

# ESTABLISHMENT OF WEB-GIS SYSTEM FOR IDENTIFYING AND MONITORING POTENTIAL WASTE DISPOSAL SITE IN MALAYSIA

Siti Nor Afzan Abdul Habib, Noryusdiana Mohamad Yusoff, Siti Muazah Md Zin, Hana Mohamed Jamil, Mohd Adha Abdul Majid, Mohd. Hakimi Abdul Rahman, Welly Anak Numpang, Nurul Suliana Ahmad Hazmi, Bismawaty Hassan, Mohammad Azizi Fadzil, Zulfikri Ithnin and Nur Dhuha Dzulkifli  
Malaysian Space Agency (MYSA), No 13, Jalan Tun Ismail, 50480, Kuala Lumpur, Malaysia  
Email: afzan@mysa.gov.my, noryusdiana@mysa.gov.my, muazah@mysa.gov.my, hana@mysa.gov.my, adha@mysa.gov.my, hakimi@mysa.gov.my, welly@mysa.gov.my, nurulsuliana@mysa.gov.my, bismawaty@mysa.gov.my, azizi@mysa.gov.my, zulfikri@mysa.gov.my and dhuha@mysa.gov.my

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**ABSTRACT:** Illegal waste disposal is a critical management issue for the government, and it has negative impacts on the health, society and the environment. Malaysia experienced the illegal dumping of chemical waste in the Kim Kim River in March 2019, affecting more than 5,000 people. The incident became national headlines and captured the country's attention, including that of Malaysian Space Agency (MYSA). The MYSA Task Force team on the Kim Kim River and Pasir Gudang incidents was established to discover the source of the dumping site and to recommend the potential waste hotspots throughout Malaysia to prevent recurrence in the future. Pleiades (0.5m resolution) and SPOT-6/7 (1.5m resolution) satellite images are used to identify the potential waste hotspots. The waste hotspots are recognized based on several risk parameters such as abandoned land, unhealthy or stressed vegetation, road accessibility, soil texture and colour, distance from residential areas, proximity to drainage systems; and waste deposit or spatial heterogeneity; using visual interpretation and preliminary deep learning research. This study implemented the MASKRCNN architecture based on RESNET50 with a model performance of 0.6 in waste hotspots detection. To disseminate this work, e-Sisa, a smart system for appropriate waste disposal site management, is developed using remote sensing, GIS and ICT technologies. This paper describes and implements a web-based Web-GIS architecture using various ArcGIS Enterprise technologies, including Portal, Server and Web AppBuilder along with multiple programming languages, including PHP, JavaScript, HTML and CSS. Web AppBuilder for ArcGIS is used to develop the graphical user interface (GUI), while Portal for ArcGIS and Server act as middleware and Oracle RDMS is the backend database. The analysis result shows that the system's capacity to deliver precise information efficiently. e-Sisa system can act as a crucial tool for authorized personnel to assist them in carrying out their routine site monitoring. To sum up, this paper concludes by outlining the advantages of a system that will help the Malaysian Ministry of Local Government and Development (KPKT) and associated organizations find more effective ways to monitor the area in real time, thereby minimizing the need for manual monitoring and verification.

## 1. INTRODUCTION

Illegal waste disposal is an important management issue for the government and might create a serious negative impact on the health, society and environment. The tragedy in March 2019, has affected more than 5000 people, mainly children with respiratory symptoms such as breathing difficulties, nausea and vomiting after breathing in the poisonous gases after being exposed to different chemicals illegally dumped into the Kim Kim River, located in Pasir Gudang, Johor, Malaysia (Atlas, 2019; Ismail, Abidin, & Rasdi1, 2020). This incident became a national headline and captured the country's attention, including the Malaysian Space Agency (MYSA). A Task Force on the Kim Kim River and Pasir Gudang incidents has been formed to investigate the source of the dumping site and to recommend potential waste hotspots throughout Malaysia to prevent recurrence in the future.

This work implemented a smart waste disposal sites management system (e-Sisa) using remote sensing, GIS, ICT, and potential deep learning support. Waste quantities, characteristics, and distribution; disposal site selection and utilization; waste collection and transportation; and environmental impact on-site and off-site disposal have been studied using remote sensing (Garofalo & Wobber, 2006). GIS and remote sensing are used worldwide for landfill site suitability studies in South America, North America, Asia, Europe, and Africa (Jerie, 2017). Remote sensing can map illegal garbage disposal sites using direct spectral signatures and indirect spatial signs like stressed vegetation (Glanville & Chang, 2015). Hydrocarbons, heavy metals, and organic compounds in soil or groundwater interfere with tree and grass metabolism and growth (Slonecker & Fisher, 2014). Previous research suggests that monitoring and mapping unlawful residential trash disposal requires very high spatial resolution data (Glanville & Chang, 2015). This study uses Pleiades (0.5 meters) and

SPOT-6/7 (1.5 meters) satellite images to identify potential waste hotspots based on risk parameters like abandoned land, unhealthy/stressed vegetation, road accessibility, soil texture and colour, distance from residential areas, proximity to drainage systems, and waste deposit or spatial heterogeneity. Unmanned Aerial Vehicle (UAV) or drone system was used to verify waste category, dumping site area estimation, nearest sensitive area affected, suspect identity, vehicle registration number, and potential threat to local authority to enter the area (Mohamad Zulkhaibri Mat Azmi & Siti Muazah Md Zin, 2020).

In addition to employing visual interpretation of satellite imagery to pinpoint possible waste hotspots, deep learning object recognition is a possible means of enhancing the visual interpretation approach. Deep learning is a subfield of Artificial Intelligence (AI) that aims to simulate the way humans acquire knowledge from data patterns (Anadkat, B V Monisha, Patnaik, R, & Syed, 2019). Deep learning techniques have been used in the field of computer vision to address the waste classification and waste dump detection issues in more recent times (Andrea Biscontini, 2021). Aghilan M (2020) uses Conventional Neural Network (CNN) in garbage waste classification with 79% accuracy. Meanwhile, Andrea Biscontini (2021) using a CNN developed with Residual Networks (ResNet) architecture has already delivered good results on the task of illegal landfills classification with an accuracy of 92%. While Devesa & Brust (2021) mapped illegal waste dumping sites using Sentinel- 2 satellite images with U-Net architecture based on CNN with a model performance of 0.6304.

Consequently, the collaboration between MYSA and the Malaysian Ministry of Local Government and Development (KPKT) has revealed the advantageous nature of the e-Sisa system in facilitating real-time monitoring of areas through the utilization of current and extensive satellite imagery. This has resulted in a reduction of the labour-intensive processes involved in monitoring and verification, which were previously reliant on drone systems.

This paper later will subsequently describe the system development process utilizing remote sensing, deep learning, GIS, ICT and related technologies, which consists of four (4) stages: data reception and processing, database design, GIS map preparation, and web development. The process starts with the reception of data from remote sensing satellites, as well as the collection of data from many other sources. The obtained data will then be processed and translated into GIS format before being stored in a database. In the next phase, the database must be meticulously designed to ensure that all data is organized and standardized. Subsequently, all data will be made available as web services. Then, the web development process will take place to provide users with access to the database, incorporating visualization and analytical functionalities according to their individual requirements.

## **2. SYSTEM DEVELOPMENT METHODOLOGY**

### **2.1 Data Collection and Processing**

#### **2.1.1 Visual Interpretation**

There are two (2) data types that are used in this project, including remote sensing and auxiliary data. Since 2019, a total of 1,115 scenes of Pleiades (0.5 meters) and SPOT-6/7 (1.5 meters) covering the territory of Malaysia have been used. The high-resolution remote sensing images will be updated periodically and processed in raster data format to produce a base map and enabled researchers to visually analyze the potential of waste hotspot areas. In this study, the potential waste hotspot area was identified based on several risk parameters such as abandoned land, unhealthy/stressed vegetation, road accessibility, soil texture and colour, distance from residential areas, proximity to drainage systems; and waste deposit or spatial heterogeneity. In addition, this e-Sisa system comprises of UAS images in particular areas to provide accurate information to local authorities for enforcement (Figure 1). Plus, the SecureWatch Web-based Application System by DigitalGlobe is also used to verify the waste hotspot area using very high-resolution images from Worldview (0.3 to 0.5 meter) and Quickbird (0.4 meters) satellite. Auxiliary data comprises solid refuse management facilities by KPKT, as well as administrative boundaries, localities, cadastral lot, and road and river network Using ArcGIS software, the data obtained from user agencies will be processed to transform geographic data, coordinates, and attributes into a format that is compatible with GIS. Non-spatial data such as land-use type, waste type, and site visit photographs will also be collected, validated, and saved in the database.



Figure 1. Identified waste hotspots using SPOT-6 and verified using UAS.

### 2.1.2 Deep Learning Algorithm

Given the anticipation of an increased volume of picture data that may serve as potential waste location indicators, the team initiates a preliminary study on the implementation of deep learning methods based on Conventional Neural Network (CNN) to enhance the identification of these locations with greater efficiency. The research team opted to employ a Pleiades image captured on 3 February 2021, depicting a particular area in Perak state, Malaysia, as a pilot study. To accomplish this task, the use of ArcGIS Pro with the Image Analyst extension is employed to execute comprehensive deep learning procedures using imagery. Geoprocessing tools are utilised for the purpose of preparing imaging training data, conducting object detection training and generating and evaluating outcomes. A total of 54 data samples were divided into two sets, with 60% of the samples allocated for training and the remaining 40% designated for testing. To ascertain potential trash disposal sites an object detection analysis technique was employed, resulting in the generation of a dataset comprising 125 chipsets. The deep learning model was trained using MASKRCNN/ResNet50 model, which is based on the Conventional Neural Network (CNN). The model achieved a performance score of 0.6, resulted possible waste disposal location (Figure 2).

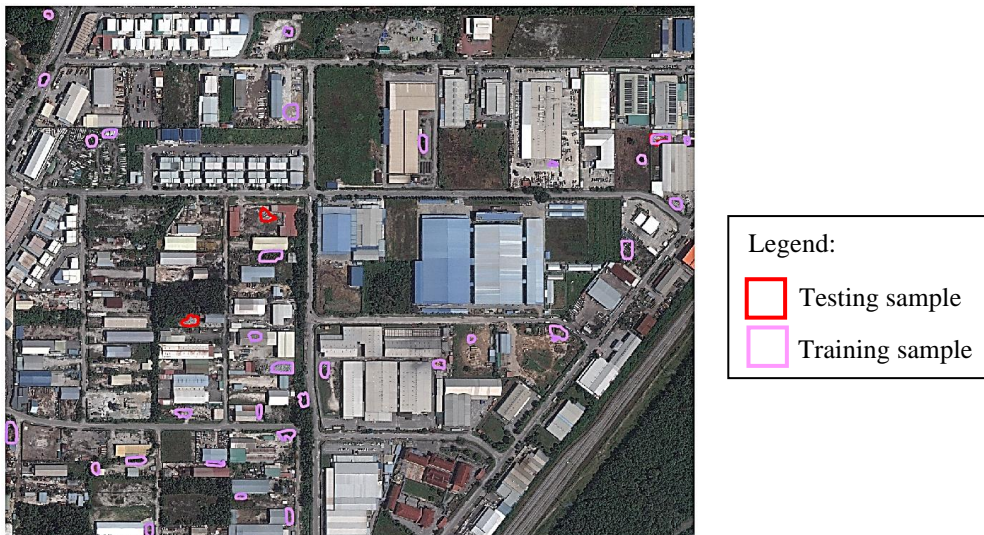


Figure 2. Figure above shows that only one (1) testing sample was successfully identified by the model. Out of the 35 objects that the model generates, 21 are possible waste disposal location and need to be verified by local authorities.

### 2.2 Database Design

By using spatial database management approaches based on ArcSDE and Oracle, GIS database server is created and built with the aim of making a centralized and secure database. Key goals include getting rid of duplicate data, improving the integrity, consistency, and clarity of information used to make decisions, and making data more reliable. Researchers have made a database for monitoring and managing disposal sites data. It is a multidimensional database with two main parts of data: information about the disposal site as the main data and basic information as the secondary data.

- i. Main data:
  - a. Potential disposal sites - Spatial table that stores all information about a disposal site including state, district, nearby location, disposal type, site status, date updated and person in charged as attributes.
  - b. Waste management facilities - Spatial table that stores information on waste management facilities including name, authorities in charged, waste type and capacity as attributes.
  - c. Local authority boundaries - Spatial table that stores information on all local authority boundaries in Malaysia including local authority name, address and contact number as attributes.
- ii. Secondary data:
  - a. State - Spatial table that stores the states boundaries in Malaysia and contains state code, state name.
  - b. District - Spatial table that stores the district boundaries in Malaysia and contains state code, district code and district name as attributes.
  - c. Localities - Spatial table that stores points of places. Table has the places code, the name of the locality and the district code as attributes.
  - d. Road networks - Spatial table that stores available road including expressway, federal, state, municipal and private. Table has road code, road type, and road name as attributes.
  - e. River networks - Spatial table that stores rivers network in Malaysia and contains river code and name as attributes.
  - f. Cadastral lot - Spatial table that stores land ownership, land categories and land status information as attributes.

Aside from that, the growth of the database includes four (4) types of geodatabase user permissions and roles: data viewer, data editor, data creator, and data administrator. Users can only view (data levels) with limited use of the data viewer. The data editor, on the other hand, lets its users see, change, and update the data. Users with the data creator role can add new data (features and layers) to the database, whereas users with the data administrator role have the capabilities of all users.

### 2.3 GIS Map Preparation

The concept of GIS data readiness involves the synchronization of datasets from several sources, encompassing diverse types, accuracies, formats, and projections, into a unified database. This process facilitates improved data management, such as updates, and helps to minimize errors, specifically reducing data redundancy, as highlighted by Gago-Silva (2016). At this stage the entirety of the GIS data contained within the geodatabase is imported into the ArcGIS Desktop software. Multiple vector layers were generated and then made available as map services, while all satellite imagery was made available as image services on ArcGIS Server. These services can be shared within the Portal for ArcGIS platform, enabling their utilization by various applications.

### 2.4 Web Development

The life cycle of web development consists of five stages: analysis, design, development, testing, and maintenance. The developer must have a thorough understanding of all the information and user requirements during the analysis phase. Functional flow diagrams, system requirements, and system architecture are examples of tasks that are part of the design process. The translation of the design into the programming language is the main emphasis of the development process. To make sure the system is operating correctly, testing must be done after the development phase. Maintenance is the final phase of this life cycle. To better serve user demands, the system is upgraded frequently. The process of developing a web application starts with database data retrieval, moves on to creating an API and is depicted in Figure 3.

This stage uses Portal for ArcGIS to create a web map. Portal for ArcGIS allows geospatial data and application sharing and security. The Portal for ArcGIS in ArcGIS Enterprise organizes, secures, and simplifies geographic information product access (Derek Law, 2014). It also gives advanced analytics that boost company productivity. Web maps comprise a basemap, a set of data layers that users may share, edit, update, and inspect. The online map retrieves the necessary data from its services. To make the user experience more intuitive, modify attributes, labels, styles, and popup information.

A tool for making interactive GIS apps that are suitable for both the web and mobile devices, the Web AppBuilder, uses this online map as input. This tool facilitates the quick construction of applications by offering a variety of templates and configurable or ready-to-use widgets that enhance the application's functionality. The last phase involves adding, configuring, and customizing all necessary widgets, including Layer List, Edit, Query, Analyze, Search, Print, Measure, Navigate, Attributes, and others, in accordance with the User Requirement Specification (URS). Programming languages

like PHP, JavaScript, HTML, and CSS are used to add new features to the application, like forms for feedback, login, registration, and password changes, as well as to amend or modify the widget functionality.

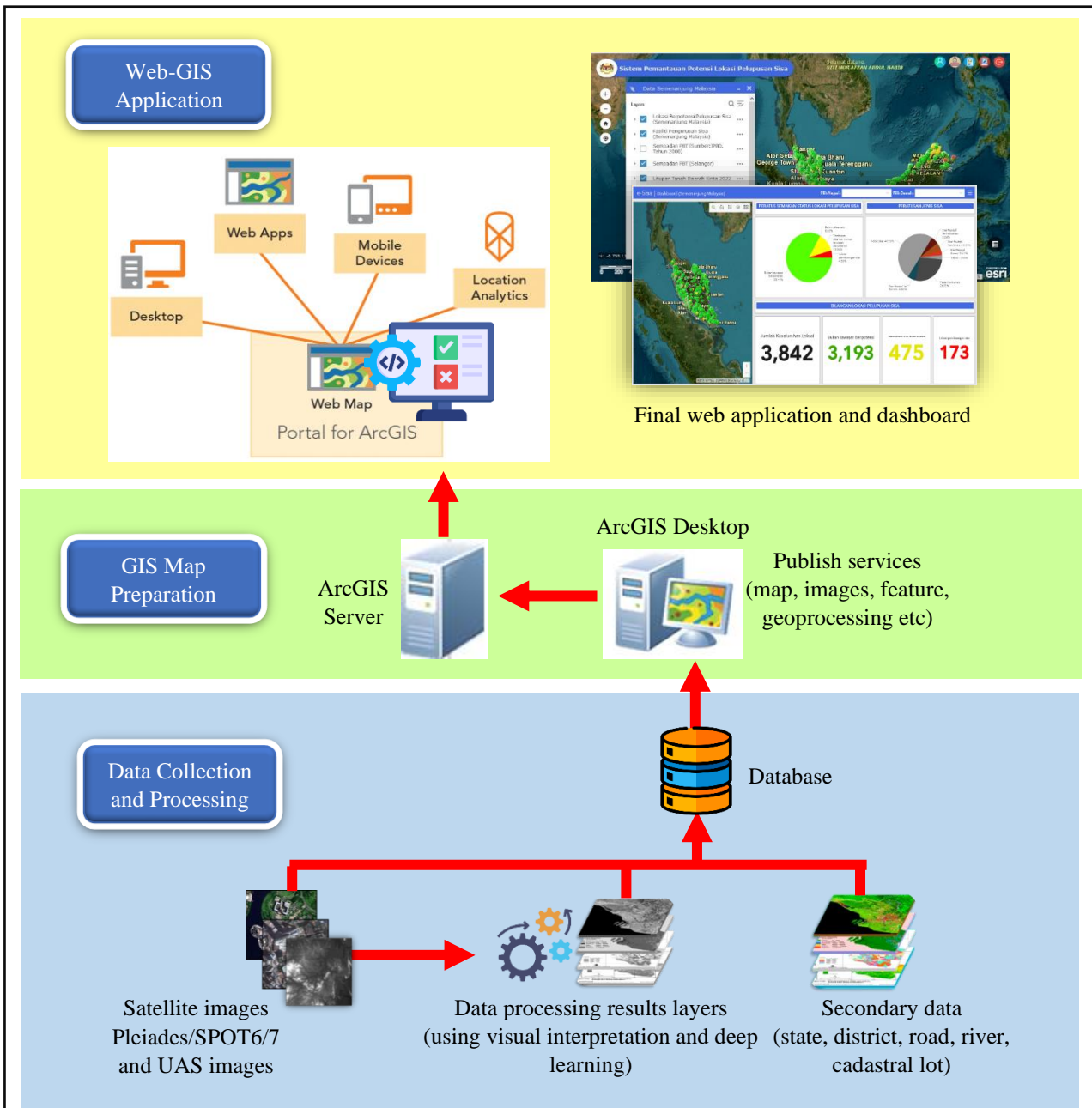


Figure 3. Web development process

### 3. SYSTEM ARCHITECTURE

The e-Sisa system has a three-tier architecture. The system architecture is shown in Figure 4. The first tier or presentation tier is the user interface and communication layer of the application. This is where users interact with the app. The major goal is to inform and collect user data. An interactive map lets users pan, zoom, identify features, modify, print, and query maps. This system can enter, retrieve, and generate reports in basic forms. Most internet-connected web browsers, such as Google Chrome and Mozilla Firefox, can access this top-level layer.

Second, the application tier includes the web server and map server to connect the first and third tiers. It processes client requests using third-tier data and logical procedures. PHP, HTML, JavaScript, and ArcGIS API for JavaScript display database data on the web using IIS as the web server. Meanwhile, ArcGIS Server offers spatial layer API services.

The third-tier handles data that includes retention, security, access, updates, data quality, and customer support are typical data management tasks. A relational database management system (RDBMS) stores data. All geographic and non-geographic data is kept in an Oracle database in this system. The middle tier and third tier use SQL to communicate.

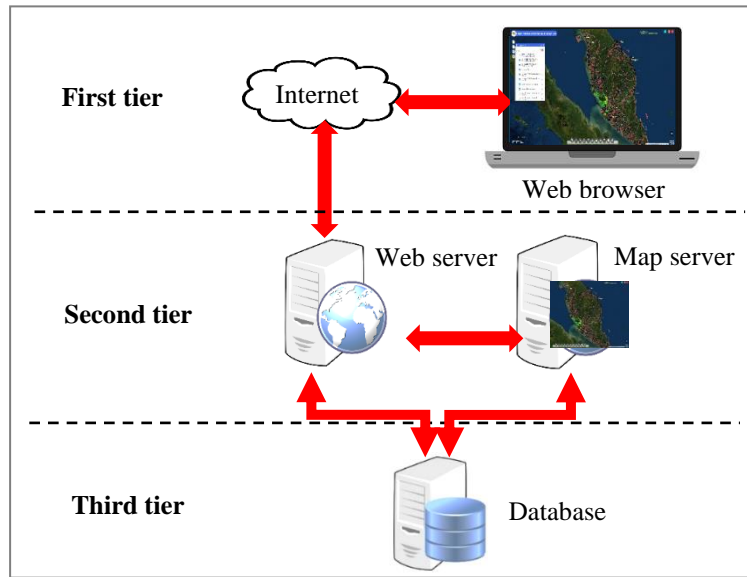


Figure 4. System architecture of e-Sisa

#### 4. MODULES

Currently, KPKT officials and a small number of users from connected agencies are accessing e-Sisa. The system was password-protected to guarantee that only authorized personnel could access it. This made it possible to regulate its use more successfully. For this application, four primary components were created: a display module, a query and analysis module, an editing module and a dashboard module.

##### 4.1 Display Module

Any web-GIS application needs a display module to be intuitive and user-friendly. Users can pan, zoom, identify landmarks, and print maps. The table of contents displays all GIS data with high- and very-high-resolution satellite images from Pleiades, SPOT6/7, and UAS. This module allows users to visually evaluate hotspot locations in three categories: waste location, no waste but potential area, and non-potential. Figure 5 displays the attribute map using the display pop-up function. Map print layout is shown in Figure 6.



Figure 5. Map with the attribute information using the display pop-up function.

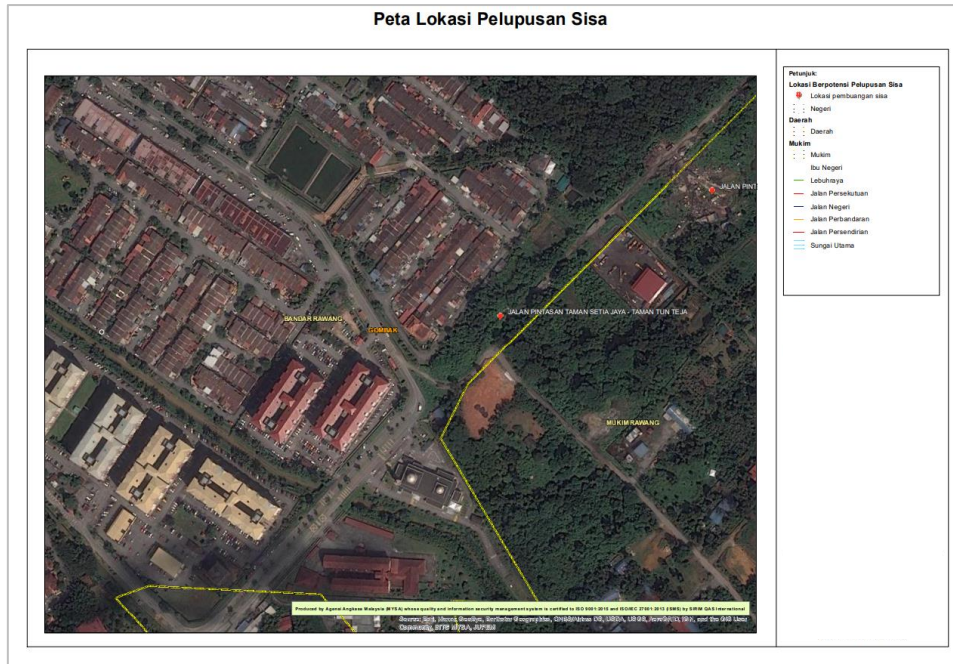


Figure 6. Map in print layout format

#### 4.2 Query and Analysis Module

The key element of this web-GIS application is the query and analysis module. Users can query spatial or non-spatial data to meet their needs. Figure 7 shows parameter-searching window. The user can view query results in the attribute table, export them to different formats, and perform statistical analysis after running a query (Figure 8).

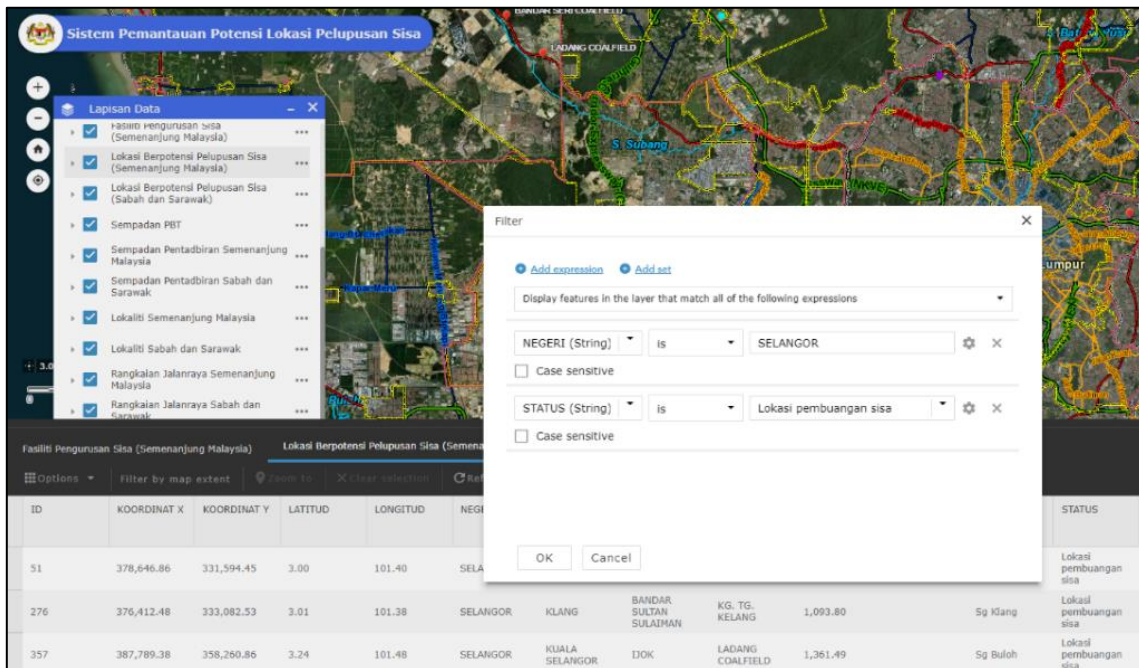


Figure 7. Searching window parameters using specific expressions

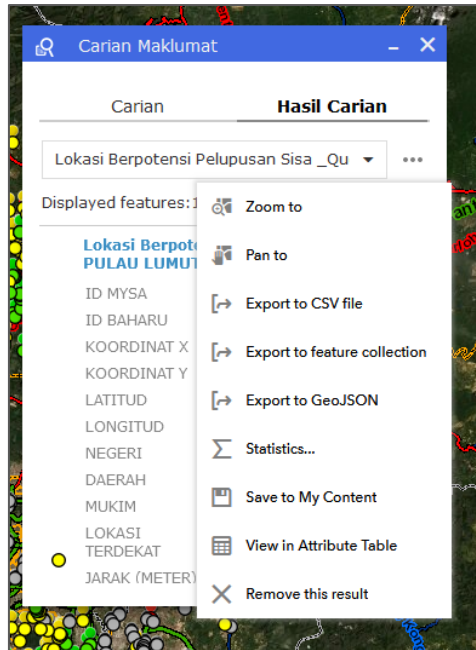


Figure 8. Query results and manipulation

The analysis module measures buffer zone, distance, and area. The buffer zone is important in landfill management. The lowering of the heavy industry buffer zone increases the probability of a catastrophic industrial accident that could harm the public (ASM, 2019). Using e-Sisa, a buffer zone was built around the waste hotspot (Figure 9). The area size and distance to the nearest road or river can also be estimated.

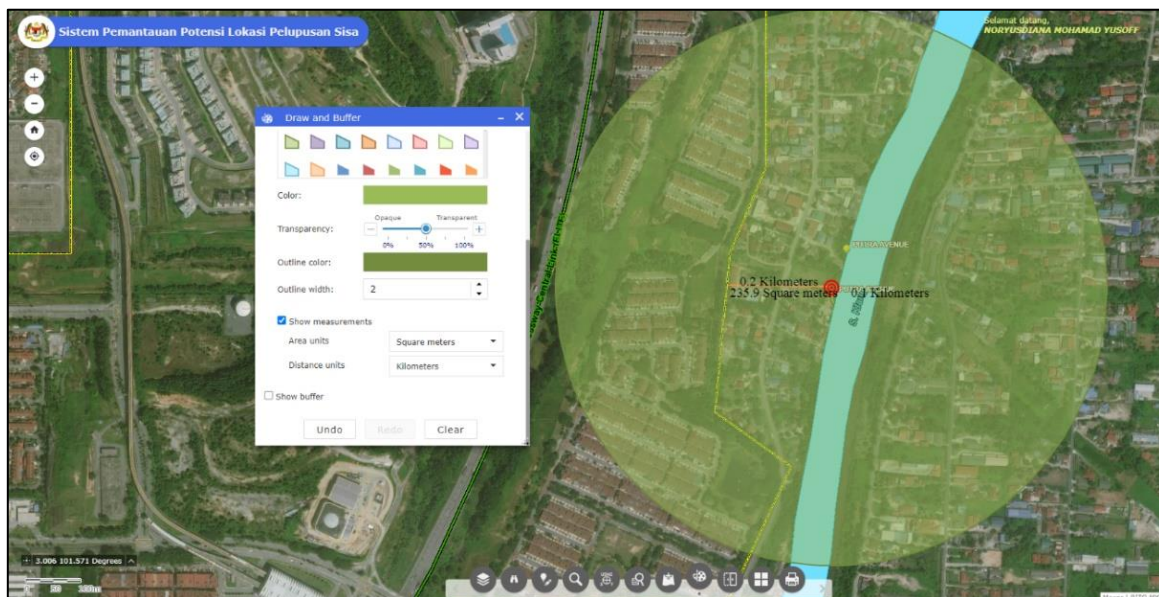


Figure 9. Buffer, area and distance measurement from the waste hotspot location

### 4.3 Edit Module

The edit module aids users in various ways. All information may be updated anytime, anyplace, saving time and money. The mobile-friendly technology lets users update data on their smartphones while field verifying and monitoring. They can add images and supporting papers if needed. High and extremely high-resolution imageries allow them to see and assess the area needing field monitoring. The editable geographical layers are existing and new hotspot areas, whereas the non-spatial data is hotspot status: waste, no waste but potential, or non-potential. Users can also edit land use and waste categories for analysis (Figure 10).





Figure 10. Smart editor allows users to classify the waste potential hotspot status into three (3) options - a) waste location; b) no waste but potential area; or c) non-potential

#### 4.4 Dashboard Module

The dashboard module is intended to display multiple visualizations concurrently on a single screen. The dashboard facilitates easy monitoring, decision-making, and viewing of trends in waste hotspot status and waste type information, particularly for decision makers (Figure 11).

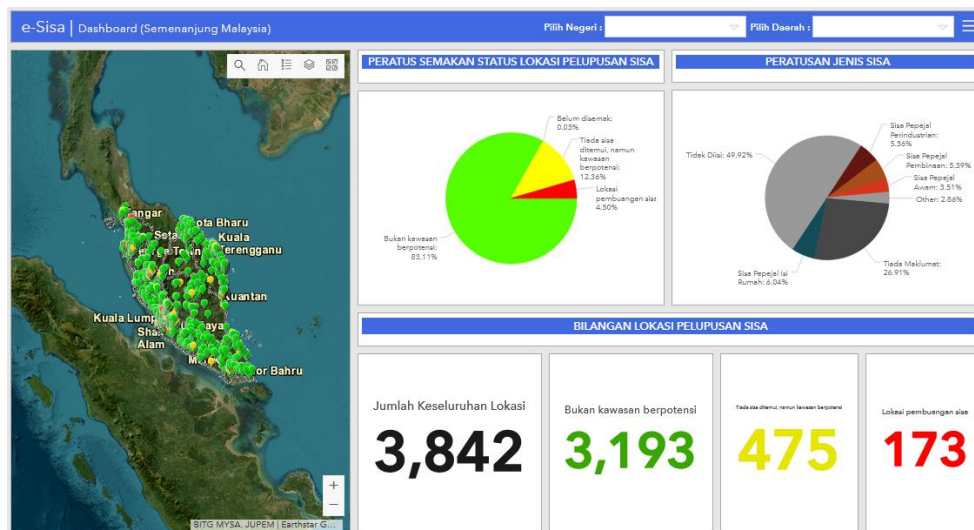


Figure 11. A dashboard that shows waste hotspot status and waste type information

### 5. CONCLUSION

The novelty of this work is the development of a smart system integrated with remote sensing, deep learning, GIS, and ICT technologies for proper waste disposal site management, namely e-Sisa. Web-GIS application provides a new data-sharing method and platform and offers a more interactive display to the user for a better understanding of the data by giving several basic functions to the application such as an infographic widget and query widget. By using this kind of system, local government agencies may monitor the area in almost real-time, eliminating the need for manual monitoring and verification. The findings demonstrate that while the deep learning model performs well in identifying unlawful dumping sites, it has challenges in certain regions lacking ground truth data. On the other hand, we discovered that deep

learning and satellite photos may be used to identify unlawful garbage disposal locations, which would lessen the need for routine human visual interpretation work.

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