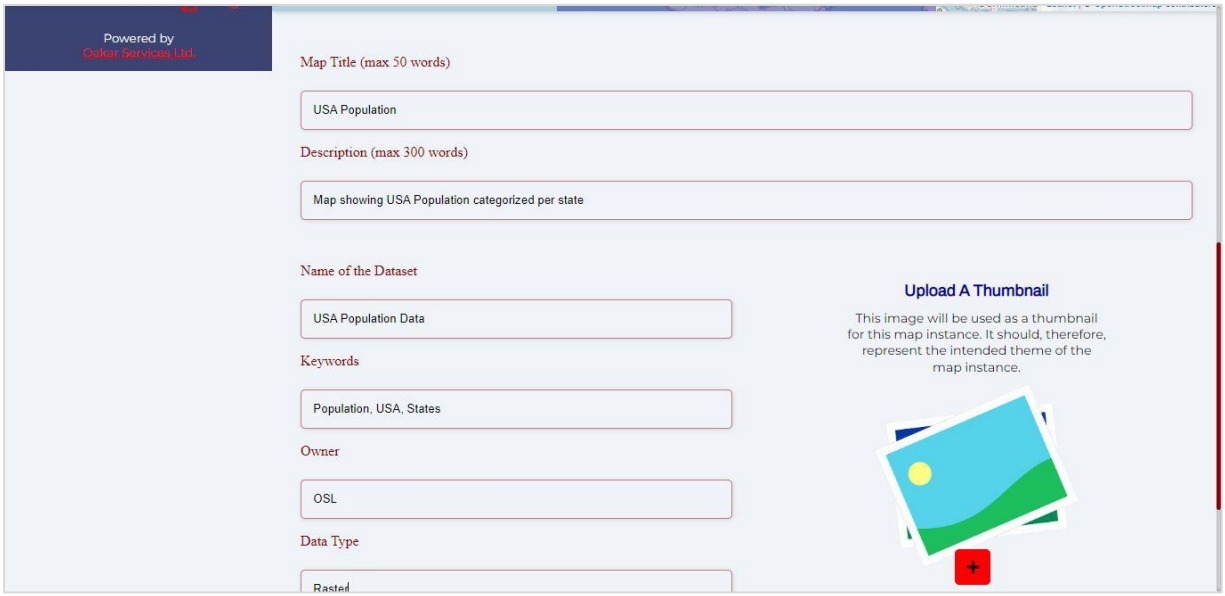
- From the drop-down menu, select the workspace you created from Geoserver then select the latter you want to publish. Click on Layers to choose a column that will be associated with the default styling that the data will be published with.



- Select a column of your choice from the drop-down menu. Columns with string values by default will have ‘Unique Classifications’ while columns with numeric values by default will have ‘Range Classification’.

NOTE: For Range classification, the labels of the ranges can be edited to suit the audience or the data.

- Scroll downwards to add descriptive information to the instance being published as shown below.



- Click on Publish Instance to Publish the data to the Geo-Platform.
- To view all the published instances, click on ‘Published Instances’

Congratulations!!