REMOTE SENSING AND GIS WEB-BASED SYSTEM FOR PROTECTION AND RESTORATION OF MANGROVE (e-PESISIR) IN MALAYSIAN'S COASTLINE

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KEY WORDS: Remote Sensing, e-Pesisir, WebGIS, Mangrove, Coastline

ABSTRACT: The mangrove ecosystem has been disrupted and destroyed as a result of development in the surrounding area. It is facing critical decline and degradation worldwide, at a rate of 1 to 2% per year. The loss of mangroves leads to the loss of valuable ecosystem services as well as significant protection for communities vulnerable to sea-level rise and disaster events. Considering these problems, the Malaysian government has implemented programs to plant mangroves in coastal areas. This paper therefore, presents the design and development of a webGIS system that enables users such as Forestry Department of Peninsular Malaysia (FDPM) to assess the success of mangrove ecosystem rehabilitation and restoration. e-Pesisir is developed using PHP, JavaScript, HTML and CSS languages along with various ArcGIS Enterprise tools such as Portal, Server and Web AppBuilder. Web AppBuilder for ArcGIS is used to build the GUI (graphical user interface), Portal for ArcGIS and Server act as middleware and Oracle RDMS is used as the backend database. The system is designed to support two types of data models: raster and vector data models. The analytical results show that the system is capable of providing accurate information in an efficient manner. It is also an alternative management tool that can be combined with other techniques, such as field monitoring, to improve mangrove ecosystem protection and restoration. In conclusion, this paper presents and highlights the advantages and benefits of the system that provides better support for related agencies in finding smart ways to restore and manage mangrove ecosystems in the Malaysian coastline. The operation of the e-Pesisir application since 2016 has improved conventional methods of mangrove ecosystem protection and restoration, and even helps stakeholders to plan more effectively and efficiently in the long term.

1. INTRODUCTION

Mangroves are a group of trees that live in the coastal intertidal zone. Mangrove trees grow in areas, where slow-moving waters allow fine sediments to accumulate. Mangrove forests only occur worldwide at tropical and subtropical latitudes near the equator. Mangrove forests are incredibly important ecosystems. The mangrove forest ecosystem plays a key role in unique ways, from providing breeding grounds for fish to carbon storage, to protection against waves and storms. Despite their importance, mangrove forests are under threat, and over 1 to 2 percent have already disappeared and are being cleared globally (Webber et al., 2016). The destruction of mangrove forests is usually positively related to humans, as they do not understand the importance and role of mangrove forests for conservation and sustenance of other economic systems. The problem is not entirely bleak. Areas of mangrove forest degradation are declining, research shows that the annual mangrove loss rate, from around 187,000 ha in 1980 to 102,000 ha between 2000 and 2005. The clearest fact is that, this indicates an increase in awareness and management of mangrove forest ecosystems (Omar et al., 2019).

Mangroves forests which, are typically distributed from mean sea level to highest tide, are often considered as a protection from hurricanes and storms, lightning, tsunamis and other floods. The 2004 tsunami left unique data to interpret, the impact of the tsunami in lush mangrove forest was substantially less than in areas with degraded mangrove forest. As of the year 2005, Government of Malaysia through FDPM implemented the national mangrove restoration projects. This project aims to restore coastal ecosystem especially mangrove forests through integrated approaches along the coastline for stabilization of the area and to provide significant benefits to biodiversity conservation, socioeconomic and protecting coastline communities (NREc, 2014). In order to improve the management of this project, the Malaysian Space Agency (MYSA) and FDPM held an MoU Signing Ceremony. Under this collaboration, GIS web-based system for protection and restoration of mangrove (e-Pesisir) has been established. The system, which was first developed in 2012 and operational in 2014, stores and provides integrated information including up-to-date satellite images to facilitate the procurement process of information required in the

planning, implementation and monitoring of mangrove forest conservation and conservation activities. The system is continuously updated and improved to meet FDPM requirements with the latest version is 3.0.

The main task of this national mangrove restoration project is to restore the mangrove forest ecosystem with mangrove species. The FDPM, is responsible for planning, identifying areas to be rehabilitated and monitoring the progress of projects at the field level. These are the works with the biggest labour shortages and, it is time and cost-consuming. However, with e-Pesisir concept, which is to help to update the mapping data on coastal stability based on the rate of recovery of tree species, restoration of restored coastal areas and buffer zones, width of coastal areas. The system helps forest managers from the forestry department to collect and record information comprehensively and systematically without intensive field visit.

This paper will later explain the system development process using remote sensing, GIS, ICT and related technologies that comprises four (4) phases which are data reception and processing, database design, GIS map preparation and web development. The process starts with data reception from remote sensing satellites and data collection from other sources. The acquired data will then be processed and converted into GIS format that can be fed into database. In the next phase, the database must be thoroughly designed to make sure all data are structured and normalized. Subsequently, all data will be published to create API in the form of web services. Finally, the web development process will take place to provide user access to the database with visualization and analysis capability according to user specifications and requirements.

2. SYSTEM DEVELOPMENT METHODOLOGY

The development of the system has four (4) important phases and each phase contributes to the successful development of e-Pesisir (Figure 1). The first phase is data reception and processing, the second phase is database design, the third phase is GIS map preparation and the last phase is web development.

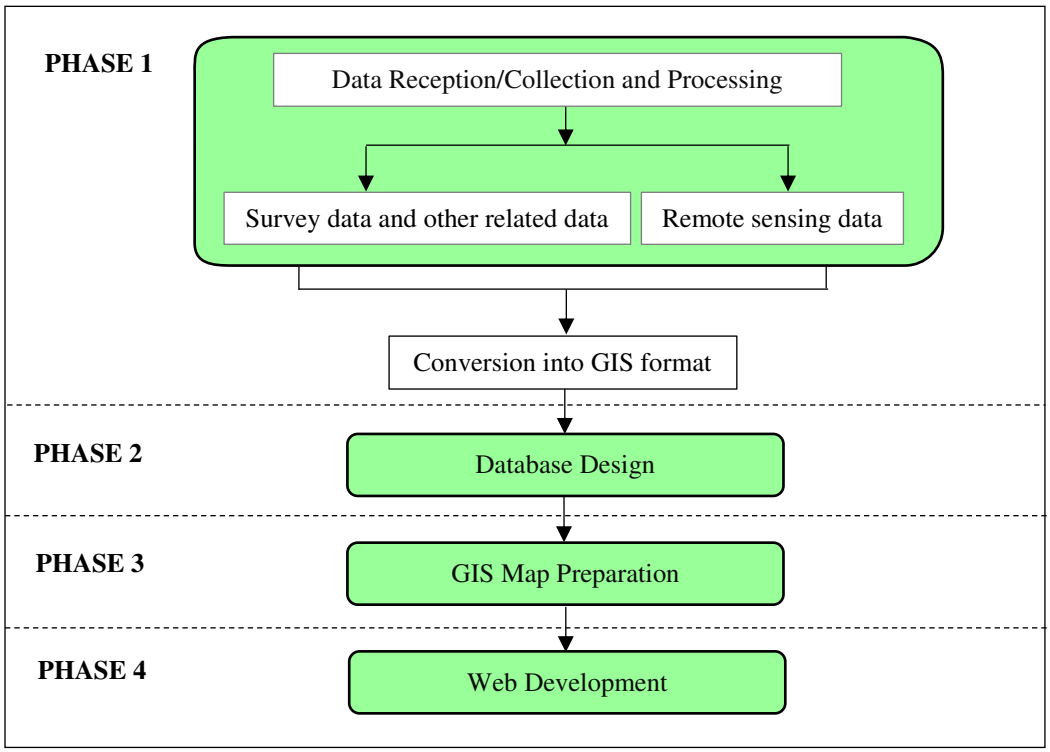

Figure 1: System development methodology

2.1 Data Reception and Processing

There are two (2) sources of data being used namely survey data and remote sensing data. Survey data is the ground data collected by the researcher consisting of location coordinates of the planting area and related attribute information. High-resolution remote sensing imagery that covers the Malaysian coastal area will be updated periodically and processed in raster data format to produce i) basemap; and ii) vector layers of land cover/ land use. Other supporting data like hydrodynamic information (current direction, current speed, wave height and sedimentation), population, coastal boundary (5km), tsunami cases area in 2004 and awareness campaign; and non-spatial data like plant treatment/monitoring will also be collected, verified and stored in the database. All data received from user agencies will then be processed using ArcGIS software to convert spatial data, coordinates, and attributes into compatible GIS format.

2.2 Database Design

GIS database or geodatabase contains all the features that have been converted into GIS format. These features or layers are included in a set of dataset that contain spatial projection, scale, and domain. The purpose of using geodatabase is the ability to store larger data size, support attachment of different formats, relationship classes, feature-linked annotation and geometric networks. The layers in the geodatabase are designed based on the purposes of the query and analysis so that the process of data retrieval and analysis will be easier.

In order to ensure all data are well structured and organized, a logical structure is constructed and an entity relationship diagram is designed to illustrate the overall tables relationship and spatial data. In this system, all the GIS data and non-spatial data are stored in Oracle database.

2.3 GIS Map Preparation

ArcGIS web services or API must be created so that all GIS data can be integrated into the web application. They represent geospatial resources such as maps, images, locators or geodatabase connections that are located in ArcGIS Server site and made available to client applications. ArcGIS Server is the main component of the ArcGIS Enterprise platform which is used to create and manage all web services.

In this phase, all GIS data stored in the geodatabase are loaded into ArcGIS Desktop. Maps with multiple vector layers were created and saved before being published to the ArcGIS Server as map services while all satellite images are published as image services. These services can then be shared in Portal for ArcGIS for application use.

2.4 Web Development

There are five (5) processes involved in the life cycle of web development namely analysis, design, development, testing and maintenance. In the analysis process, the developer must understand all the information and requirements of FDPM. While in the design process, it covers activities towards the architecture of the system, functionality flow diagrams and system specifications. Development is the process that focuses on how the design is translated into the programming language. After the development process, the system must go through testing process to make sure the system is functioning properly. The last process in this life cycle is the maintenance. It includes frequent system updates to comply with the requirements of FDPM. Figure 2 shows the web development process starting with data retrieval from a database, API creation and finally creating web application.

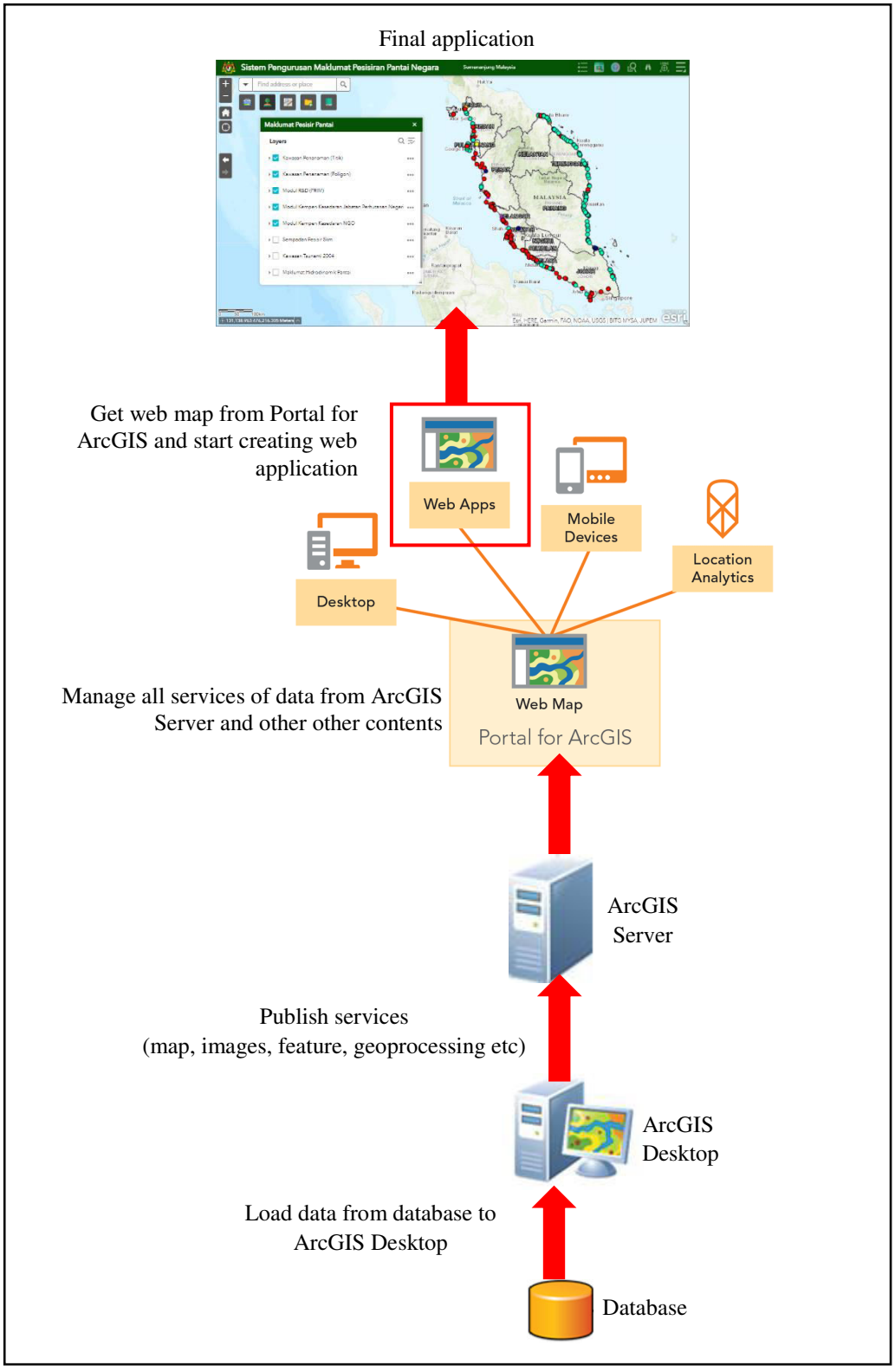

Figure 2: Web development process

In this phase, a web map will be created in the Portal for ArcGIS. The use of Portal for ArcGIS allows users to share and secure the geospatial data and applications. The Portal for ArcGIS is a component of ArcGIS Enterprise that helps organize, secure, and facilitate access to geographic information products (Derek Law, 2014). It also provides advanced analytical capability to the organization. A web map is an interactive display of geographic information and contains a basemap, a set of data layers where users can share, modify, update and perform analysis. The web map will then load all services data required by the system. Some modifications and changes to

the attributes, labels and pop-up information need to be done to make it user-friendly and intuitively improve user experience.
This web map will be the input for the Web AppBuilder which is a tool for making web and mobile-friendly interactive GIS applications. It is a rapid application development tool that provides various templates and ready-to-use or configurable widgets which add diverse functionality to the application. In this final step, all relatable widgets like layer list, edit, query, analysis, search, print, measurement, navigation, attribute and others will be configured and customized accordingly regarding User Requirement Specification (URS). PHP, JavaScript, HTML and CSS are used to add other functions to the application like forms for login, feedback and change password.

3. SYSTEM ARCHITECTURE

Basically, the system structure is arranged using a three-tier architecture. Figure 3 shows the system architecture of e-Pesisir. The first tier or presentation tier is the user interface and communication layer of the application, where the end-user interacts with the application. The main purpose is to display information and collect information from the user. The user can access an interactive map and perform basic mapping operations like pan, zoom in/out, identify features, edit, perform query and print maps. Other than that, the system can perform data entry, information retrieval and report generation in simple and understandable formats. This top-level tier can run on most web browsers like Google Chrome and Mozilla Firefox with internet connection to access the system.

The second tier is the application tier that includes the web server and map server to bridge the communication between the first tier and the third tier. It will gather and process requests from clients and perform its logical procedure to produce the results, by taking the information from the third tier. Using the Internet Information Services (IIS) as the web server, information from the database is displayed on the web using PHP, HTML, JavaScript and ArcGIS API for JavaScript. Meanwhile, ArcGIS Server is used to publish the spatial layers as APIs.

The third tier is the data tier that manages the data. Data management typically includes storage and retrieval of data, as well as managing updates, providing security, ensuring data integrity and providing support services such as data backup. These services are provided by a Relational Database Management System (RDBMS), and the data is stored in a relational database. In this system, all GIS data and non-spatial data are stored in Oracle database. The middle tier communicates with the third tier using Structured Query Language (SQL).

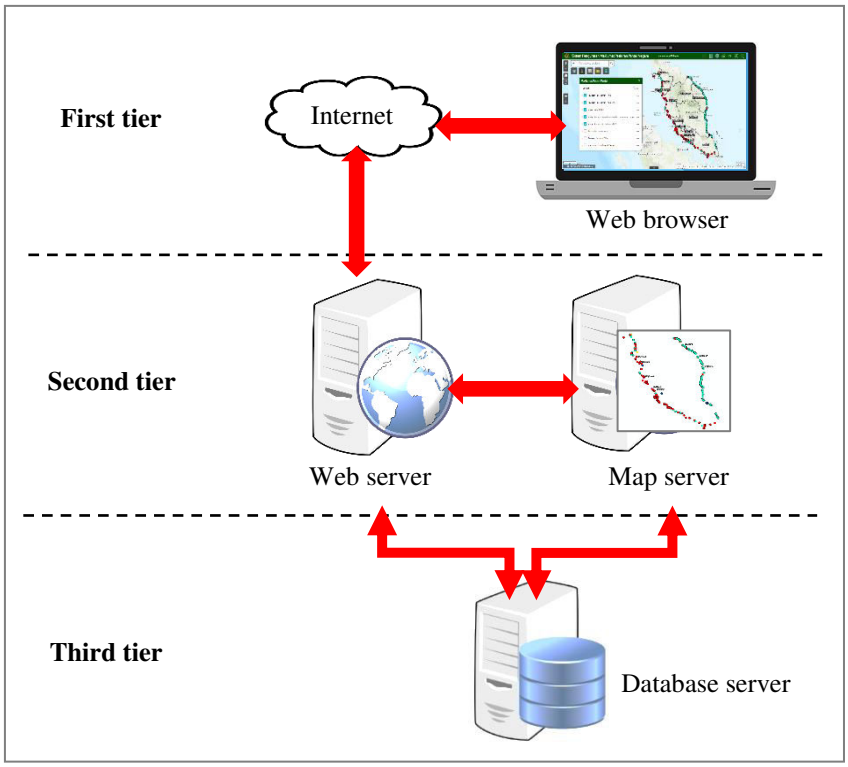

Figure 3: System architecture of e-Pesisir

4. MODULES

e-Pesisir is currently being accessed by officers from FDPM; and few other users from related agencies. The access level was controlled with password protection which can provide better control on the usage of the system. For this application, three (3) important modules have been developed namely display module, query and analysis module; and edit module.

4.1 Display Module

The display module is the essential module of any webGIS application. Users can perform basic mapping operations like pan, zoom in/out, identify features; and print a map. They can view all GIS data in the table of contents while overlaying them with high-resolution satellite images of 0.5m-1.0m resolution such as Pleiades and SPOT6/7. This module gives users visual interpretation capability to facilitate them in monitoring and observing the planting area, tree growth, coastal erosion and land cover/land use changes. Figure 4 shows the map with the attribute information using the display pop-up function. Figure 5 shows the map in print layout format.

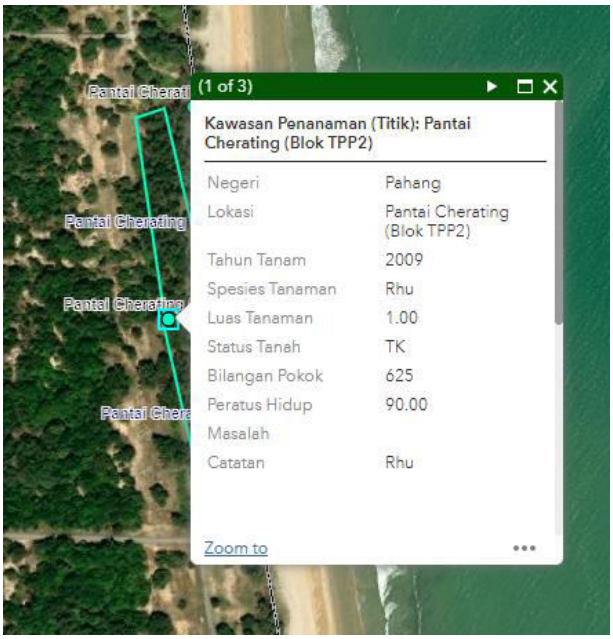

Figure 4: Map with the attribute information using the display pop-up function

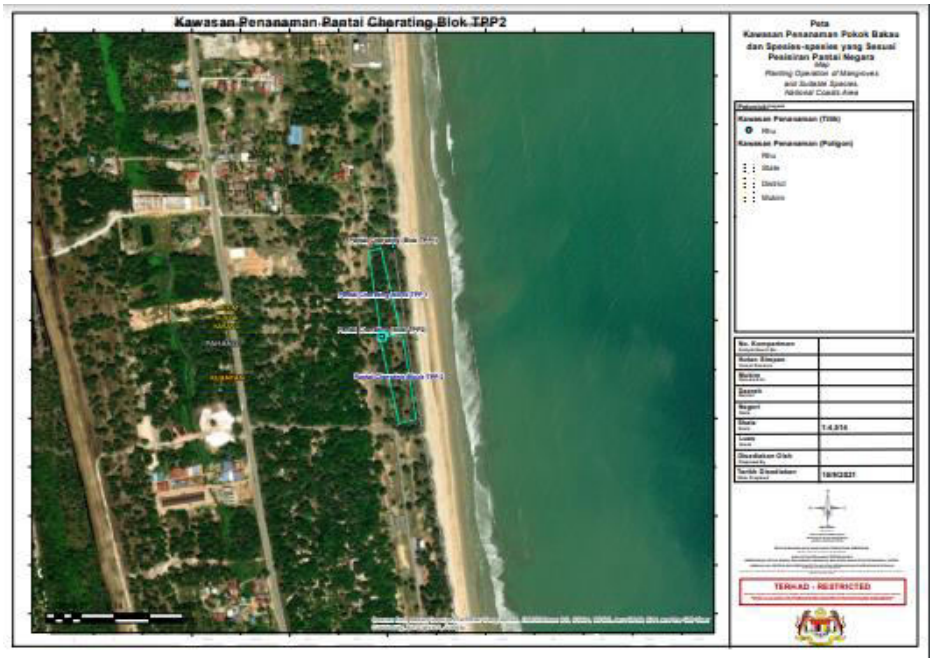

Figure 5: Map in print layout format

4.2 Query and Analysis Module

The query and analysis module is the core component in this webGIS application. Query allows users to specifically search spatial or non-spatial data according to their need. Figure 6 shows the parameter searching window. After performing a query, query results will be shown and the user can manipulate the results like viewing them in the attribute table, export them to other formats and perform some statistical analysis; such as in Figure 7.

The analysis module allows users to perform an analysis of the potential location of mangrove planting. Parameters that are taken into considerations are current speed, wave height, land cover/ land use and land status. By combining all these parameters, users can have a potential location for future planting areas.

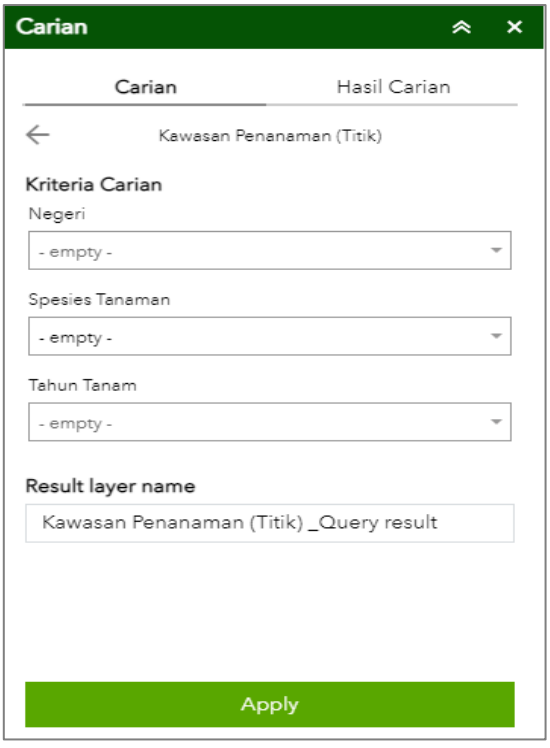

Figure 6: Parameter searching window

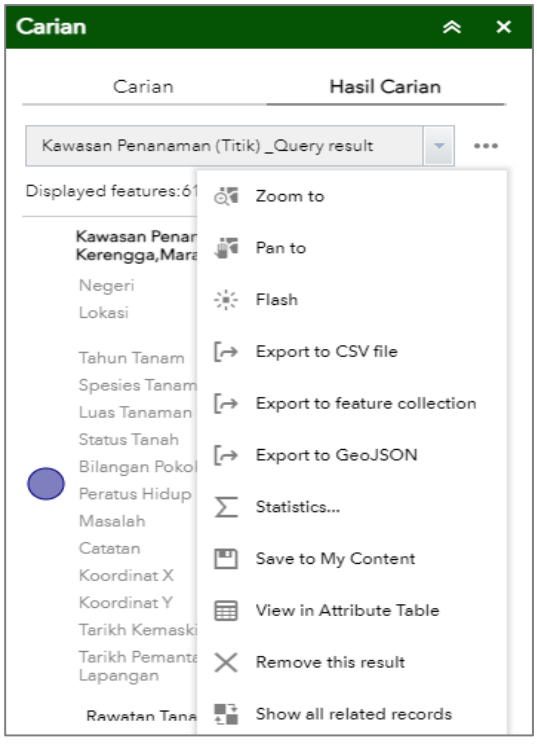

Figure 7: Query results and how user can manipulate the results

4.3 Edit Module

Edit Module helps users in many ways. It saves time and reduces cost since they can update all the information anytime at any place. Since the system is mobile-friendly, users can update data using their smartphone while doing field monitoring. They can insert pictures and all related documents if needed. Currently, field monitoring has become optional since they can now view and assess the area using the high-resolution images in the system. Spatial layers that can be edited are planting areas (point and polygon) and awareness campaign while non-spatial data is plant treatment/monitoring.

5. CONCLUSION

As for the conclusion, this paper highlights the implementation of remote sensing, ICT, GIS and related technologies that enhance the efficiency of mangrove planting program. WebGIS application provides a new data-sharing method and platform and offers more interactive display to the user for better understanding of the data by giving several basic functions to the application such as infographic widget and query widget. In the meantime, MYSA and FDPM are working towards expanding the usage of the system to include users from other agencies/NGOs and improving the analysis module to make it more accurate and reliable. After seven (7) years of operation and continuously updating and improving the content, MYSA will continuously support FDPM in empowering the mangrove planting program.

6. ACKNOWLEDGEMENT

Special thanks to FDPM as a strategic partnership in data sharing; and in the development and operationalization of e-Pesisir. The authors also acknowledge MYSA for providing related geospatial data and satellite imageries. We would also like to thank the staff of MYSA especially in this research team for working hard during the completion of this project.

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