Design and Implementation of an Interactive Dashboard in the Monitoring Process of Flood Vulnerability Index

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Abstract. This study aims to build a web-based interactive visualization dashboard from granular flood vulnerability index estimation maps using data from satellite imagery. The approach used to build this visualization dashboard is a two-dimensional (2D) approach created with the qgis2web python plugin facilitated with a JavaScript leaflet. Raw data from satellite imagery consisting of indicators of the causes of flooding are extracted in comma-separated value (CSV) format. Furthermore, the data is integrated based on its spatial attributes and stored in Geographic JavaScript Object Notation (GeoJSON) format to produce a visualization of the flood vulnerability index map. In web views, dashboards are built by utilizing hypertext markup language (HTML), cascading style sheets (CSS), and JavaScript (JS). This interactive dashboard has several useful features in helping the process of monitoring the flood vulnerability of an area such as zoom, "show me where I am", measure distance, search, legend, and change year. Thus, the flood vulnerability estimation map dashboard is expected to assist the government in monitoring areas with extreme flood vulnerability and support the decision-making process related to mitigation of areas that have high flood vulnerability.

1. Introduction

Disaster vulnerability is the condition of the community and environment that is disturbed to cause losses due to a certain disaster [1]. According to the National Board for Disaster Management of Indonesia (BNPB), disaster vulnerability is divided into 4 levels, namely social vulnerability, economic vulnerability, physical vulnerability, and ecological/environmental vulnerability [2]. The flood vulnerability index is used as a more specific instrument in measuring losses caused by disasters, especially floods. Flooding is a condition where topographically and geomorphologically dry areas (not swamps) are inundated because the soil drainage level has been saturated and the ability of water infiltration into the soil has reached its maximum limit [3]. Flooding is one type of hydrometeorological disaster, which is a natural disaster that occurs in the atmosphere, water, and oceans [4]. The impact caused by this flood disaster can paralyze several activities, for example in the productive economic sector, infrastructure, and social facilities, especially in flood-affected areas and surrounding areas [5].

BNPB in analyzing disaster vulnerability, especially flood disasters utilizes information sources from Central Statistics Agency (BPS) reports such as provinces/districts in numbers and Village Potential Surveys (PODES) which still use conventional methods and there is a time lag for publication of publications, especially PODES which is only published three times in ten years. In addition, the data presented in the publication has not been able to reach the region to the smallest level. Comprehensive flood vulnerability mapping requires detailed information related to flood disasters and other vulnerability aspects to produce more granular disaster vulnerability maps and the speed of data collection time is useful in identifying evolving conditions. Thus, a way is needed to obtain fast, precise, efficient, and granular data using remote sensing. Remote sensing is a method of obtaining the characteristics of a region on Earth using electromagnetic recording remotely with the help of satellites [6]. Characteristic data of an area from the results of remote sensing in the form of indicators that contribute to causing flooding is then determined the weight of its contribution using the Analytical Hierarchy Process (AHP) method which is one type of method of multicriteria decision analysis (MCDA). The advantage of this AHP method can produce more objective conclusions because the analysis process is carried out simultaneously and integrated with each indicator [7]. The AHP method combined with this Geographic Information System (GIS) enables the use of coherent and efficient spatial data in mapping flood vulnerability.

The map that has been built using the AHP method still produces a static flood vulnerability map at the grid level of 1.5 km. Even though the static map is not necessarily understandable by everyone. Moreover, in the policy-making process, a supporting tool is needed that can be used quickly, precisely, and accurately. According to research conducted by Mina and Chunning in 2020, visualizing smart city performance using interactive dashboards can provide great benefits to collecting, visualizing, analyzing, and informing regional performance to support sustainable smart city development [8]. Based on research conducted by Gayane et al in 2018, dashboard development aims to improve performance in the decision-making process by visualizing based on expected conditions to detect potential problems that may occur [9]. By using an interactive dashboard, users are expected to easily monitor and visualize emergency response conditions quickly when there is a certain disaster [10]. According to [11]–[14] Geospatial dashboards strongly support the purpose of smart cities, namely with their ability to track city performance measurements. Thus, the development of interactive visualization dashboards of this map is very potential to be used, especially in the policy-making process.

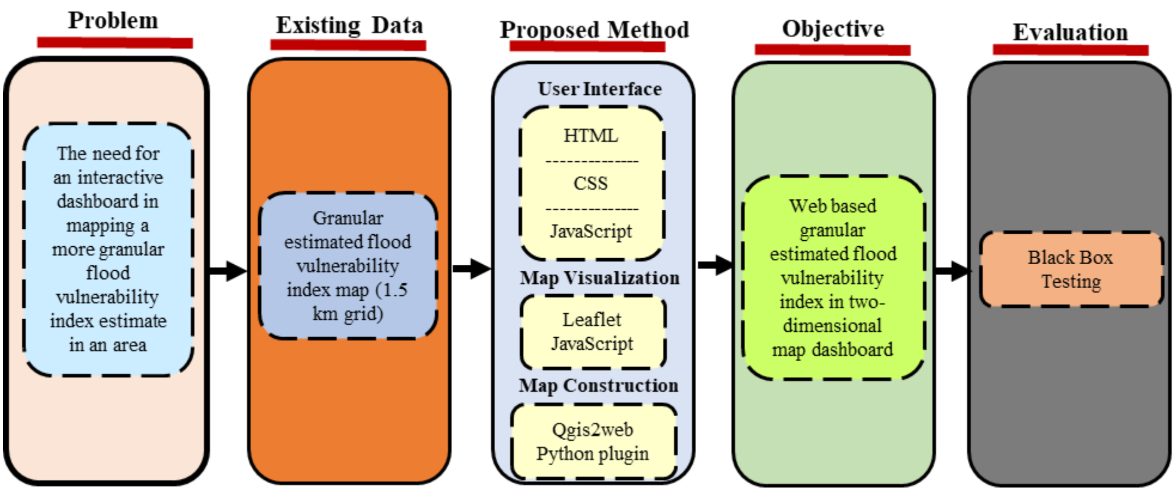

Figure 1. Research Framework

2. Methods

2.1. Granular Flood Vulnerability Data

The indicators used in this study include Built-Up Index (BUI) to detect the level of built-up land that has paid attention to the effect of vegetation, Soil Adjusted Vegetation Index (SAVI) to detect the level of vegetation that has paid attention to soil brightness factors, Normalized Difference Water Index (NDWI) to detect the level of land wetness, Normalized Difference Built-Up Index (NDBI) to detect the level of built-up land, Normalized Difference Vegetation Index (NDVI) for Detect vegetation levels, slope to detect the degree of slope of an area, and elevation to detect the elevation level of an area. The BUI, SAVI, NDWI, NDBI, and NDVI indicators are obtained from Sentinel-2 while the slope and elevation indicators are obtained from the National Aeronautics and Space Administration of the Shuttle Radar Topography Mission (NASA-SRTM). Table 1 below provides detailed information regarding the data used in the construction of this flood vulnerability estimation map.

Table 1. Data used in the construction of flood vulnerability index maps

Indicator	Data Source	Spatial Resolution	Bands Used	Year	References
Built-Up Index (BUI)	Sentinel-2	10m	B4 (Red), B8 (Near Infrared/NIR), and B11 (Shortwave Infrared/SWIR 1)	2020	[15]
Soil Adjusted Vegetation Index (SAVI)			B4 (Red) and B8 (NIR)		[16]
Normalized Difference Water Index (NDWI)			B8 (NIR) and B11 (SWIR 1)		[17]
Normalized Difference Built-Up Index (NDBI)			B8 (NIR) and B11 (SWIR 1)		[18]
Normalized Difference Vegetation Index (NDVI)			B2 (Blue), B4 (Red), and B8 (NIR)		[19]
Slope	NASA-SRTM	30m	Elevation	2000	[20]
Elevation					[21]

This raster data collection was carried out by closing the study area, namely the entire East Java Province, using polygons carried out with the help of Google Earth Engine. Raster derived from Sentinel-2 in the process of retrieval should be calculated according to the formulation of the respective raster forming bands shown in Table 1. The results of all rasters obtained will then be further processed using the Quantum-GIS (QGIS) application.

The preparation of the flood vulnerability index using the Analytical Hierarchy Process (AHP) method is carried out by identifying in advance through a literature review what indicators play an important role in causing floods. From the indicators that have been collected, weights are then determined that interpret the comparison of the level of importance between indicators in affecting flooding using the values agreed in Saaty's research in 1990 [22]. Next, a pairwise comparison matrix is prepared and normalizes the value of each row in the matrix to get the weight of each indicator that will be included in the model. However, to validate whether the weight has been determined at the beginning, it is necessary to calculate the consistency ratio (CR) value obtained from the results of the division of the consistency index and random index [23]. If the CR value of this calculation result is ≤0.1 then the weight that has been determined at the beginning is consistent and can be continued at the next stage. The next step is to calculate the flood vulnerability index using linear combination based on indicators that contribute to causing flooding along with the weight of each indicator [24]. In the following figure, a map of the results of the Linear combination (LC) calculation with weights obtained from the AHP method is displayed. This flood vulnerability map has been able to classify areas into very low, low, medium, high, and very high vulnerabilities. Very low vulnerability index values are found in the range of 0 – 0.2. Low vulnerability index values are found in the range of 0.2 – 0.4. The medium vulnerability index value is in the range of 0.4 – 0.6. High vulnerability index values are found in the range of 0.6 – 0.8. Very high vulnerability index values are found in the range of 0.8 - 1.

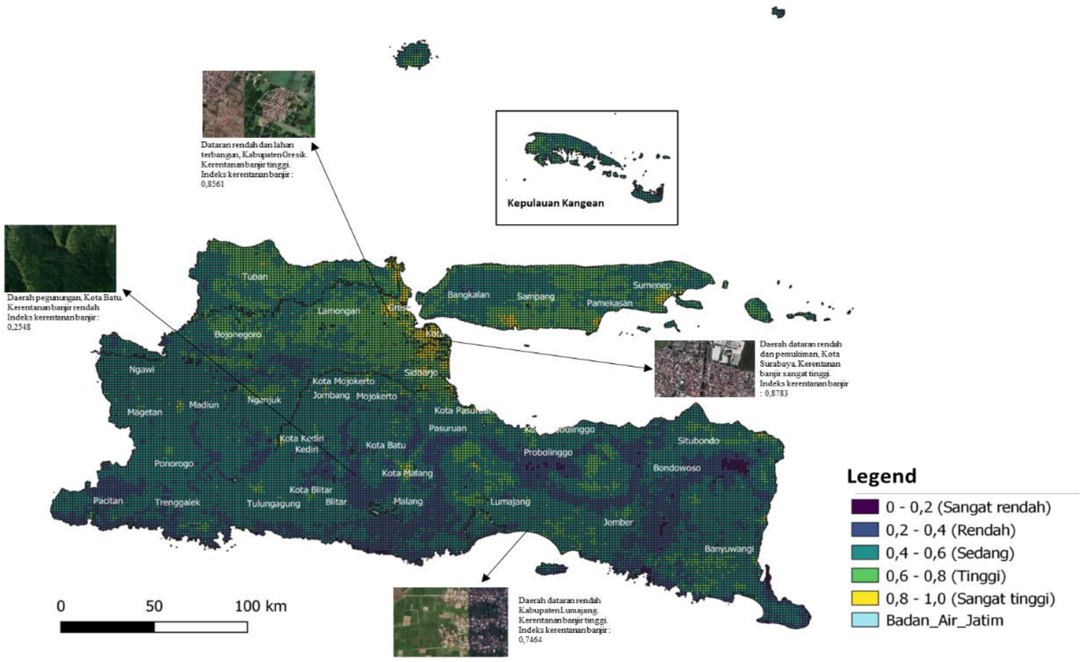

Figure 2. Static visualization of East Java granular flood vulnerability index map

2.2. Dashboard Development

This flood vulnerability index estimation map dashboard is built with a two-dimensional (2D) data visualization approach. The development of the flood vulnerability index estimation map dashboard is mainly intended for the government to monitor flood vulnerability conditions in an area. For the government, it is necessary to pay attention to areas with high flood vulnerability to determine the right policies both in order to reduce the risk of flooding and determine appropriate mitigation efforts. For example, in order to prepare a plan for the construction of facilities that can reduce the occurrence of floods, it can be done in areas that have high flood vulnerability status. With this flood vulnerability index estimation map dashboard, it is hoped that the process of monitoring flood vulnerability conditions in an area can be carried out quickly, precisely, easily, and accurately so that the appropriate policy-making process can be carried out immediately. Therefore, a dashboard is needed that can visualize indicators that contribute to flood prediction and have been grouped into specific vulnerability categories. In addition, to facilitate the monitoring process so clients can understand the meaning of visualization in one glance, in addition to grouping indicator values that contribute to flood prediction, it is also necessary to have colors used as markers related to flood vulnerability status in the area. Thus, the dashboard of the flood vulnerability index map presented will be equipped with colors that are in accordance with the condition of flood vulnerability in an area, including very low, low, medium, high, and very high flood vulnerability.

Before entering the dashboard section at the end of the page, readers are first treated to the home page which contains a glimpse of information related to flood vulnerability to the methodology used in preparing this flood vulnerability map. The dashboard setup flow is described in figure 3-5 below. Starting from the process of collecting raw data in figure 3 in the form of satellite images containing indicators that contribute to flood prediction consisting of BUI, NDWI, NDBI, NDVI, SAVI, slope, and elevation. The target indicators were obtained from Sentinel-2 and NASA-SRTM which were collected using Google Earth Engine (GEE) and then extracted in csv format.

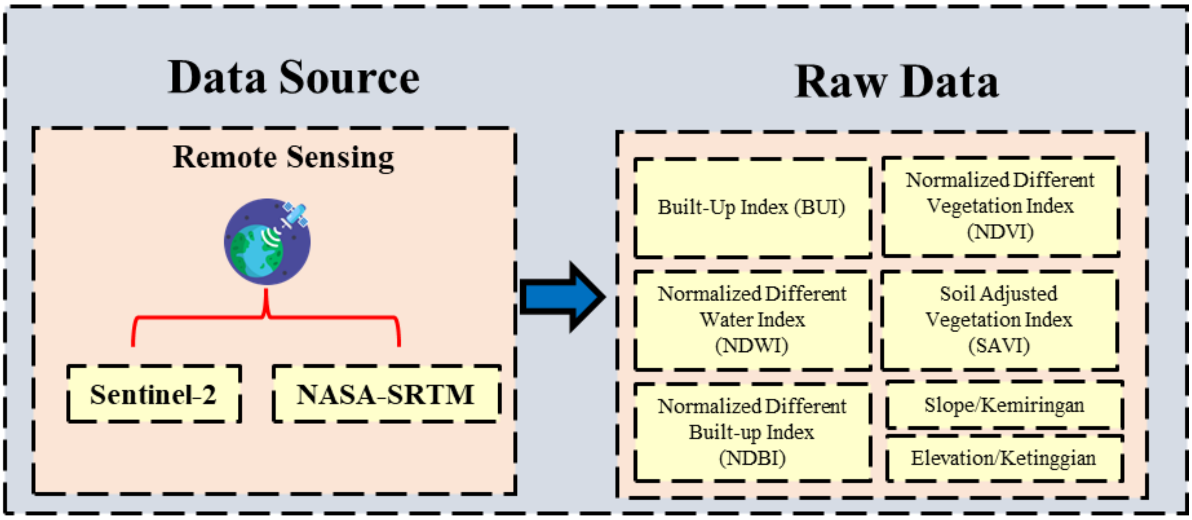

Figure 3. Data preparation of granular flood vulnerability index map dashboard

Furthermore, in the data management stage in figure 4, the data is integrated based on its spatial attributes and stored in geojson format to produce a visualization of the flood vulnerability index map. Visualization of flood vulnerability index from indicator data with geojson format is done with QGIS software and assisted by Qgis2web plugin. In detail it is described in figure 5.

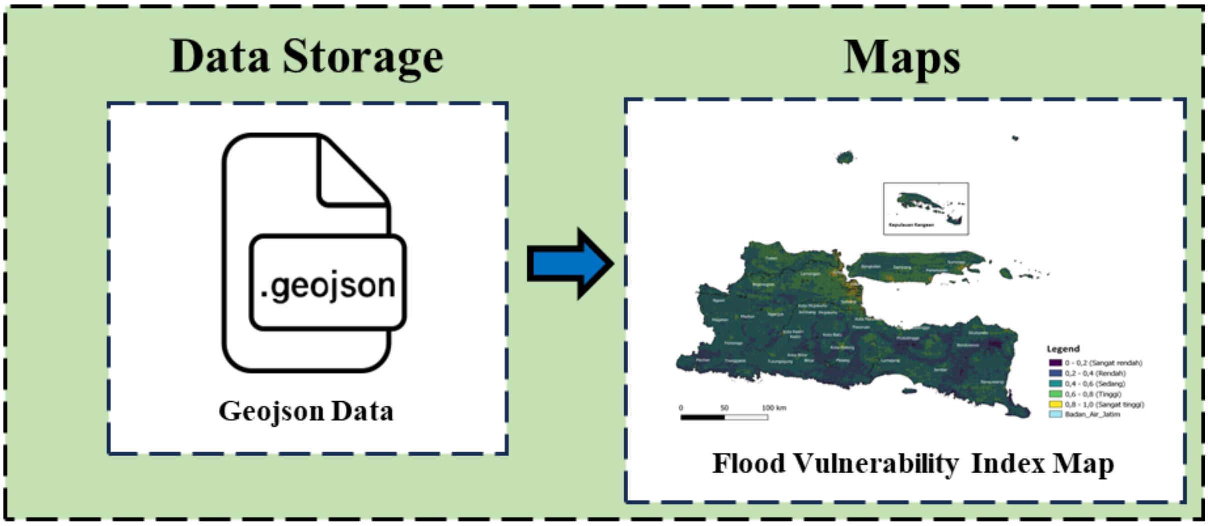

Figure 4. Data management of granular flood vulnerability index map dashboard

Figure 5 shows the process of presenting this flood vulnerability index map dashboard in a web view. Web dashboards are built by utilizing hypertext markup language (HTML), cascading style sheets (CSS), and JavaScript (js) especially for the user interface. The creation of a two-dimensional flood vulnerability index estimation map dashboard is assisted by using the Qgis2web plugin which is a python plugin to convert geospatial layers into HTML, JavaScript, and CSS files. Thus the dashboard that displays flood vulnerability indicator data can be integrated into the website display which will make it easier for users to access flood vulnerability conditions in an area.

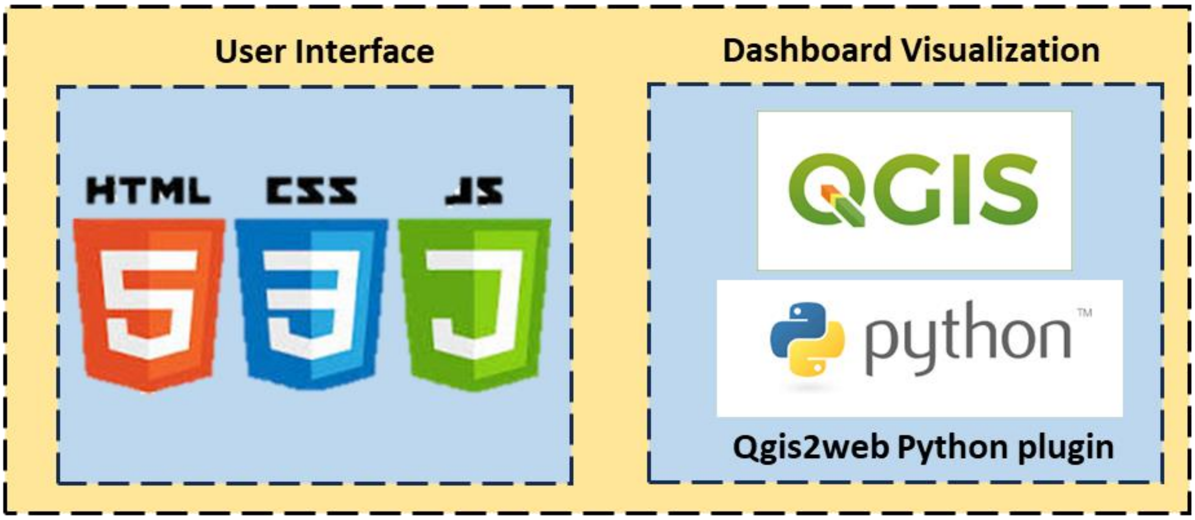

Figure 5. Methodology of granular flood vulnerability index map dashboard

This two-dimensional flood vulnerability index dashboard feature aims to monitor areas based on their flood vulnerability index and look for areas that have extreme flood vulnerability points.

2.3. Evaluation

The evaluation carried out to validate the functionality of the dashboard in this study was by using black box testing. Black box testing is often also called functional testing, which is by designing a set of test cases based on information from predetermined specifications [25]. Black box testing is the process of testing the functionality of software or applications from the user's point of view, without knowing the internal structure or design of the structure. Thus the tester who evaluates the construction of this dashboard can be done by anyone, even those who do not understand programming. This is because black box testing provides several test cases in the form of specific interaction descriptions that testers must perform to test this dashboard [26]. This black box testing is done to meet the needs of end users who play an important role in handling valid and invalid processes from the user's point of view [27]. The end user here refers to the government on which the dashboard of this flood vulnerability index map is built. The government is considered an end user because it sees its duties as a policymaker so that this dashboard can facilitate and accelerate the policy-making process, especially policies in reducing the intensity and risk of flooding in an area.

The recent development in Earth observation technology of satellite imagery analytics provides abundant opportunities to monitor geospatial features on Earth's surface precisely and effectively [28-30]. Multiple available sensors such as optic, radar, thermal, and Light Detection and Ranging (LIDAR) serve as major sources of cheap, frequently updated, and granular representation of land uses, land covers, and sea surfaces for various beneficial use cases of machine learning [31-34].

3. Results

3.1. Technical Details

The flood vulnerability index estimation map dashboard can be accessed via the following link https://bigdata.stis.ac.id/pemetaan-indeks-kerentanan-banjir . When users access the link, they will be taken directly to a page that displays the 2020 flood vulnerability index dashboard and users can choose to switch to the 2021 and 2022 vulnerability maps.

3.1.1. User Interface. This user interface section will explain the display given to users when visiting the web-based flood vulnerability index estimation map dashboard.

Home Page User Interface

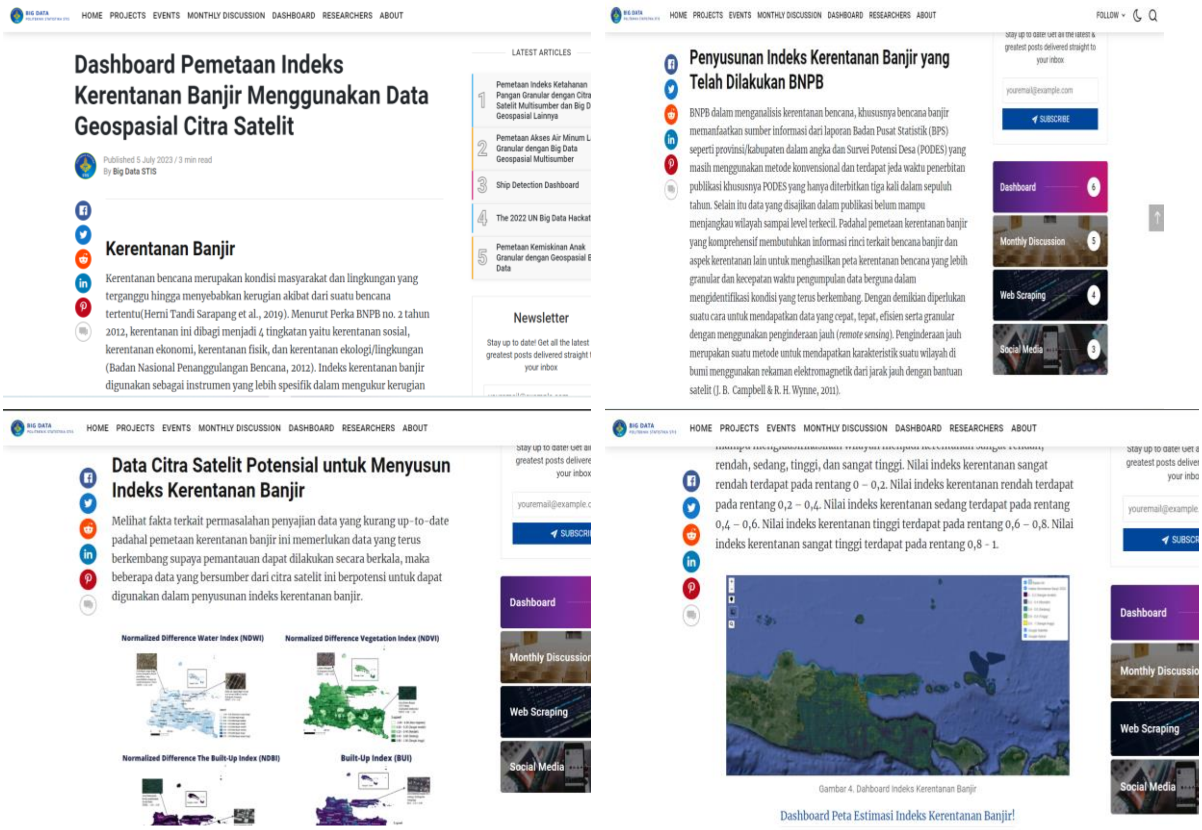

Figure 6. Home page user interface dashboard

Two-Dimensional (2D) Dashboard User Interface

The two-dimensional flood vulnerability index estimation map is presented in the following view shown in Figure 7.

Figure 7. Two-dimensional (2D) granular flood vulnerability index map dashboard user interface

Figure 8 previews the interface that will be displayed when the user visits the dashboard link of the flood vulnerability index estimation map. Next are some explanations related to the feature points that exist on the two-dimensional dashboard display.

1) Canvas; is the area used to display the map
2) Zoom; is a feature to zoom in and out of the map
3) "Show me where I am!"; used to position the map according to the user's actual point at the moment.
4) Measure distance; is a feature to measure the distance between two selected points on the map
5) Search; used to search for specific areas on the map.
6) Legend; Displays the layer being displayed and as a dictionary to see the meaning of each color on the map related to the flood vulnerability category.
7) Change year; used to perform year-on-year data that can be visualized on the dashboard

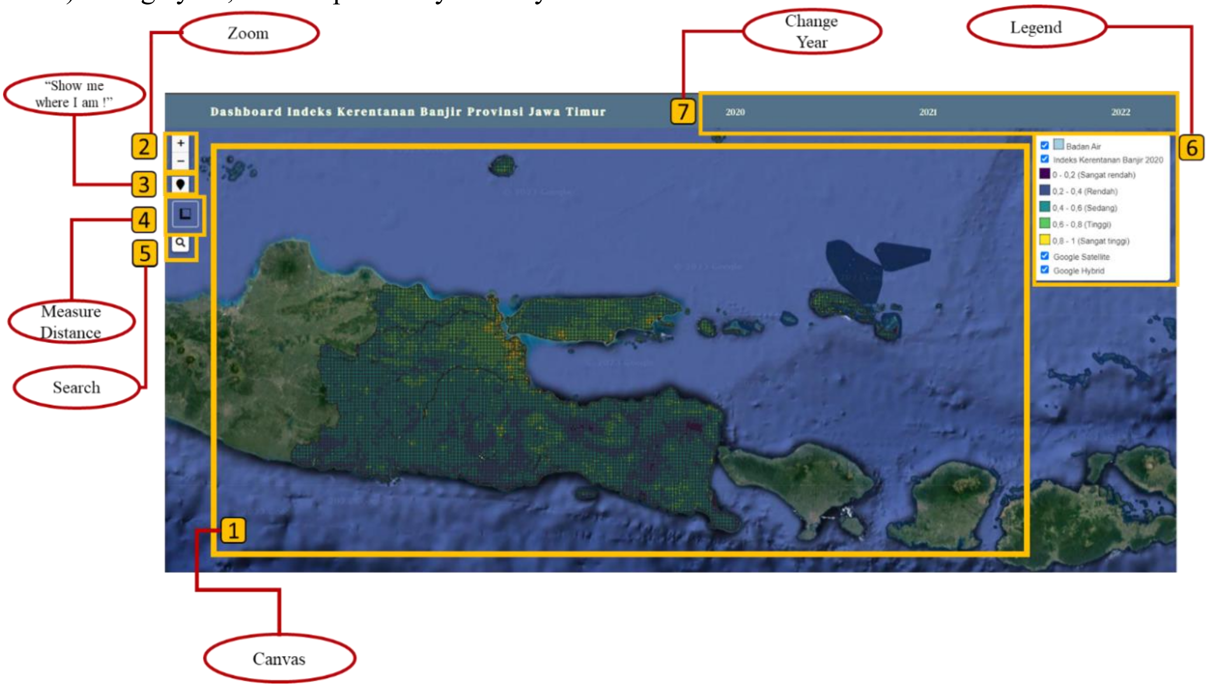

Figure 8. Two-dimensional (2D) granular flood vulnerability index map dashboard user interface with detailed explanation in features

3.1.2. Functional Features. In this functional features section, we will discuss in detail the functional features in the two-dimensional interactive dashboard hence that it can help in decision-making, especially in preparing appropriate mitigation related to handling flood problems.

Two-Dimensional (2D) Dashboard Features

By using this two-dimensional flood vulnerability index estimation map dashboard, it is very easy for users to identify the flood vulnerability status of each area at the 1.5 km grid level. This convenience is offered because this dashboard has several supporting features such as grid hover, legend, zoom, search, measure distance, and change year.

a. Grid Hover

Using this hover grid feature, users can hover the mouse over the desired grid area. When the mouse is in a grid area, the dashboard will instantly display detailed information related to conditions in the designated 1.5 km grid area. The information that will appear consists of the area id, BUI, NDBI, NDVI, SAVI, NDWI, Slope, Elevation value, subdistrict name, district name, and flood vulnerability index value. From this hover grid feature, it is hoped that users can monitor a grid area classified as a flood vulnerability category and can further analyze that areas classified as certain vulnerability categories are marked with such indicator values. This simulation of using a hover grid is shown in the figure 9.

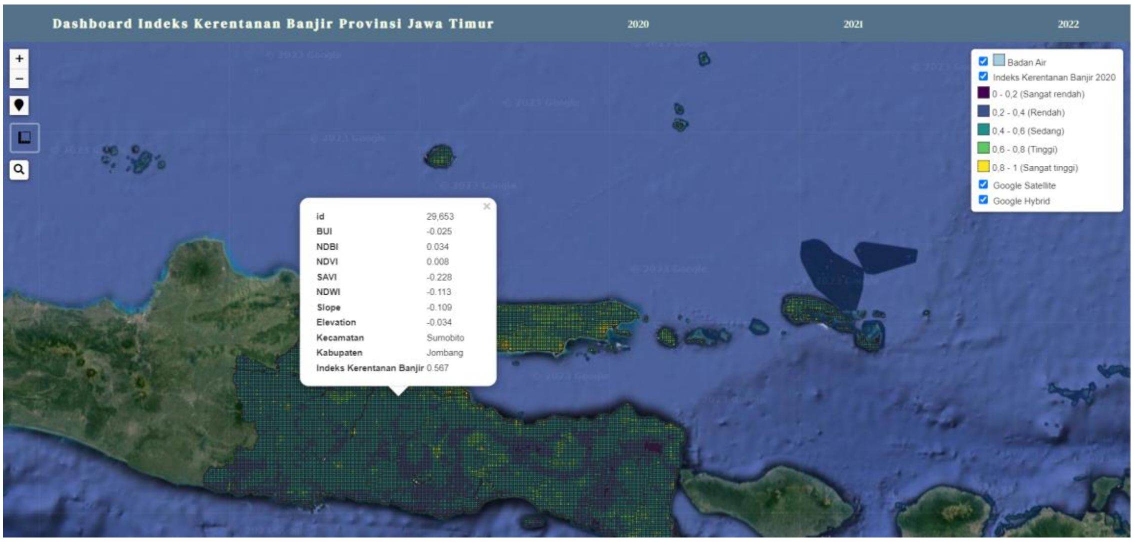

Figure 9. Visualization of grid click feature application

b. Zoom

This zoom feature is useful for zooming-in and zoom-out flexibly. Thus users can make detailed observations using this feature because the points to be observed can be zoom-in and zoom-out.

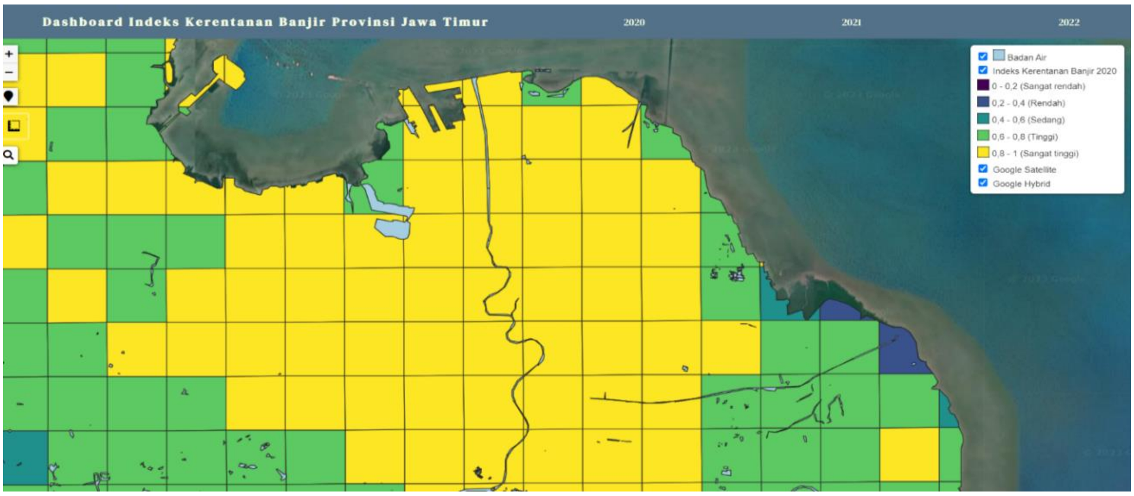

Figure 10. Visualization of zoom feature application

c. Legend

The legend on the map dashboard estimates the flood vulnerability index is used to give meaning to each color on the map is at the level of flood vulnerability is very low, low, medium, high, or very high. In addition, this legend also displays symbols for water bodies that can be used as a characteristic of open water bodies in an area and are not recognized as flooded areas.

d. Search Map

This search feature is useful for users who want to monitor a certain area but want to instantly find it. Thus users can take advantage of this search feature and enter the name of the area they want to search, for example in the example figure 11 is Ambulu District. The dashboard will display Ambulu District by pinning the area and users can easily hover at that point to find out the category of flood vulnerability in Ambulu District.

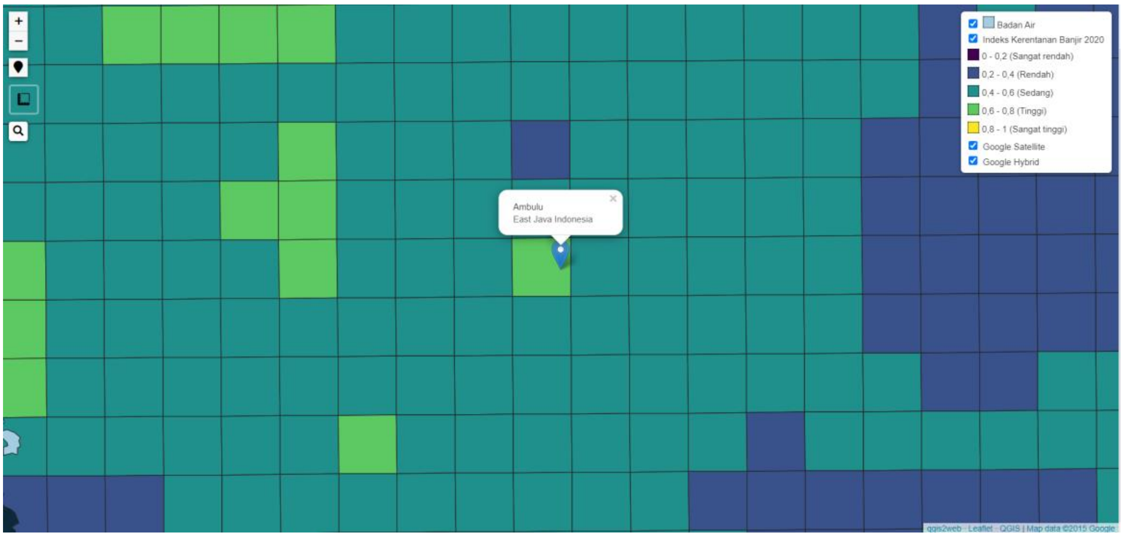

Figure 11. Visualization of search feature application

e. Measure Distance

Measure distance is useful for measuring the distance of two points of the area on the map. Suppose in the example figure 12. The user can specify the start point and end point that you want to determine the distance, then in the column "Measure distance and areas" will be displayed coordinate points along with the results of measuring the distance between the two points.

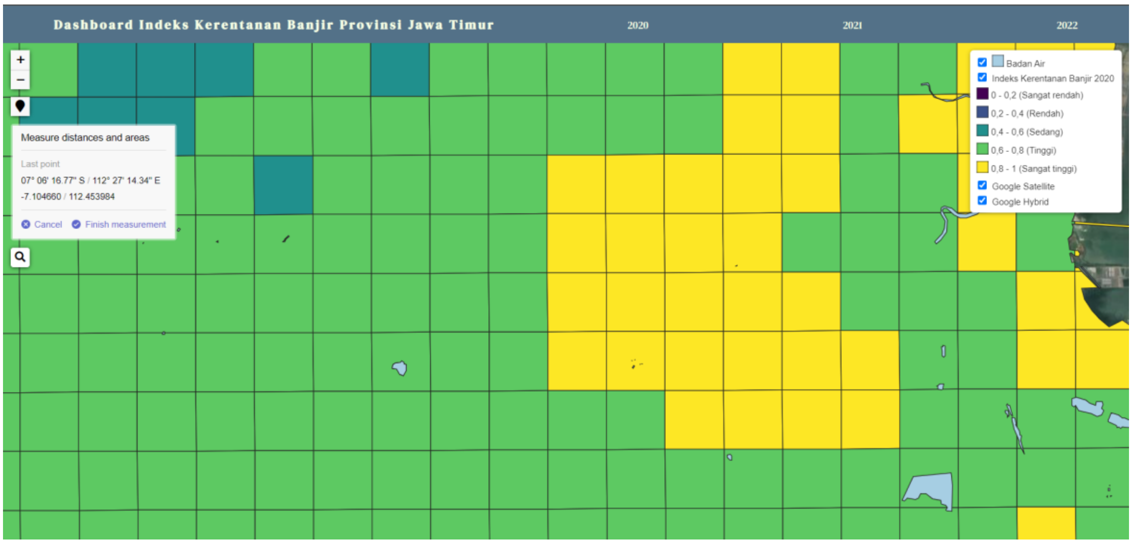

Figure 12. Visualization of measure distance feature application

f. Change Year

The change year feature is useful for switching map visualizations based on the year of data used. On the figure 13 The following is an example if the user selects 2021, a map of the estimated flood vulnerability index for 2021 will be displayed. Likewise, in the figure 14 when users select 2022, a map of the estimated flood vulnerability index in 2022 will be displayed.

Figure 13. Visualization of change year feature application when user click option "2021"

Figure 14. Visualization of change year feature application when user clicks option "2022"

3.2. Evaluation Results

In Table 2 below, the results of the evaluation using Black Box testing that has been carried out are displayed. The test results show that the test case in the form of a description of specific interactions on this dashboard functionality has run as expected.

Table 2. Black Box testing result

No.	Test Scenario	Expected Result	Test Result
		Home Page	
1	The user clicks zoom button on index visualization map	The system displays the zoomed-in version of the index visualization map in the web	Succeed
2	The user clicks “Dashboard Peta Estimasi Indeks Kerentanan Banjir!”	The system displays an interactive map-dashboard of the estimated flood vulnerability index	Succeed
		Two-Dimensional (2D) Map Dashboard	
3	The user hovers the mouse over one of the grids on the map	The system displays detailed flood vulnerability index information on the corresponding grid	Succeed
4	The user selects the menu 2020 or 2021 or 2022	The system view will display map a map by corresponding year	Succeed
5	The user clicks the zoom-in and zoom-out menu	The system will display a map view zoom in or zoom out	Succeed
6	The user clicks legend’s checkbox menu	The layer clicked by the user will be active and displayed on the dashboard	Succeed
7	The user clicks 'show me where I am' button	The system will focus the display on the coordinates of the location where the user is located	Succeed
8	The user clicks on the 'measure distance' button and clicks on started point and finished point	The system will calculate the distance of the start and finish point	Succeed
9	The user enters the name of a specific area in the search field	The system will display and focus on the search area by marking the location pin	Succeed

4. Discussion

This flood vulnerability dashboard has been able to present information that changes depending on which part of the grid the user points to. This dashboard is useful for the government in monitoring because through this dashboard it can be shown in real-time the condition of each 1.5 km grid along with the indicator values of each region and its vulnerability index. From the information that appears, users are expected to be able to analyze approximately the area in the category of very low, low, medium, high, and very high flood vulnerability. An example is shown in the following Figure 15.

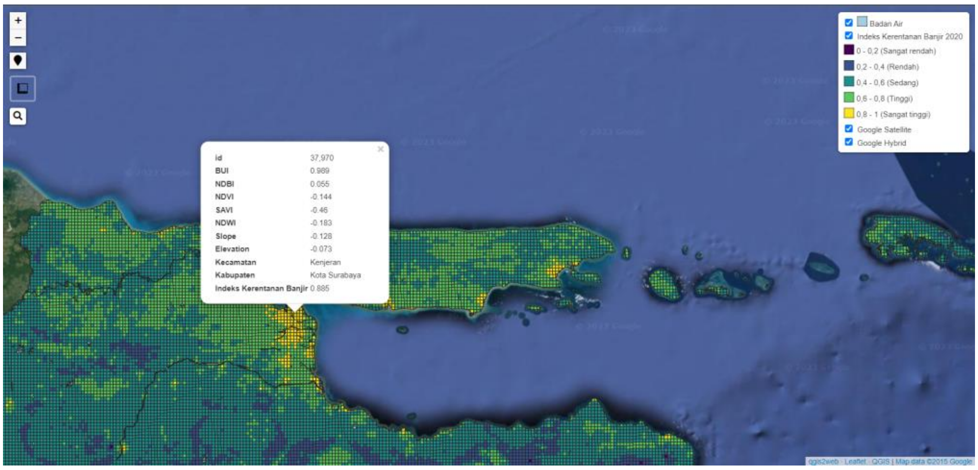

Figure 15. Map view of the results of the selection of one of the grids Kenjeran District

For example, the picture shows a 1.5 km grid located in Kenjeran District, Surabaya City, which has a flood vulnerability index of 0.885. This means that when viewed in the legend, Kenjeran District is in the category of very high flood vulnerability because it is located between the value range of 0.8 – 1. This dashboard is also equipped with Google satellite and Google hybrid layers that can be used to see the real condition of the grid identified as an area with very high flood vulnerability. In Kenjeran sub-district, which is identified as being included in this very high vulnerability category when displayed in the Google satellite layer, is shown in the following Figure 16.

Figure 16. google satellite display on the grid of Kenjeran District from previous appointments

It turns out that after being displayed on the Google satellite layer, the 1.5 km grid area located in Kenjeran District has real conditions in the form of dense residential areas. This condition follows the identification of areas that are prone to flooding, namely areas that have high levels of built-up land, low vegetation areas, and low elevations and slopes. Following the existing theory areas with high levels of built-up land cause the water catchment area to decrease so that when rainfall is high, the soil is unable to absorb water so a lot of water is stagnant on the surface and flooding occurs. In addition, the Kenjeran District area is also located in a coastal area that has geographical conditions in the form of lowlands which are included in the identification of flood-prone areas.

Seeing the condition of Kenjeran District like that, through this interactive dashboard should be used as a guide for the government in making decisions related to development planning, for example. Areas that are in the category of high flood vulnerability and have geographical conditions like this must be reconsidered if they are to be included in development plans by the government. In addition, the government can also use this information to provide input to the decision-making process that requires information on the flood vulnerability of an area.

5. Conclusion

This research has succeeded in building an interactive dashboard for flood vulnerability index estimation which can be visited through the following link https://bigdata.stis.ac.id/pemetaan-indeks-kerentanan-banjir/. This dashboard that is built uses a two-dimensional (2D) visualization approach. This dashboard has features that include canvas which is an area used to display maps. Then the zoom feature is used to zoom in and out of the map. Furthermore, the "show me where I am!" feature is used to position the map according to the user's actual point currently located. In addition, there is a measure distance feature is feature to measure the distance between two selected points on the map. This dashboard is also equipped with a search feature that is used to search for certain areas on the map. In addition, there is also a legend feature to display the layer that is being displayed and a dictionary to see the meaning of each color on the map related to the category of flood vulnerability. It is also equipped with a change year menu which is used to change the year data that can be visualized on the dashboard.

On this dashboard, a hover grid can also be done where when the mouse is hovered on the grid will display information related to the value of each indicator that causes flooding on the grid along with the value of the flood vulnerability index. Thus, the flood vulnerability index estimation dashboard can be used as a supporting instrument for the government in monitoring flood vulnerability areas and as input in determining policies. Our results are potentially beneficial to support disaster risk management by government agencies and relevant subject matters.

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