DEVELOPMENT OF THE IM4MANILABAY MAPABLE WEB PORTAL

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ABSTRACT:

Products and outputs for water quality monitoring are made available in the IM4ManilaBay MapABLE Web Portal, a web-based GIS platform that serves as a repository of processed maps for Manila Bay and linked systems. The Portal is also linked with the MASDAN mobile application that has been developed to allow the public to report different environmental issues. The web development involved the utilization of geospatial content management system, spatial database system, operating systems, programming, and style language. Services included frontend and backend development. The Web Portal serves as a repository for all outputs derived for water quality monitoring. It contains processed results, technical overview on the developed models and tools, historical data viewing and use of basic geoprocessing tools, and viewing of reported incidents from the MASDAN app. It is expected that the Web Portal will contribute significantly in the efforts of communities and environmental agencies to implement policies for sustainable development and management of Manila Bay and its watershed.

1. INTRODUCTION

The Philippines has an abundance of water resources with total available freshwater resource of 145,900 million cubic meter per year (MCM/year) based on 80 percent probability for surface water, and 20,000 MCM/year groundwater recharge or extraction rate (Greenpeace Southeast Asia, 2007; Rubio et al., 2008). This ensures an adequate supply of water and high freshwater storage capacity. However, seasonal variations and geographic distributions often result in water shortages (Greenpeace Southeast Asia, 2007).

The Department of Environment and Natural Resources (DENR) classifies surface and coastal water, identifies the current beneficial use, and implements water quality standard measurement criteria through DENR Administrative Order (DAO) 34 issued in 1990. The Environmental Management Bureau (EMB), under DAO 33, has defined parameters for water quality per water body classification, both for inland surface waters and groundwater. Water quality assessment from 2001 to 2005 by EMB National Water Quality Status Report monitored and analyzed a total of 196 inland surface water. Parameters included the dissolved oxygen (DO), biochemical oxygen demand (BOD), total suspended solids (TSS), total dissolved solids (TDS), and heavy metals. In relation, several water-related incidents occurred in the Philippines. This greatly impacted the quality of water including oil and chemical spills, and illegal dumping of wastes that resulted in water contamination and fish kills.

The National Capital Region (NCR)'s access to freshwater is becoming inadequate due to degraded water quality, depleted water resources, and inefficient infrastructure caused by poor governance, lack of regulation and resource overuse. Measures to improve water quality are adopted through building and expanding sewage treatment facilities and sewerage infrastructure. Relocation of informal settlers along riverbanks are also part of the measures (Jalilov, 2018).

Despite the allocation of resources by the government, inadequate understanding and information on its monetary value undermines the importance of improving water quality for sustainable urban planning and development and proper management of resources (Jankowski et al., 2007; Jalilov, 2018). While many water quality monitoring efforts have been done, effective management and utilization of data and related monitoring efforts are still lacking (Jankowski et al., 2007).

Development of Web Portals for access and dissemination of information are becoming relevant. Portals are effectively used for information development in many regions of the world (Yamashkin et al., 2019). Hence, the availability of water quality monitoring data and watershed management models in a web-based GIS will provide easy data access and increased information, and will help improve the countries' capacity in understanding water resources' processes and proper management, sources of water quality degradation and analysis of derived-parameters and products (Jankowski et al., 2007).

Water quality data are easily shared and managed through Web Portals. Over the past few decades, web-based Portals have become solutions for spatial data access, sharing and management. It is equipped with functionalities for accessing geographic information as well as Earth Observation (EO) data for scientific purposes and to support decision-making for sustainable development and environmental management (Jiang et al., 2019). There are water quality Web Portals developed for the public. Some of these are shown in Table 1.

The IM4ManilaBay MapABLE Web Portal is a web-based GIS platform for the repository of water quality maps processed using geospatial technologies for Manila Bay and linked systems generated by the Development of Integrated Mapping, Monitoring and Analytical Network System for Manila Bay and Linked Environments (MapABLE) Project. MapABLE is under the Integrated Mapping, Monitoring, Modelling, and

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Management System for Manila Bay and Linked Environments (IM4ManilaBay) Program.

The Web Portal contains downloadable products and outputs and is being used as a water quality monitoring system which facilitates collaborative monitoring and management of Manila Bay through MASDAN, a mobile application for citizen science that allows the public to report environmental problems namely algal bloom, fish kill, ongoing reclamation, pollution of water bodies and hyacinth infestation in rivers and waterways, and a monitoring system that allows authorities to view incoming reports and provide feedback on the action taken (Figure 1).

Water Quality Web Portals	**Description**
Aquadata – A Web Based Water Quality Public Portal (https://webreports.esdat.net/SCC#results-map)	Water quality portal for viewing water quality sampling results in Shoalhaven, Australia (ESdat, 2021)
Water Quality Portal (WQP) (https://www.waterqualitydata.us)	WQP is a repository of publicly available water quality monitoring data collected by over 400 state, federal, tribal and local agencies. Data can be downloaded in Excel, CSV, TSV, and KML formats (USGS et al., 2018).
International Initiative on Water Quality (IIWQ) World Water Quality Portal (http://sdg6-hydrology-tep.eu)	The Web Portal is based on Earth Observation and Environmental Services (EOMAP) providing near-real time water quality data such as turbidity, chlorophyll and indicators for cyanobacteria bloom (UNESCO n.d.).

Table 1. Examples of Web Portals for water quality monitoring data.

The Web Portal can be accessed at http://mapable.tcagp.upd.edu.ph/. The Project envisions that the Web Portal, as well as the products and developed tools, will be used by communities, environmental agencies, and other stakeholders in monitoring and managing the Manila Bay environment.

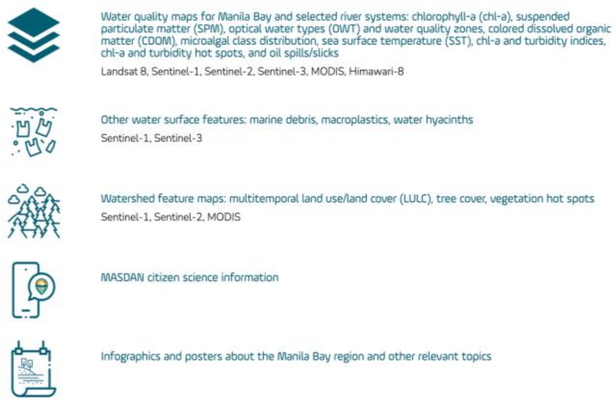

Figure 1. Project MapABLE data products publicly available in the Web Portal. Products and outputs include water quality maps for Manila Bay and selected river basins, other water surface features, watershed feature maps, MASDAN citizen science information, and infographics about the Manila Bay regions.

2. WEB PORTAL DEVELOPMENT

The web development involved the utilization of geospatial content management system, spatial database system, operating systems, programming, and style language. Services included frontend and backend development.

2.1 WebGIS and Applications

WebGIS is an advanced form of Geographic Information System (GIS) available on the web platform. This is where the exchange of information takes place between a server and a client, where the server is called a GIS server and the client can be a web browser, mobile or desktop application (VizExperts, n.d.). WebGIS is not just a platform that enables collaboration among spatial environments and integration of geospatial information. It has a diverse range of applications such as mapping, visualization and spatial query; geospatial analysis; business models which are used for advertising and branding based on mapping (i.e. google map); design and planning management system for different projects like flood management, forest mapping, and natural disaster; location-based services such as parcel tracking, locating the nearest stores, etc.; and technology for research collaboration.

Water quality databases are easily accessed, stored and managed through web-based platforms. The Water Quality Portal (WQP), developed by the United States Geological Service (USGS), provides data through form-based queries. Parameters, such as the location, site area, date range and results, are easily modified for easy searching and customization of output results (USGS et al., 2018). UNESCO, through the International Initiative on Water Quality (IIWQ), provides a water quality online portal for freshwater systems, lakes and rivers derived from EO data. The IIWQ World Water Quality Portal enables users to access a comprehensive range of satellite-based water quality measurements (i.e. turbidity, chlorophyll-a (chl-a) and indicators for cyanobacteria bloom) to help assist in global water quality assessment and capacity building (UNESCO, n.d.).

2.2 Development Cycle

The development follows Alesheikh, et al. (2019) entitled "WebGIS Technologies and Applications". Activities considered in the development are shown in Table 2.

Web development is not limited to what hardware or software should be used; it is a cycle that starts with requirement analysis and ends with the continuous use, availability, and system maintenance (Figure 2).

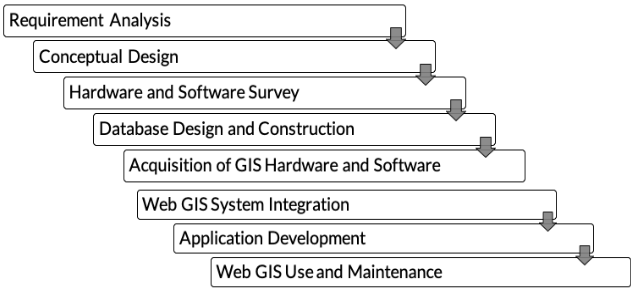

Figure 2. WebGIS development cycle (Alesheikh et al., 2019).

2.2.1 **Requirement Analysis:** As part of the requirement analysis, creation of user stories and feature lists were done. Inputs were requested from researchers, potential partners, users and stakeholders to identify needs, required functions and products/outputs. Results of user stories were used as a basis in the development of which features and tools are to be considered, as well as platforms that will be used.

2.2.2 **Conceptual Design:** Platforms on which the Web Portal will be deployed were evaluated. Fundamental differences between the on-premise and cloud-based systems were reviewed. Factors considered in the selection are cost, security, scalability, resilience and software (Table 3).

2.2.3 **Hardware and Software Survey:** Software has been evaluated in terms of functionality, performance and mostly with respect to the list of features identified from the user stories. For the hardware, size of data, speed of internet connection, and required specific hardware configuration were considered. Various Web Portal platforms were considered and assessed. The selection of platforms in the development has considered the target applications, target user, and features and tools needed for water quality monitoring and assessment.

2.2.4 **Database Design and Construction:** Required applications, structure of the attribute files, layer and scale, output layout and formats, and management and security restrictions were considered. Activities included source selection for each product -- entity and attribute included in the entity-relationship diagram; database design setup; data conversion; and database management and maintenance. Additionally, system and platform (system-PostgreSQL, spatial database-PostGIS), data standardization (file naming convention, scales, formats), data information (metadata, field attribute/scheme), and data migration are considered.

2.2.5 **Acquisition of Hardware and Software:** Design, testing, hardware and software selection and acquisition were conducted simultaneously and iteratively. Aside from the required tools and functionalities, functional capabilities, vendor support, cost and maintenance fee, and necessary renovation of space, wiring, environmental remodelling and system implementation were also assessed.

Software for the management of geospatial information, and tools for managing virtual machines and automating installation and configuration have been considered.

2.2.6 **Web Portal System Integration**: Integration and migration of hardware and software are done at this stage, testing and checking if these are functional and if required tools for GIS analysis are working.

2.2.7 **Use and Maintenance**: The end goal of this cycle is to put the system to use (i.e. system integration and testing, all applications available for use, and systems to be released to users) and maintain support and service to users, and system maintenance.

Activities	Description
Requirements gathering	Creation of user stories and feature list Identify platforms that will be used in the project
Setup of development environment and deployment to GeoNode 3	Vagrant setup and upgrade of deployment from GeoNode 2.10 to GeoNode 3
Maintenance of services	Maintain the services
Deployment on Amazon Web Services (AWS)	Deployment of GeoNode
User Interface (UI) design	Design and layout of website
Migration of datasets	Uploading of data to GeoNode
Timeslider and swipe tool using MapStore	Historical data viewing option
Geoprocessing tools using MapStore	Area computation, intersection, union and query
Mobile application for citizen science integration	Incidents reported using the mobile application will be accessible in the Web Portal. Respective agencies will be given access to verify the reported incident
About page	Contains information on projects and derived-products/outputs
Share button	User can share layers, maps, documents using the share button
Newsletter	Mailing subscription system that send out updates to users regarding new data and information

Table 2. MapABLE Web GIS development activities.

Factors	On-Premise	Cloud
Cost	(+) Cheaper in the long run (+) No monthly cost (-) Significant upfront hardware cost (-) Significant hardware maintenance cost (-) Storage upgrades require procurement of new hardware (-) Requires a team to maintain	(+) Predictable pricing costs (+) No upfront costs (+) Maintenance is included in monthly cost (-) Monthly cost
Security	(+) Organization in full control of data locally (-) Requires knowledgeable security team to harden (-) Significant risk if organization does not have appropriate expertise	(+) Security is already managed by a dedicated team (-) Data is handled by a third party
Scalability	(+) Upgrades can be controlled by the organization (-) Organization needs to plan time and cost to upgrade and deploy new hardware when the old one becomes obsolete (-) Procurement of replacement hardware can be hard for the organization (-) Will tend to underutilize hardware	(+) Organization can rapidly upgrade or downgrade based on demand (-) Cost can escalate if mismanaged
Resilience	(+) Cost effective if 99.99% uptime is not a concern (-) Backups can easily double the cost; adds the need for a second data center if the organization wants to do it properly	(+) Redundancy can easily be achieved using multi-site server and storage setups (+) Backup and restore are easy to set up (-) Outside of the organization's control, hence relying on cloud service providers
Software	(+) Highly customizable if needed (-) Firmware updates and other security updates must be done by the organization (-) Reliability issues can be caused by mismanagement of server software setup	(+) Cloud provider handles all updates (+) Highly reliable infrastructure (-) Minimizes the ability to modify the platform

Table 3. Pros (+) and cons (-) between on-premise and cloud systems.

3. DISCUSSION OF RESULTS

The development of the Web Portal uses the requirement analysis as the baseline on which features, tools, platforms, data and outputs are to be considered. The Web Portal is being hosted and deployed in a cloud service, Amazon Web Services (AWS). Processed results, technical overview on the developed models and tools, historical data viewing and use of basic geoprocessing tools, and viewing of reported incidents from MASDAN have been made accessible (Figure 3).

Project MapABLE aimed for the system to be a web-based application and platform. GeoNode, an open source geospatial content management system, designed for uploading, managing and sharing geospatial data, was used in the development of the Web Portal and will serve as a repository for integrating and disseminating data (OsGeo, 2012) (Figure 4).

Pre-processed satellite images, water quality maps and land cover classification maps are available and downloadable in the Web Portal (Table 4).

The front-end development uses the Hypertext Markup Language (HTML), Javascript and Cascading Style Sheet (CSS). Backend, on the other hand, uses PostGIS and Ubuntu.

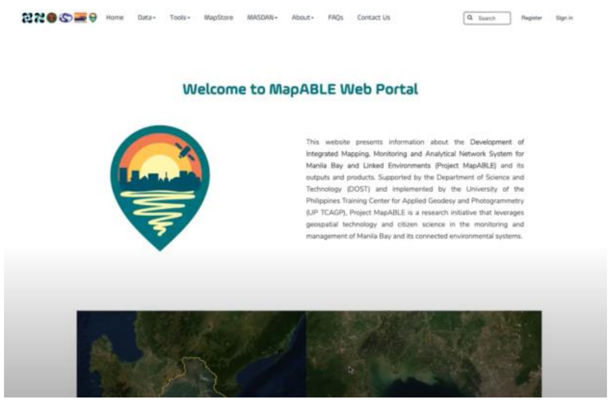

Figure 3. Home page of the MapABLE Web Portal.

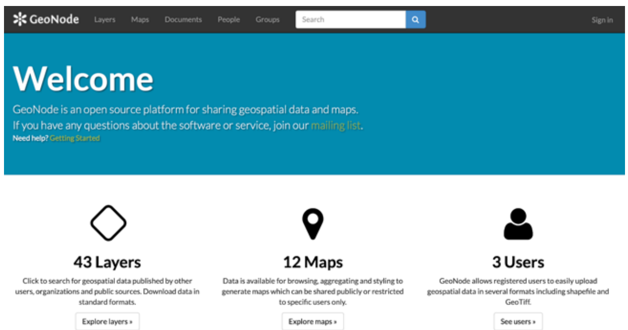

Figure 4. Default interface of GeoNode where geospatial data and web services, layers and interactive maps, are accessed, uploaded, managed and shared. Collaboration with other users is also allowed.

Type	Data Products
Pre-processed satellite images	Cloud and shadow-masked images Normalized images
Bio-optical	Sentinel-3 Case-2 Regional CoastColour (C2RCC)-derived chlorophyll-a (chl-a) and total suspended matter (TSM) maps
Regression	Maps for Pasig River water quality ordinary least square (OLS) models (first and second quarters of 2019) from Pasig River Unified Monitoring Stations (PRUMS) and Sentinel-2
Water quality	Water quality zoning maps Chl-a concentration maps Himawari-8-derived chl-a maps Suspended particulate matter (SPM) concentration maps Algal bloom index maps Colored dissolved organic matter (CDOM) concentration maps Coliform concentration maps Phytoplankton classification maps Oil spill maps Marine debris maps Water hyacinth maps Himawari-8-derived TSM maps Pasig River pseudo shapefile Pasig River time-series analysis (second quarter of 2018 and 2019) from PRUMS
Land cover classification	Multitemporal land cover maps MODIS-derived land cover maps Mangrove Vegetation Index (MVI)-derived mangrove maps Vegetation loss hotspots maps Vegetation anomaly maps

Table 4. Data products available in MapABLE Web Portal.

3.1 Application Development and Deployment Setup

GeoNode contains features that allow easy management of geospatial information such as raster and vector files. It is built on top of Django and Postgres along with the PostGIS extension. GeoNode utilized GeoServer as a platform for sharing geospatial data and Django as a high-level Python framework. GeoNode and GeoServer are deployed in an open source operating system, Ubuntu 18.04.

GeoNode version 2.8 and Mapbox were used in the development of the Project Tanglaw Web Portal, a previous project that worked on the water quality assessment for Laguna Lake. Throughout the development, GeoNode 2.8 and Mapbox were shifted to GeoNode 2.10. There were lots of features added in 2.10 that are useful in the development. From GeoExplorer in 2.8, GeoNode 2.10 uses MapStore2 as the default web mapping client which can perform various mapping applications such as attribute and spatial filter, customizable widgets, 3D view, and time-series animation that are all part of the identified feature list in WebGIS development. Table 5 shows the comparison between GeoNode 2.8 and 2.10.

GeoNode 2.8	GeoNode 3
Uses GeoExplorer as default web mapping client	Uses MapStore2 as default web mapping client
Can perform attribute queries on layers	Can perform spatial and attribute queries on layers Can perform search by entering location name or coordinates Can add different widgets such as charts, tables and texts Can visualize data in 3D view Can display time-series animations thru a plugin

Table 5. Comparison of GeoNode 2.8 and GeoNode 3.

It was planned that Project Tanglaw's Web Portal will be used as a baseline for the development of Project MapABLE Web Portal utilizing GeoNode 2.10. GeoNode requires Python, however Python 2.7 ended in 2020. GeoNode needed an overhaul for Python 3 compatibility, in which GeoNode 3 was released. Since Python 2.7 has ended and is no longer supported, the development setup and deployment for the Project MapABLE Web Portal has been upgraded to GeoNode version 3.

GeoNode 3, as the latest stable release of the software, was used. This version is also tightly coupled with a deployment of GeoServer 2.18, a Java-based software that implements Open Geospatial Consortium (OGC) Compliant services such as Web Feature Service (WFS) and Web Mapping Service (WMS). These services are useful for storing and presenting geospatial data. GeoServer also provides efficient storage and data management API's for vector and raster data types. GeoNode takes advantage of these features.

Vagrant is an open-source tool for managing virtual machines across different operating systems. It can be used to easily deploy local development environments in projects with multiple developers or developers with multiple machines. Machine specifications are managed through configuration files to ensure repeatable and consistent deployments. Vagrant is configured to set up an Ubuntu 18.04 long-term support (LTS) virtual machine on VirtualBox. Having the setup with a virtual machine allows the developers to work in any host operating system. The vagrant configuration file sets up the operating system, networking, and triggers the custom (Figure 5).

Ansible is an open-source tool for automating software installation and configuration. Installation scripts in Ansible are packaged into "roles" and "playbooks". For MapABLE, the team has created a mapable.geonode role for setting up a complete GeoNode based stack. These scripts are used for local and cloud deployments ensuring that all development environments are full copies of production deployments. The setup ensures seamless development and operations integration.

The Ansible role is loosely based on the official GeoNode installation guide found at http://docs.geonode.org/en/master/tutorials/install_and_admin/quick_install.html. Figure 6 shows the main Ansible script.

```
Vagrant.configure("2") do |config|
  config.vm.define "mapable"
  config.vm.box = "ubuntu/bionic64"
  config.disksize.size = '30GB'

  config.vm.provider "virtualbox" do |v|
    v.memory = 6144
    v.cpus = 2
  end

  config.vm.hostname = "mapable.local"
  config.vm.network "forwarded_port", guest: 8000, host: 8000
  config.vm.network "forwarded_port", guest: 8080, host: 8080
  config.vm.synced_folder "../mapable", "/home/vagrant/mapable-geonode/mapable"

  config.vm.provision "ansible_local" do |ansible|

    ansible.extra_vars = "./vars.vagrant.yml"

    ansible.groups = {
      "webservers" => ["mapable"]
    }

    ansible.verbose = true
    ansible.install_mode = "pip"
    ansible.galaxy_role_file = 'requirements.yml'
    ansible.playbook = "playbooks/setup.yml"
  end
end
```

Figure 5. Vagrant configuration file for Web Portal development environment.

```
---

# Create a swap file
- include: swap.yml
  when: "install_swap == true"

# Install postgres
- include: postgres-core.yml

- include: postgres-local.yml
  when: "install_postgres_local == true"

- include: postgres-dbs.yml

# Install redis
- include: redis.yml
  when: "install_redis == true"

# Install geoserver
- include: geoserver.yml

# Pull code from repository if needed
- include: code.yml
  when: "pull_code == true"
  tags: ['code']

# Install geonode
- include: geonode.yml

- include: static.yml
- include: uwsgi.yml
  when: "install_uwsgi == true"
```

Figure 6. The main Ansible script for full stack setup. Each yml included in the file contains specific steps for component set up.

The same script is also automatically triggered whenever new code in a Git branch is merged. This allows the developers to deploy software updates almost instantly with minimal need for downtimes and manual setup.

3.2 Products and Outputs in the Web Portal

MapABLE products migrated in the Web Portal included the water quality maps for Manila Bay and selected river systems (chl-a, suspended particulate matter (SPM), optical water types (OWT) and water quality zones, colored dissolved organic matter (CDOM), microalgal class distribution, sea surface temperature (SST), chl-a and turbidity indices, chl-a and turbidity hot spots, and oil spills/slicks, other water surface features (marine debris, macroplastics, water hyacinths), and watershed feature maps (multitemporal land use/land cover (LULC), tree cover, vegetation hot spots) (Figures 7 to 10). MASDAN citizen science information and its monitoring system are accessible in the Portal (Figure 11).

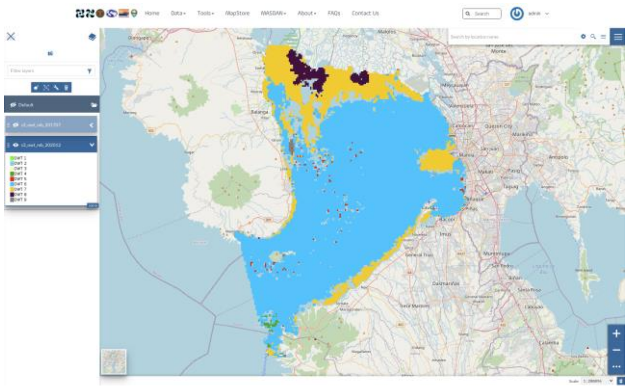

Figure 7. December 2020 OWT map of Manila Bay. Sentinel-3 data acquired from European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) EO Portal are processed using Sentinel Application Platform (SNAP) OWT Tool.

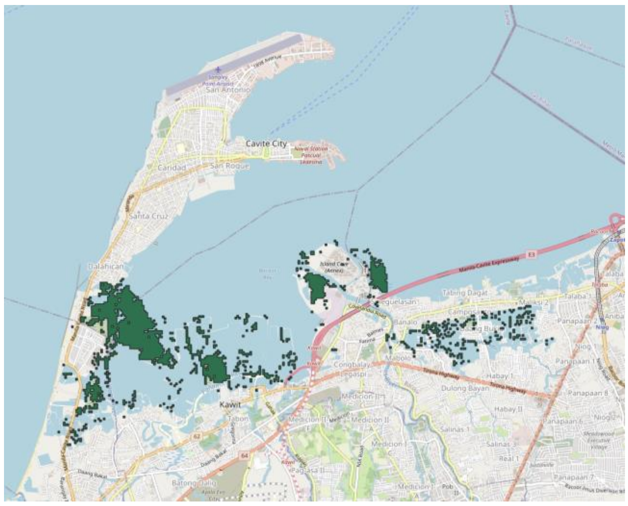

Figure 8. 2020 Mangrove Vegetation Index (MVI)-derived Mangrove map of Manila Bay. Landsat-5, Landsat-7, and Landsat-8 data were acquired from USGS/Earth Explorer. Shapefiles include mangrove maps of Manila Bay derived from MVI.

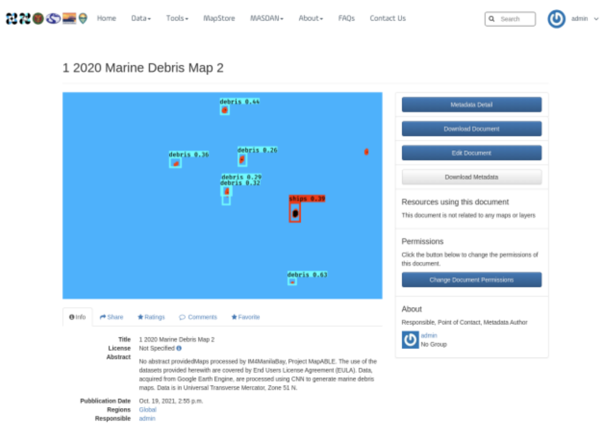

Figure 9. 2020 Marine debris map. Data acquired from Google Earth Engine (GEE) are processed using convolutional neural networks (CNN) to generate marine debris maps.

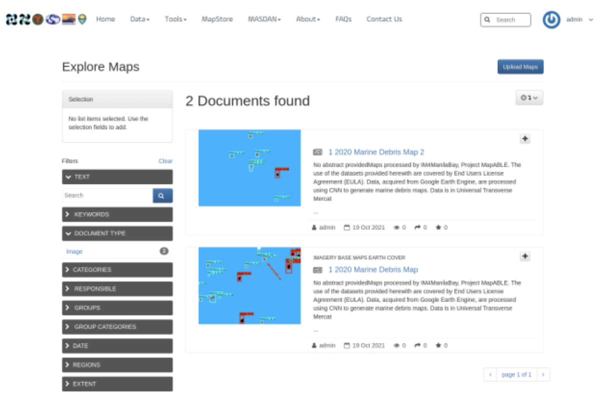

Figure 10. 2020 Marine debris maps shown in the Data/Maps page of the MapABLE Web Portal.

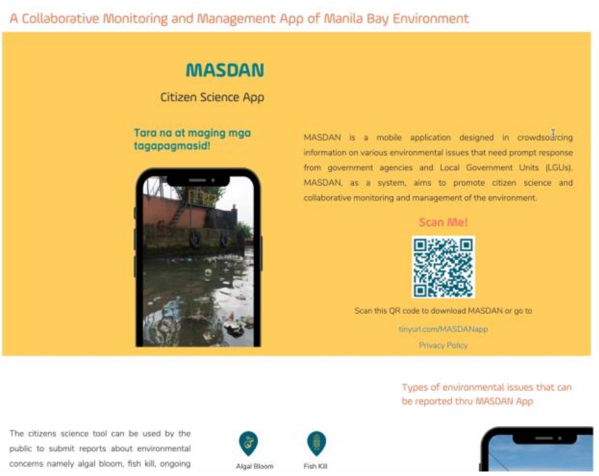

Figure 11. MASDAN citizen science app accessible in the Web Portal.

4. SUMMARY AND FUTURE WORK

The MapABLE Web Portal serves as the repository of products, outputs, and tools developed by the IM4ManilaBay Project MapABLE. It contains downloadable water quality maps, water surface maps and watershed feature maps. It also facilitates the monitoring and management system of the Manila Bay environment. It is expected that the Portal will contribute significantly for communities and environmental agencies in implementing policies for sustainable development and management of Manila Bay.

WebGIS has a diverse range of applications, from mapping, queries, analysis, developing models, management system, location-based services, to technology improvement for collaborations and integration among geospatial environments.

The development of the Portal involved frontend and backend services. The front-end development used HTML, Javascript and CSS. While the backend used PostGIS and Ubuntu. Spatial management and database systems, operating system, programming and style languages were also utilized. Web development starts with the analysis of requirements and ends with the maintenance, support and continuous use of services to users.

The Portal is being hosted and deployed in AWS. GeoNode 3, coupled with the deployment of GeoServer 2.18, was used. Virtual machines are managed using the vagrant configuration file and software installation and configuration are automated using the ansible script.

Water quality Web Portals can be further enhanced by adding a monitoring site for continuous near-real time monitoring and access of datasets. Water quality data is processed on a per hour basis (i.e. derived-measurement parameters from Himawari) and status of water for a particular time range is easily accessible on the site. Access to these data can support various forms of decision-making processes from collaborative work and participation of the public, agencies and local and government units.

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