SINGAPORE MANAGEMENT UNIVERSITY

SMT201 Geographic Information Systems for Urban Planning 15/11/2021

KEEP CALM AND KALI ON

Site Suitability Analysis for Indonesia's New Capital

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1.0 Introduction

1.1 Indonesia

Indonesia is a country located in Southeast Asia which stretches across the equator and is situated in both the Pacific and Indian Oceans (Legge, 2021). Consisting of a total of 17,508 islands, Indonesia is the fourth most populated country in the world with a population of 275.1 million people as of mid-2021 (O'Neill, 2021). Additionally, it is the country with the largest Muslim population in the world, despite it not being an official Islamic state (ASEAN IP, n.d.). The capital of Indonesia has been Jakarta since 1945. In 2019, the president of Indonesia, Joko Widodo announced that he plans to relocate the capital of Indonesia to the edge of eastern Borneo Island, East Kalimantan (CNA, 2019). This is due to the fact that "the burden Jakarta is holding right now is too heavy as the centre of governance, business, finance, trade and services." Jakarta is one of the most densely populated cities in the world with a population of 10 million people. Due to the overcrowding, Jakarta experiences heavy traffic congestion leading to huge economic losses.

In East Kalimantan, more than 50% of the population is employed in the agriculture sector (Britannica, 2019). Additionally, the manufacturing sector is dominated by industries such as logging and mining which has boosted the local economy. There are two airports in this area, one in Balikpapan which handles international flights and a smaller one in Samarinda which handles domestic flights. The president mentioned that the site of East Kalimantan is in a very favourable location as it is in a central location of Indonesia and close to urban areas (CNA, 2019). He also added that the area is at a low risk of natural disasters. Thus, we will be looking into East Kalimantan, the newly proposed site for the new capital of Indonesia.

1.2 Project Motivation

This project aims to plan a new-province level city and to relocate the capital of Indonesia to Kalimantan on the island of Borneo. This is in line with reducing the developmental inequality between Java and other islands in the Indonesian archipelago and to reduce Jakarta's burden as Indonesia's Primary hub.

1.3 Project Objective

The project aims to analyse the study area in terms of the following aspects:

- Population and demographic
- Economic and Business

- Transport and Communication
- Infrastructure
- Environment and Hazard

We will also select a suitable site that meets the following requirements for capital relocation:

- The proposed new capital city should be between 4500-5500 hectares in size.
- It should avoid steep slopes. Steep slope developments are relatively more costly because they involve cut-and-fill and are less environmentally friendly.
- It should be away from potential natural disaster risk areas such as sea coasts, major rivers and volcanoes.
- It should be near to current urban settlement areas but not at the current major settlement areas.
- It should avoid natural forest as much as possible.
- It should avoid areas prone to forest fire.
- It should be highly accessible via road transport.
- It should be near to airport(s) and seaport(s).

2.0 Step-by-step Guide

2.1 Data Sources

Data Source	Name	Description	Link
Indonesia Geospatial	BATAS DESA DESEMBER 2019 DUKCAPIL KALIMANTAN TIMUR	Village boundary and population data for East Kalimantan 2019	https://www.indonesia-geospasial.com/2020/04/download-shapefile-shp-batas-desa.html
Indonesia Geospatial	Geology Kalimantan Timur	Geology Shapefile of East Kalimantan	https://www.indonesia-geospasial.com/2020/03/download-data-shapefile-shp-geologi-se.html

Indonesia Geospatial	KOTA BALIKPAPAN	Topographical data layers of Balikpapan City	https://www.indonesia-geospasial.com/2020/01/shp-rbi-provinsi-kalimantan-timur.html
Indonesia Geospatial	KOTA SAMARINDA	Topographical data layers of Samarinda City	https://www.indonesia-geospasial.com/2020/01/shp-rbi-provinsi-kalimantan-timur.html
Indonesia Geospatial	KUTAI KARTANEGARA	Topographical data layers of Kutai Kartanegara Regency	https://www.indonesia-geospasial.com/2020/01/shp-rbi-provinsi-kalimantan-timur.html
Indonesia Geospatial	OSM Buildings	Detailed building footprints throughout Indonesia	https://www.indonesia-geospasial.com/2020/12/download-shp-pemukiman-detail-seluruh.html
Indonesia Geospatial	PENAJAM PASER UTARA	Topographical data layers of Penajam Paser Regency	https://www.indonesia-geospasial.com/2020/01/shp-rbi-provinsi-kalimantan-timur.html
Indonesia Geospatial	30. Provinsi Kalimantan Timur	Digital elevation model at 30m resolution	https://www.indonesia-geospasial.com/2020/01/download-dem-

			srtm-30-meter-se-indonesia.html
Indonesia Geospatial	Titik Api Hotspot se-Indonesia Tahun 2014 - 2019	Indonesia fire Hotspot data from 2014-2019	https://www.indonesia-geospasial.com/2020/04/shapefile-shp-titik-api-hotspot.html

2.2 General Notes

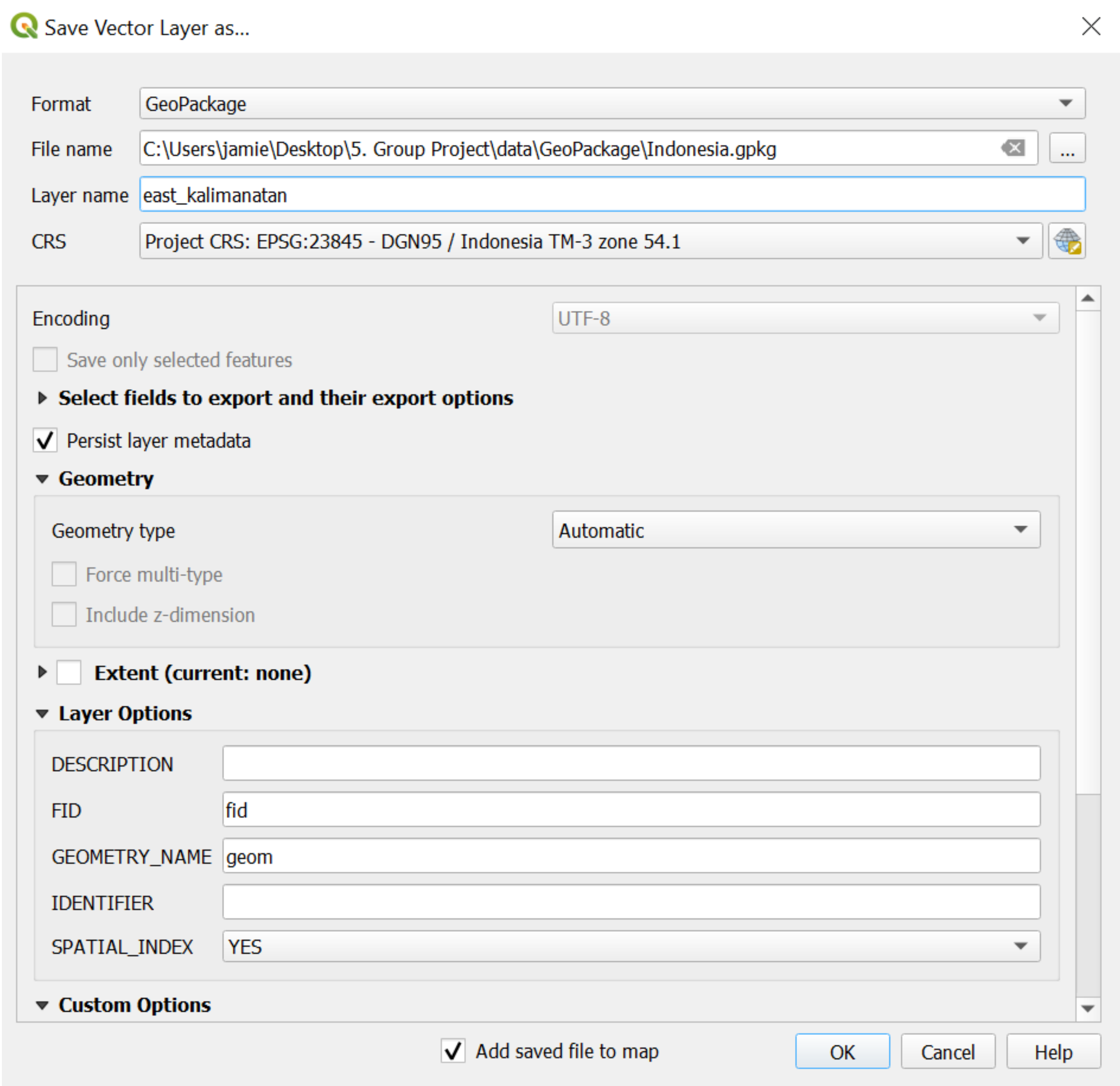
2.2.1 Saving layers in GeoPackage format

Always remember to save all the layers in a GeoPackage format.

- Right click on the layer → Export → Save Features As...

The Save Vector Layer as dialogue box will appear.

- Format: GeoPackage
- File name: Navigate to the GeoPackage file in which you want to save your layer in → **Indonesia.gpkg**
- CRS: Set this to the project CRS, **ESPG: 23845** - DGN95 / Indonesia TM-3 zone 54.1.



- Click on OK and close the dialogue box.
- Delete the unnecessary layers after GeoPackaging it.

2.3 Data preparation

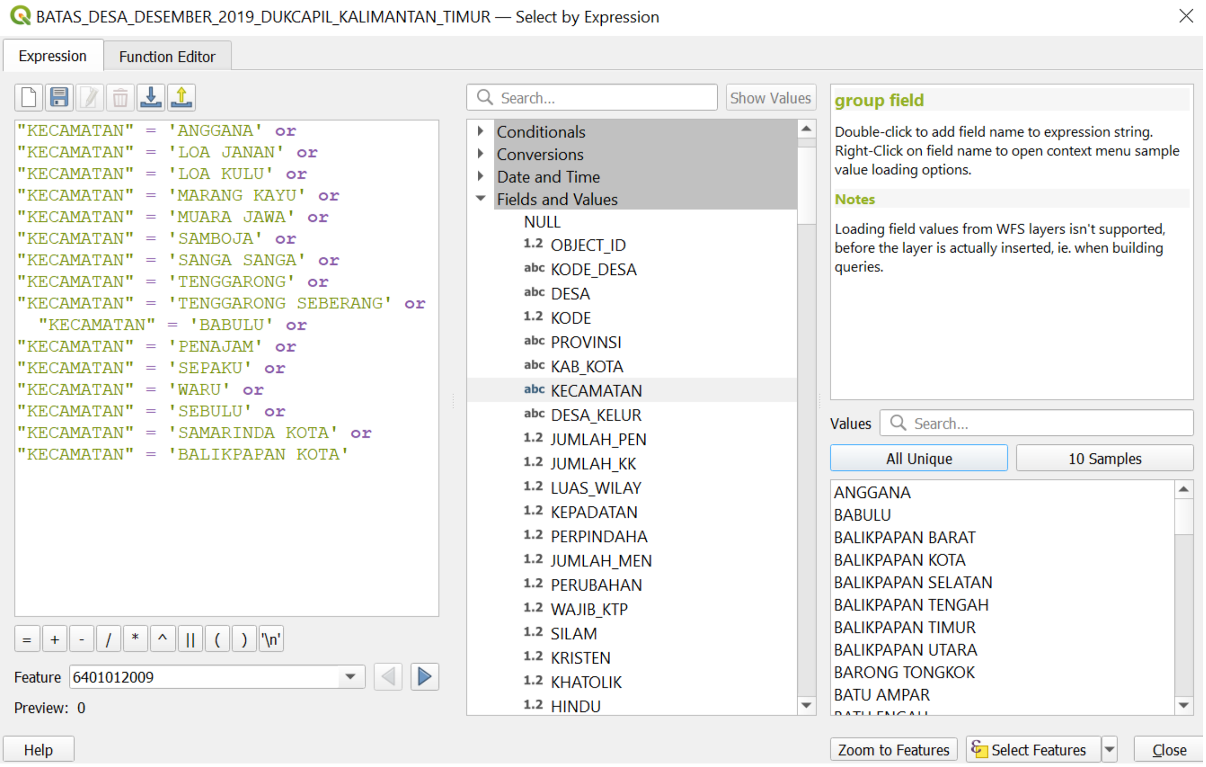
2.3.1 Selecting study area polygon

- Add BATAS_DESA_DESEMBER_2019_DUKCAPIL_KALIMANTAN_TIMUR layer, open attribute table and click on **Select by Expression**.

The Select by Expression dialogue box will appear.

- Under the Fields and Values drop-down list, double click on KECAMATAN which represents districts.
- Click on equal sign
- Click on the All Unique button at the right column

- Add the expression into the expression pane as shown below to select the required study area.



- Right click on the layer → Export → Save selected features as
- Geopackage the selected features and name the layer **east_kalimantan**.

2.3.2 Adding the necessary layers for analysis

We will now be adding layers we need for both the Report of Survey (Task 1) and Site Selection (Task 2). These layers can be found in the Kota Balikpapan, Kota Samarinda, Kutai Kartanegara and Penajam Paser Utara data files that were previously downloaded. For hotspots data, it can be found in the Titik Api Hotspot se-Indonesia Tahun data file from 2014 - 2019.

The following shapefile layers should be added into QGIS:

English Name	**Layer to be added**
Agriculture - Plantation	Agrikebun
Agriculture - Rice field	Agrisawah
Agrifield	Agriladang

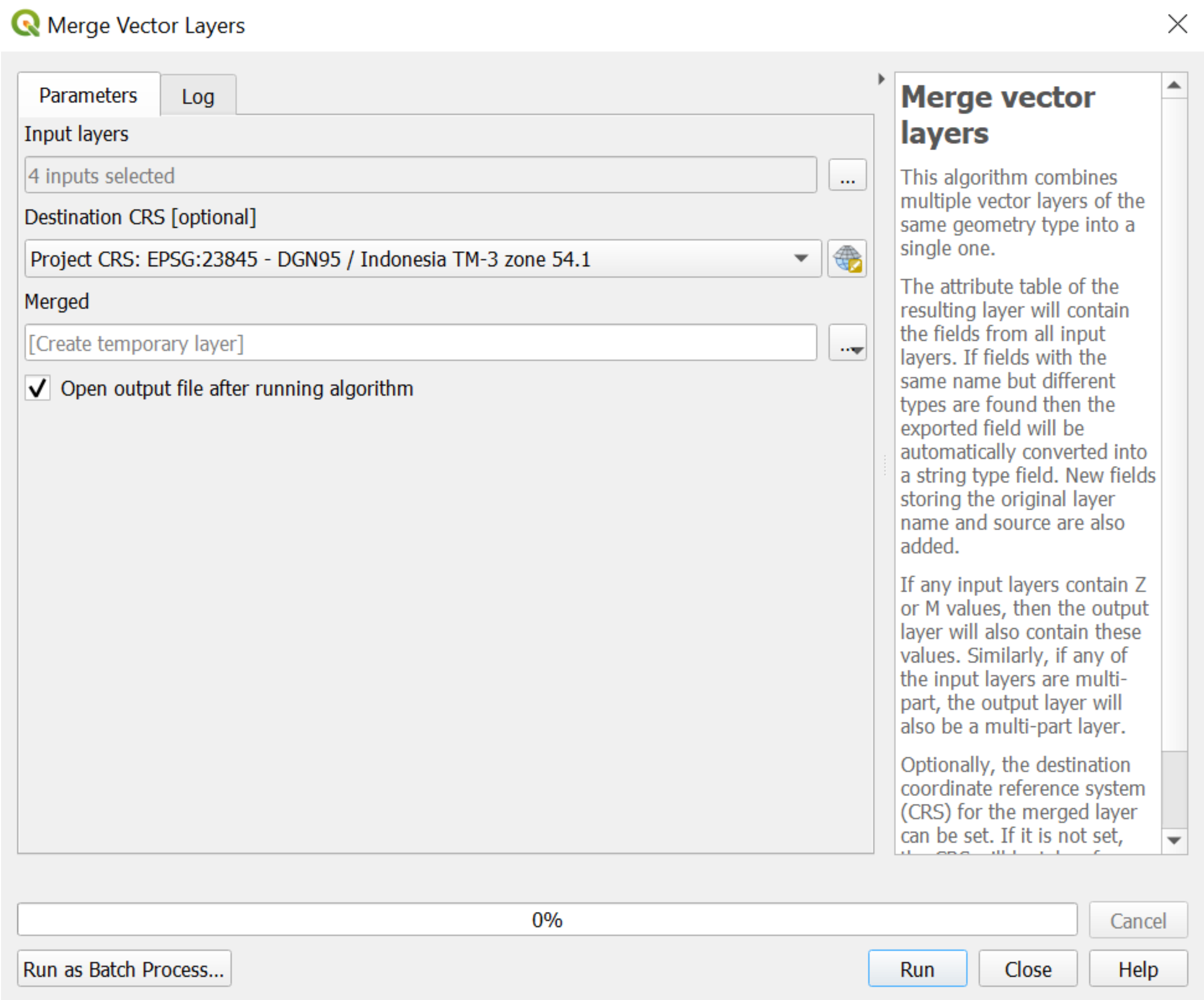
Airport points	Airport_PT
Airport polygons	Airport_AR
Bus terminals	Terminal Bus
Coastline	Pesisir
Education	Pendidkan
Electricity	Genlistrik & Menaralistrik
Forest - Wet	Non agri hutan basah
Forest - Dry	Non agri dry forest
Forest - Reed	Nonagrialang
Forest - Shrubs	Non agri semak belukar
Health Services	Layanan kesehantan
Hospitals	Rumah sakit
Hotspots	Titik Api Hotspot se-Indonesia Tahun 2014-2019
Industry	Industri
Manufacturing	Further extracted from Industri layer called 'Industri Manufaktur Lainnya' under REMARK
Mining - Coal	Further extracted from Industri layer called 'Pertambangan Batu Bara'under REMARK
Mining - Other	Further extracted from Industri layer called 'Pertambangan Lainnya'under REMARK
Mining - Open (Surface Mining)	Tambang_AR

Phone Towers	Menaratelpon
River	Sungai_LN
Roads	Jalan
Seaport points	Pelabuhan_PT
Settlements	Pemukiman

2.3.3 Merging layers

Since we have data scattered in different folders (e.g. road shapefiles from Kota Balikpapan, Kota Samarinda and more), we will be merging them into one layer for a cleaner QGIS environment. The layers in the table in section 2.3.2 should be merged as they are from the 4 different folders.

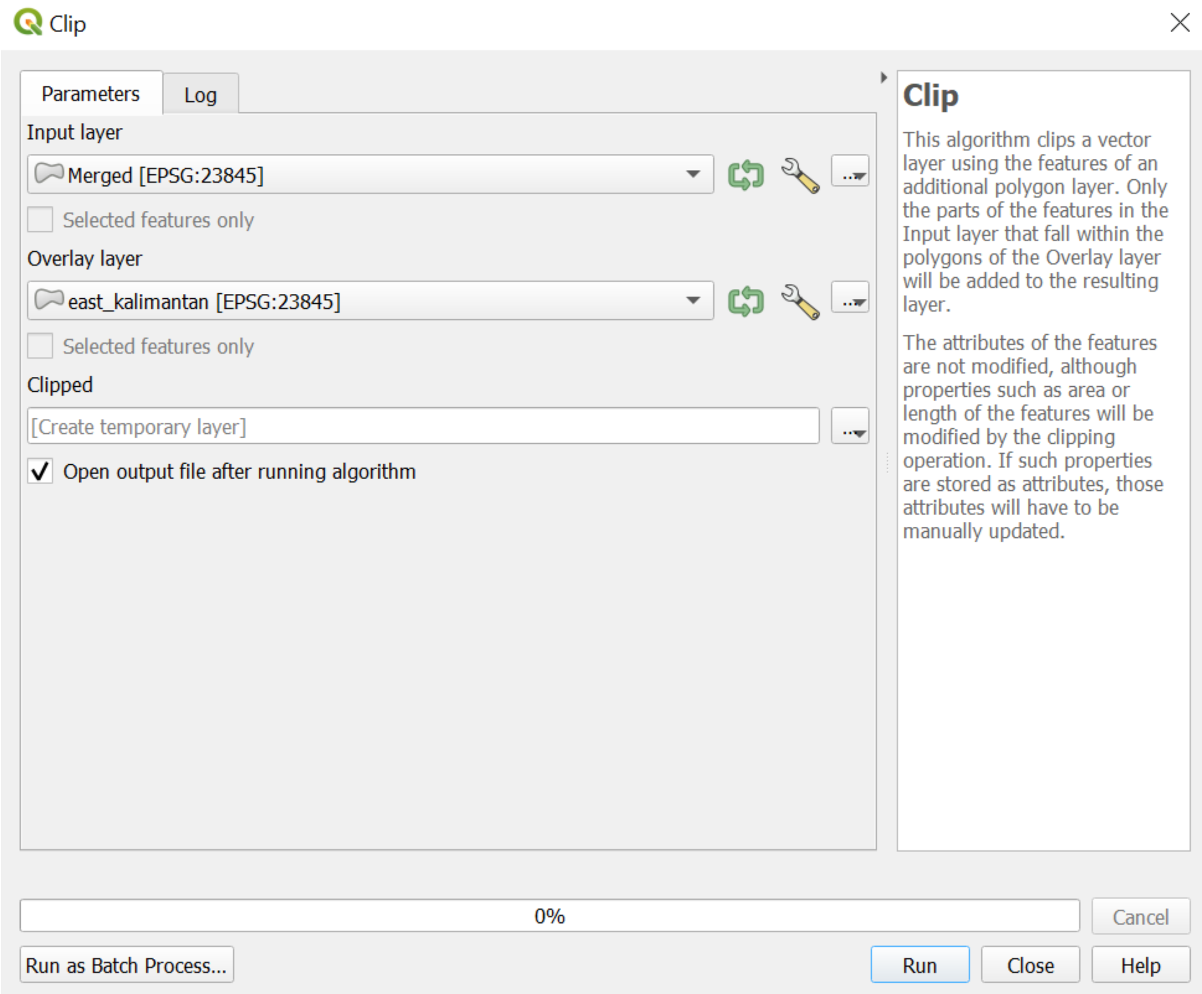
- From the top menu bar, select Vector → Data Management Tools → Merge Vector Layers.



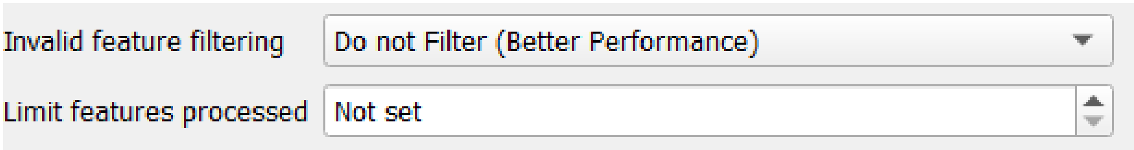
- Under Input layers, click on the more icon at the end to select the layers in which you want to merge.
- For destination CRS, select the project CRS (EPSG:23845)
- Click on **Run.**
- A temporary merged layer will be created.
- The temporary layer should be clipped (section 2.3.4) to remove all unnecessary points and then saved into GeoPackage format.
- **Repeat** this process of merging for all the other necessary layers

2.3.4 Clipping the various layers

- We will be clipping the layers as mentioned above so that points outside of east_kalimantan will be cleaned away to keep only the points and polygons within our study area.
- From the top menu bar, click on Vector → Geoprocessing → Clip



- For the Input layer, select from the drop down menu the layer in which we would like to clip. Note that all the layers merged in the previous section should be clipped.
- Click on the spanner beside the Input layer and select from the drop down menu **Do not Filter (Better Performance).**

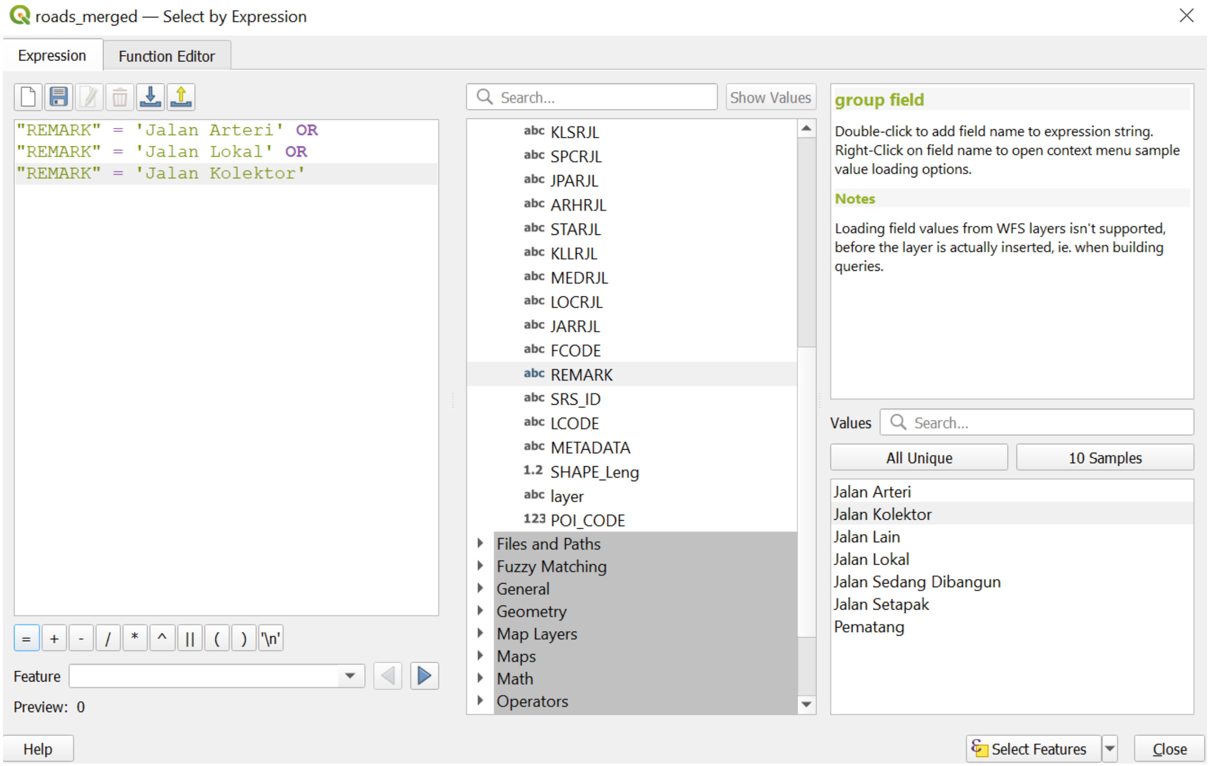


- For Limit features processed, select **Not set**
- For Overlay layer, select Indonesia east_kalimantan.
- Click on the spanner beside the Overlay layer and select from the drop down menu **Do not Filter (Better Performance).**
- Geopackage clipped layer and remove the temporary clipped layer and merged layers.
- **Repeat** this process of clipping for all the other necessary layers.

2.4 Data cleaning

2.4.1 Road network

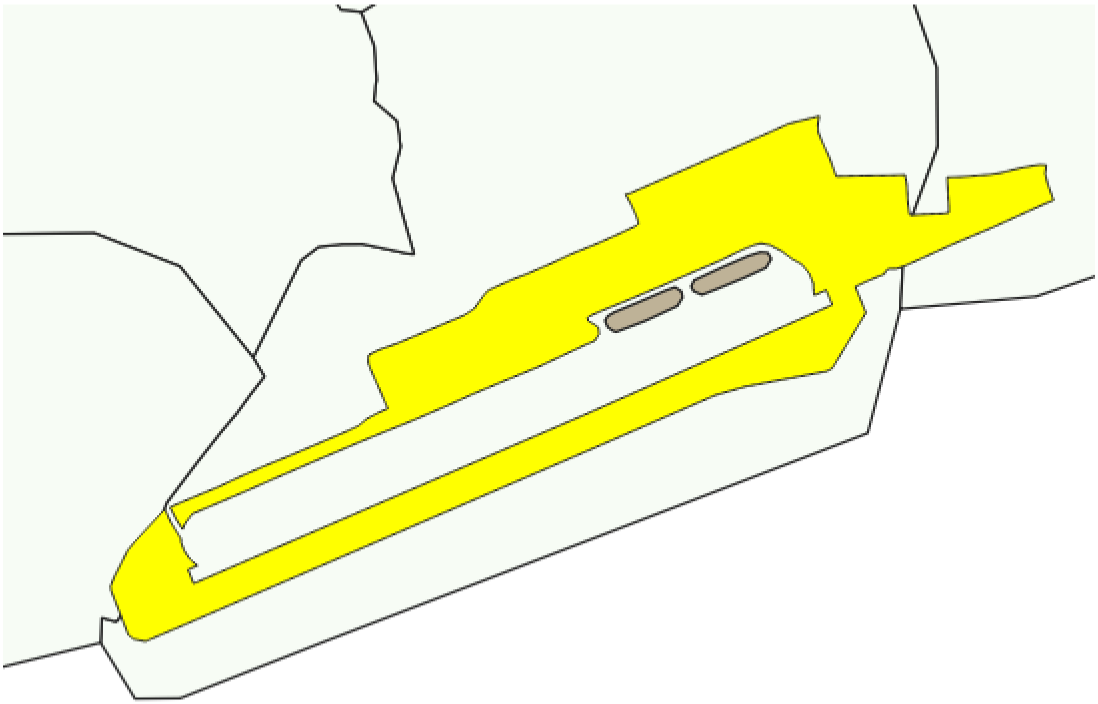
- Right click on the layer **roads_merged** and open attribute table.
- Select by expression the following roads: Jalan Arteri, Jalan Lokal, Jalan Kolektor.



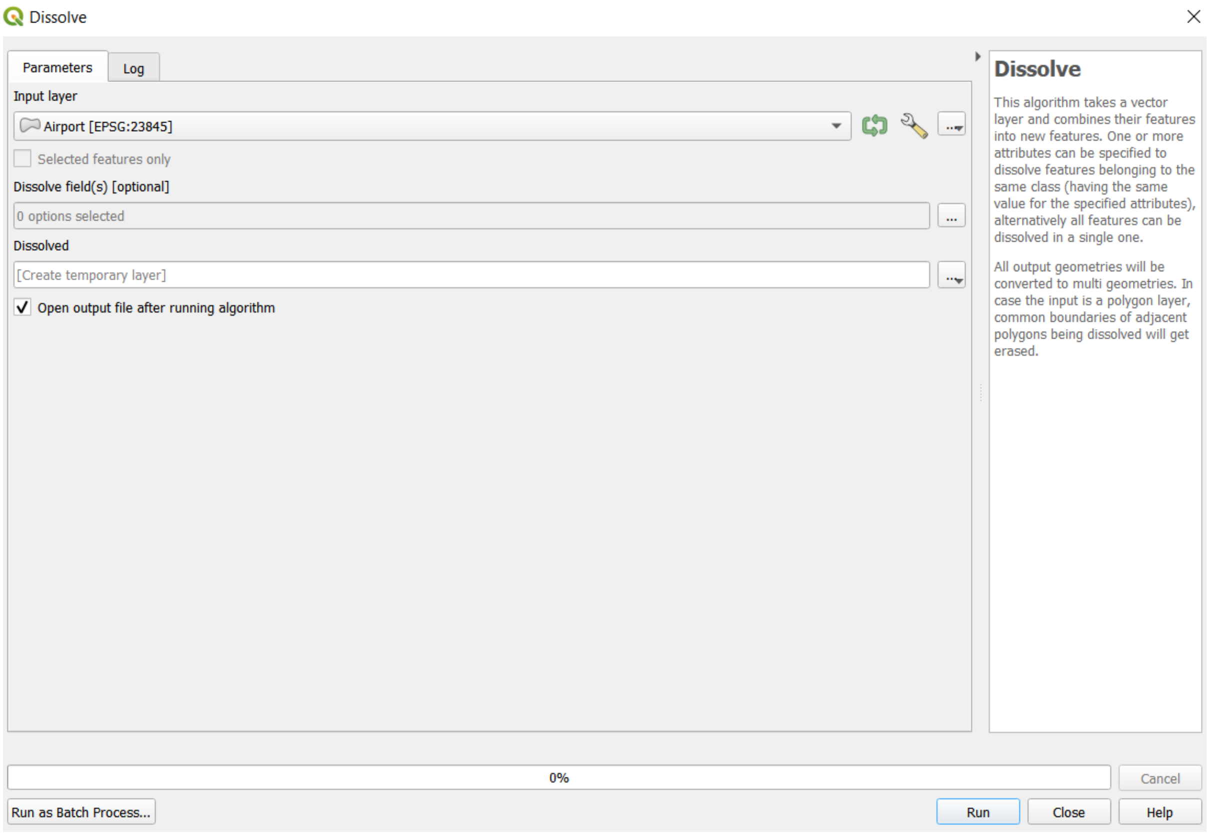
- Next, save the selected features into the GeoPackage and name the layer **connectingRoads**.

2.4.2 Airport buffer

We will first dissolve our airport polygon layer as we do not want to create multiple buffers for scenario like this where there are 3 different polygons representing 1 airport

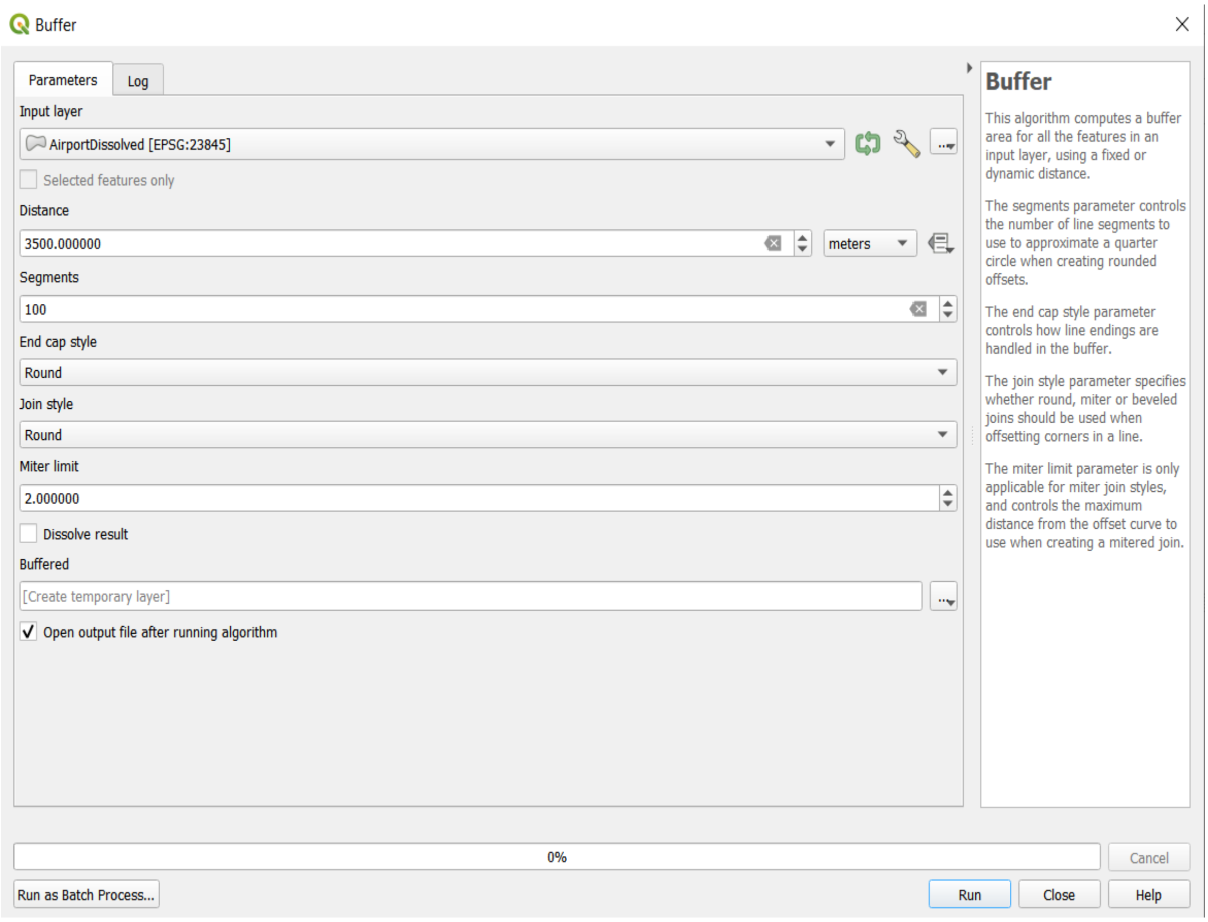


- Go to vector → geoprocessing tools → dissolve
  - For the input layer, we will select Airport
  - Click on **run**



- We will have a layer called ‘Dissolved’. Save it to the Geopackage and rename it as AirportDissolved

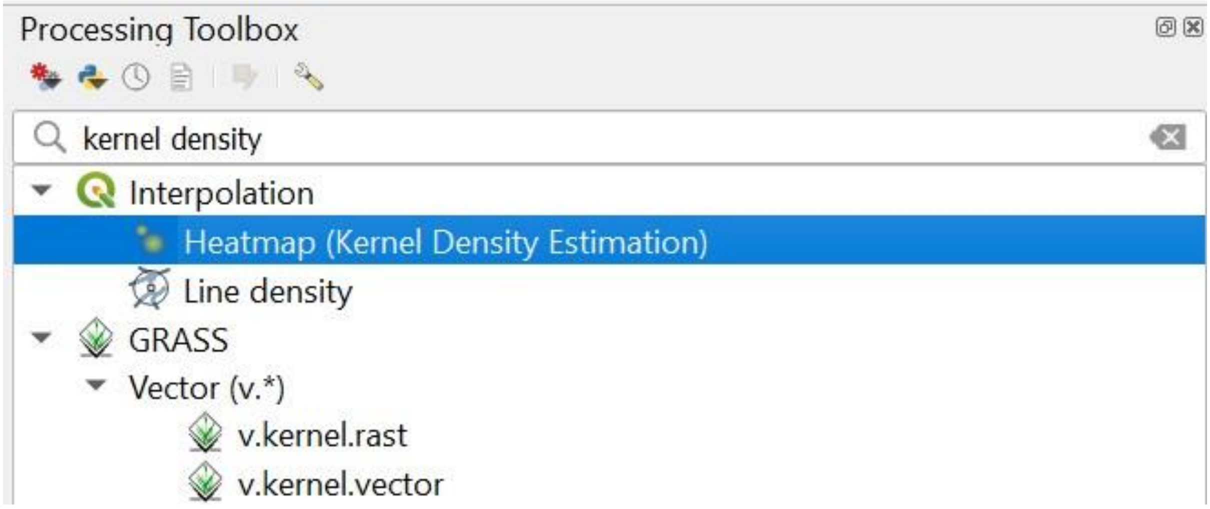
- Next, we want to create a buffer zone of 3.5km to airport for our accessibility to airport
- According to our research, a buffer zone of 3.5km from the airport zone will be used so as to minimize noise pollution in our proposed capital site.
- Using the AirportDissolved layer, we will create a 3.5km buffer
- Go to Vector > Geoprocessing tools > Buffer
    - For the input layer, we will select **AirportDissolved**
    - Segments we will change to 100
    - End cap style and Join style will be Round and Miter limit will be default at 2
    - Click on run



- A new layer called buffer will be created.
- Save it to our GeoPackage as **AirportBuffer**

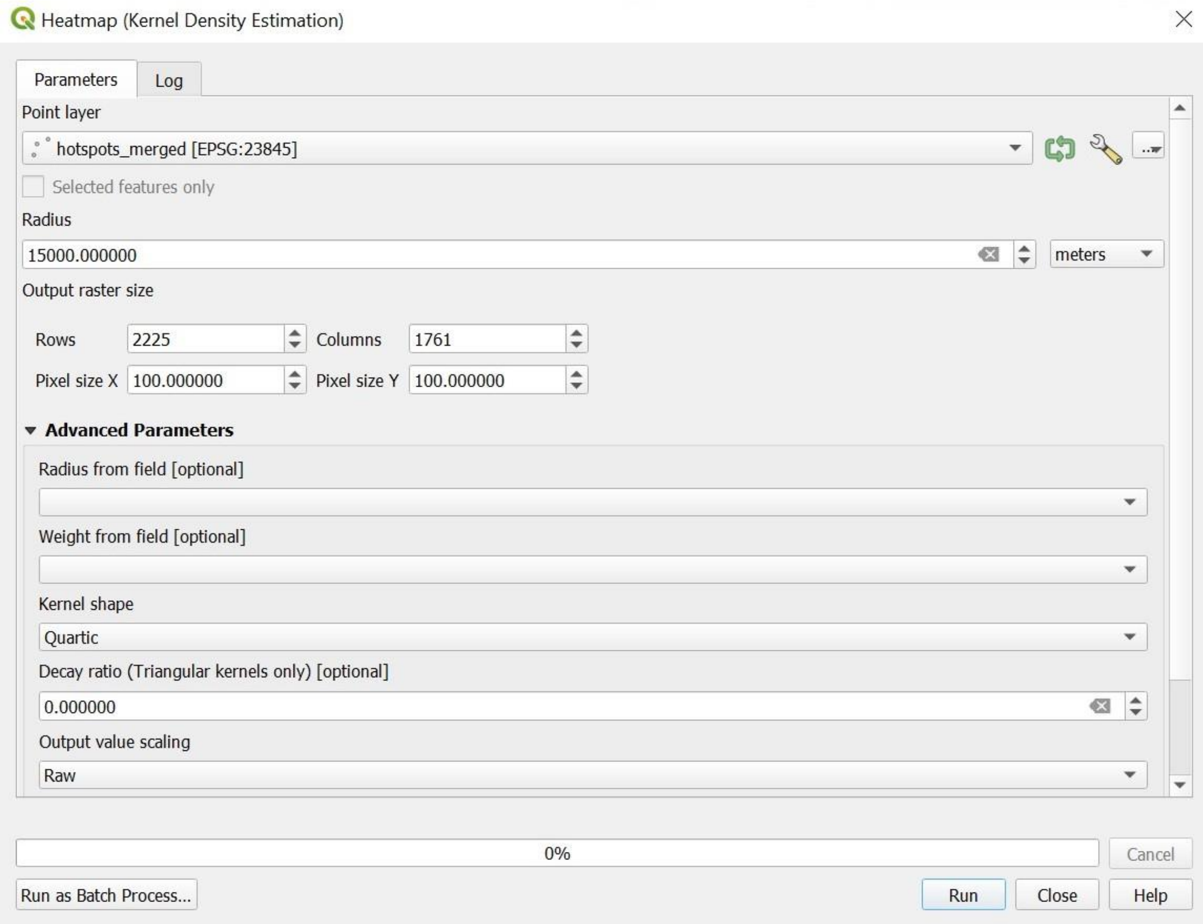
2.4.3 Hotspot heatmap

- From the top menu bar, select Processing → Toolbox → search for **kernel density**
- Select Heatmap (Kernel Density Estimation)



In the Heatmap dialog window:

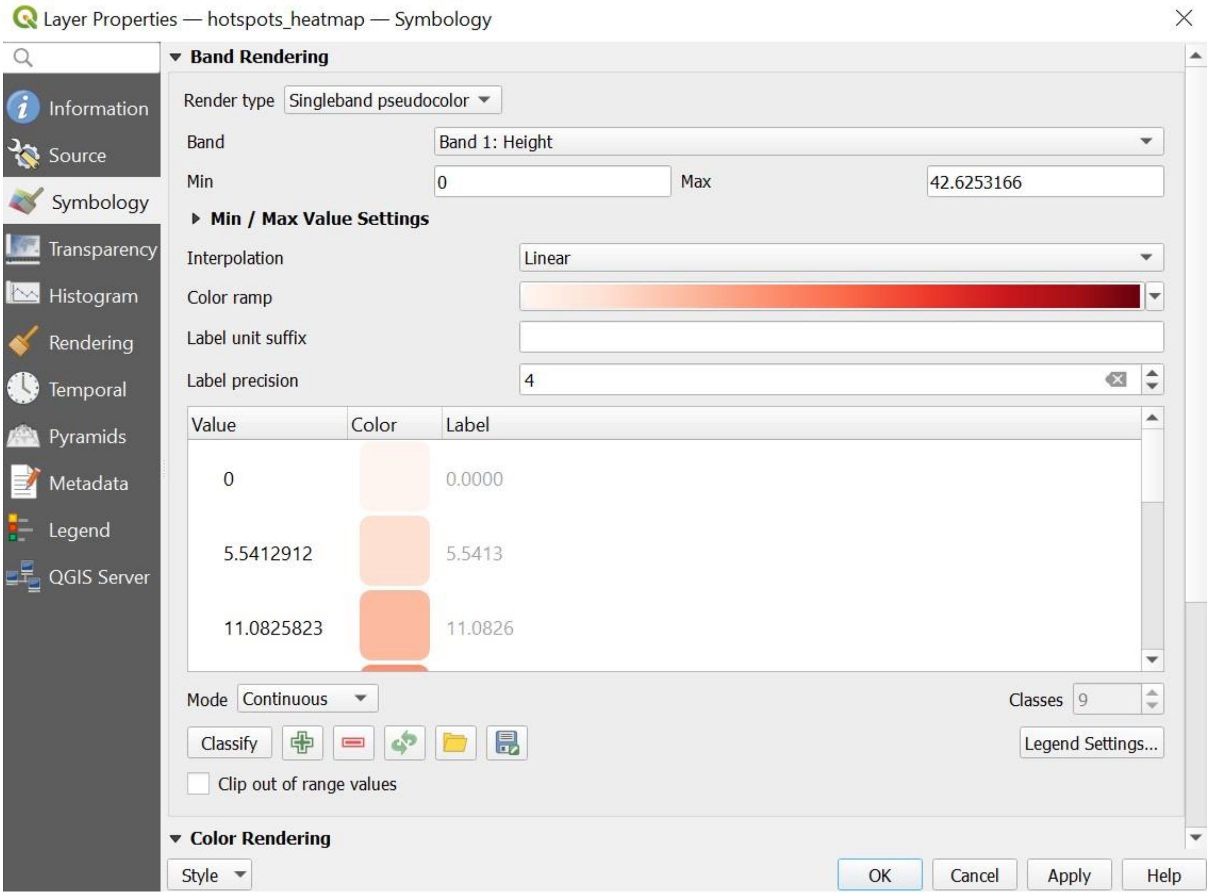
- Point layer: hotspots_merged
- Radius will be 15000 meters
- X and Y size pixels = 100



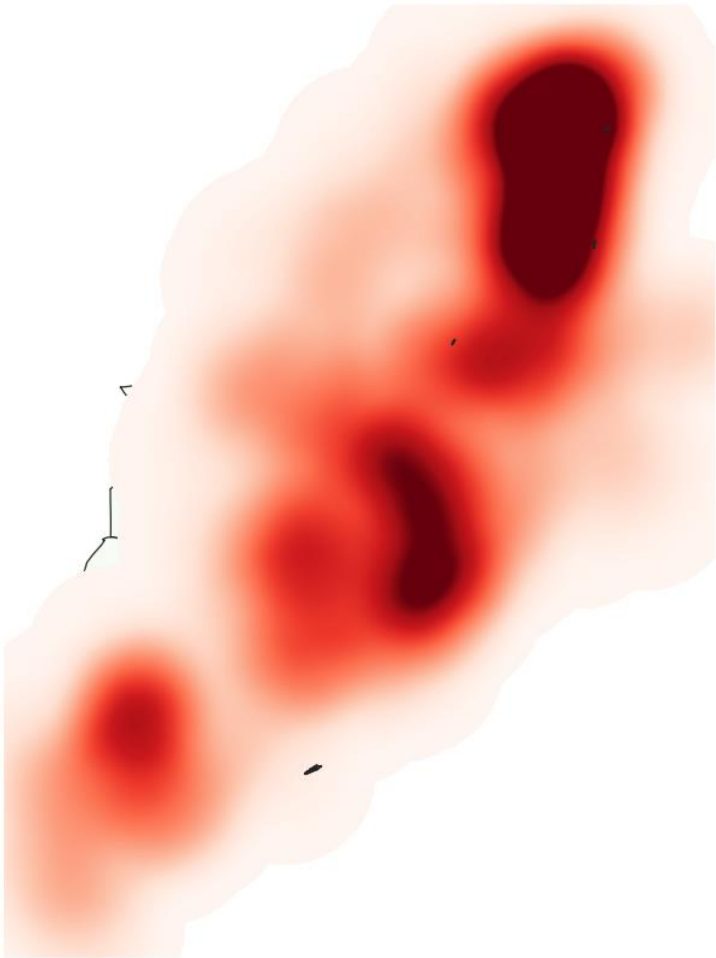
- Click on **Run** and close the dialogue box.
- Save this into the GeoPackage as **hotspots_heatmap**.

We will now change the symbology of this layer to better visualise it.

- Right click on the layer and click on Properties → Symbology
- Render Type: Singleband Pseudocolour
- Colour Ramp: **Red**



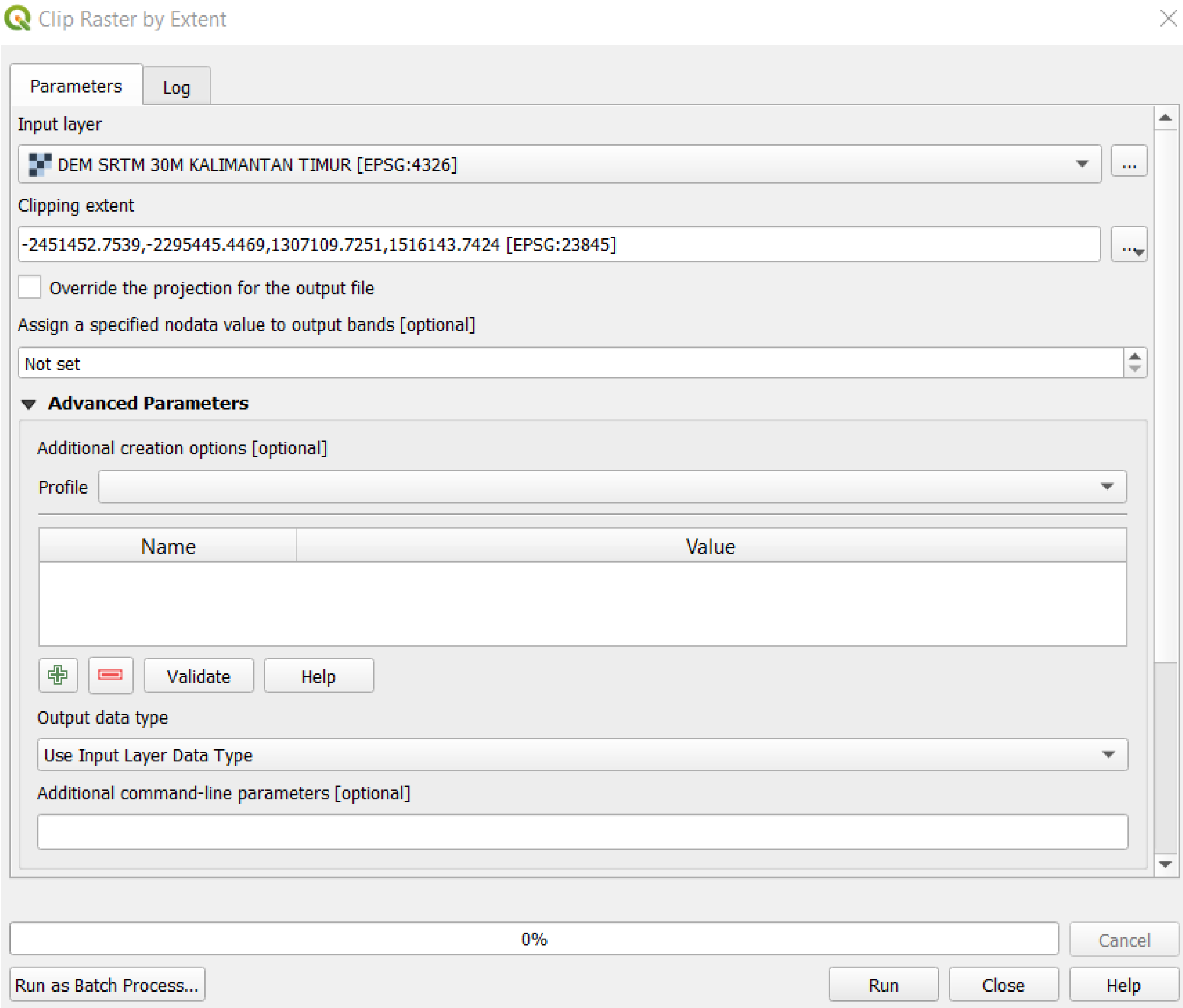
The map should look like the image below.



2.5 Raster, proximity and slope

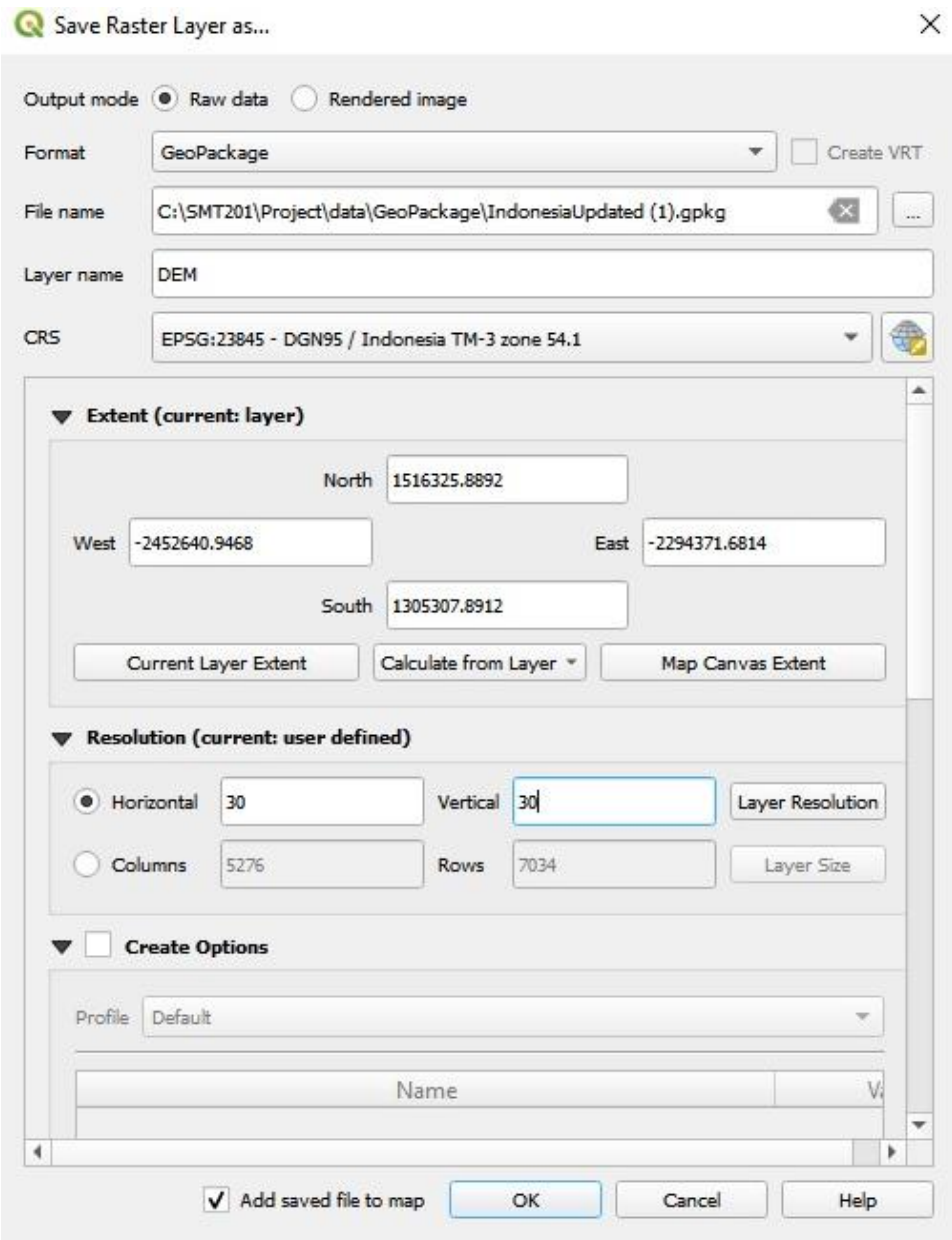
2.5.1 Extracting raster data

- Import the DEM SRTM 30M KALIMANTAN TIMUR layer.
- From the menu bar, select Raster → Extraction → Clip Raster by Extent.
- For Input layer, select **DEM SRTM 30M KALIMANTAN TIMUR** from the drop-down list.
- For Clipping extent, click on the icon at the end of the option then select Calculate from Layer.
- Select **east_kalimantan** from the drop-down list.



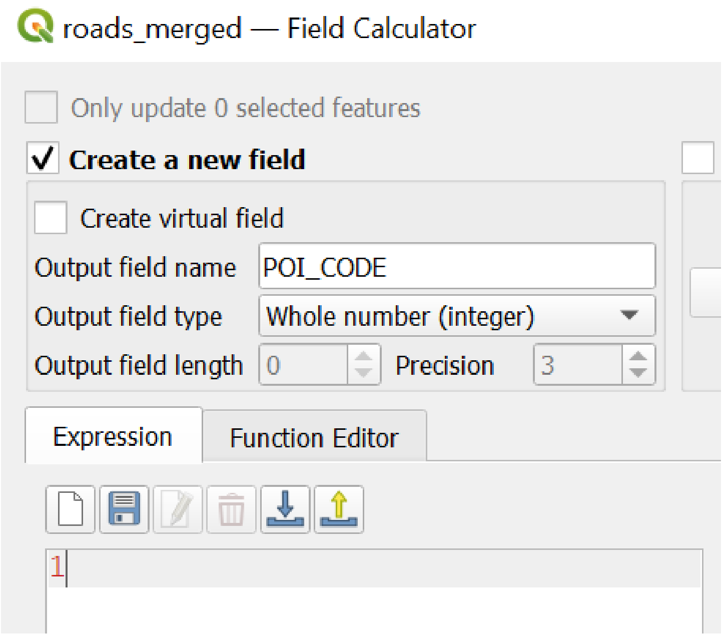
Geopackage the clipped raster.

- Make sure to change Format to Geopackage in the drop-down list.
- For Layer name, call it **DEM**.
- Under extent, click on the drop-down list **Calculate from Layer** and Select **east_kalimantan**.
- Set resolution of 30m by 30m



2.5.2 Creating attribute field for rastering

- At the **Layers** panel, click on **connectingRoads**
- From the icon bar, click on the Open **Attribute Table** icon and click on **Open field calculator**.
- For **Output field** name, type POI_CODE.
- At the **Expression** pane, type *1*.

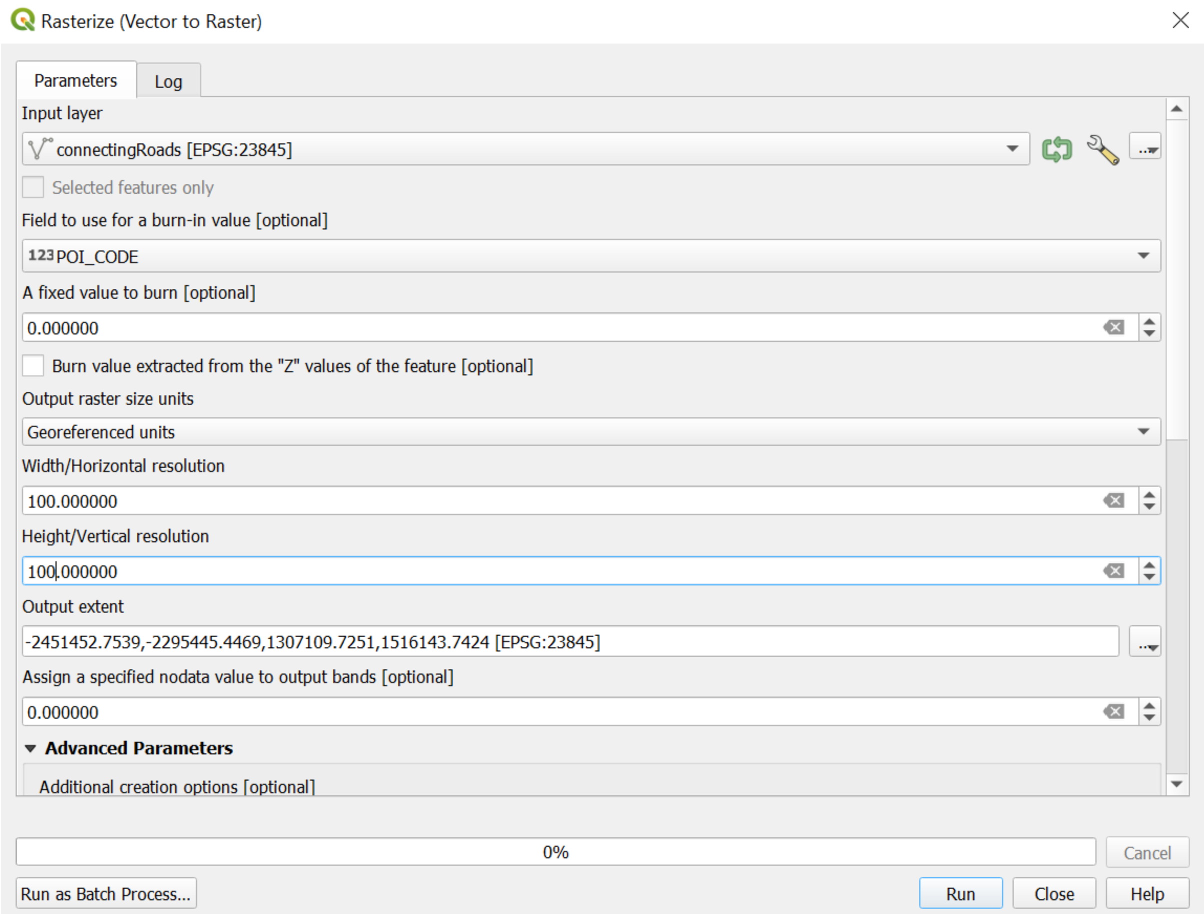


- Click on the **OK** button to run the function.
- A column called **POI_CODE** will be created.

SHAPE_Leng	layer	POI_CODE
0.00186973239	Indonesia kota_...	1
0.00457959166	Indonesia kota_...	1
0.00592640788	Indonesia kota_...	1
0.00119205636	Indonesia kota_...	1
0.00054970943	Indonesia kota_...	1
0.00047356629	Indonesia kota_...	1
0.00471807678	Indonesia kota_...	1
0.00480029199	Indonesia kota_...	1
0.00282475488	Indonesia kota_...	1
0.00174042936	Indonesia kota_...	1
0.00133171433	Indonesia kota_...	1
0.00163154788	Indonesia kota_...	1

2.5.3 Rastering the layers

- From the menu bar, select **Raster → Conversion → Rasterise (Vector to Raster)**.
- For **Input layer**, select roads_merged from the drop-down list.
- For **Field to use for a burn-in value**, select POI_CODE from the drop-down list.
- For **Output raster size units**, select *Georeferenced units*.
- Keep both horizontal and vertical resolutions at **100** (meaning 100m by 100m resolution).
- For **Output extent**, click on **Calculate from Layer**.
- Select **DEM** from the drop-down list.



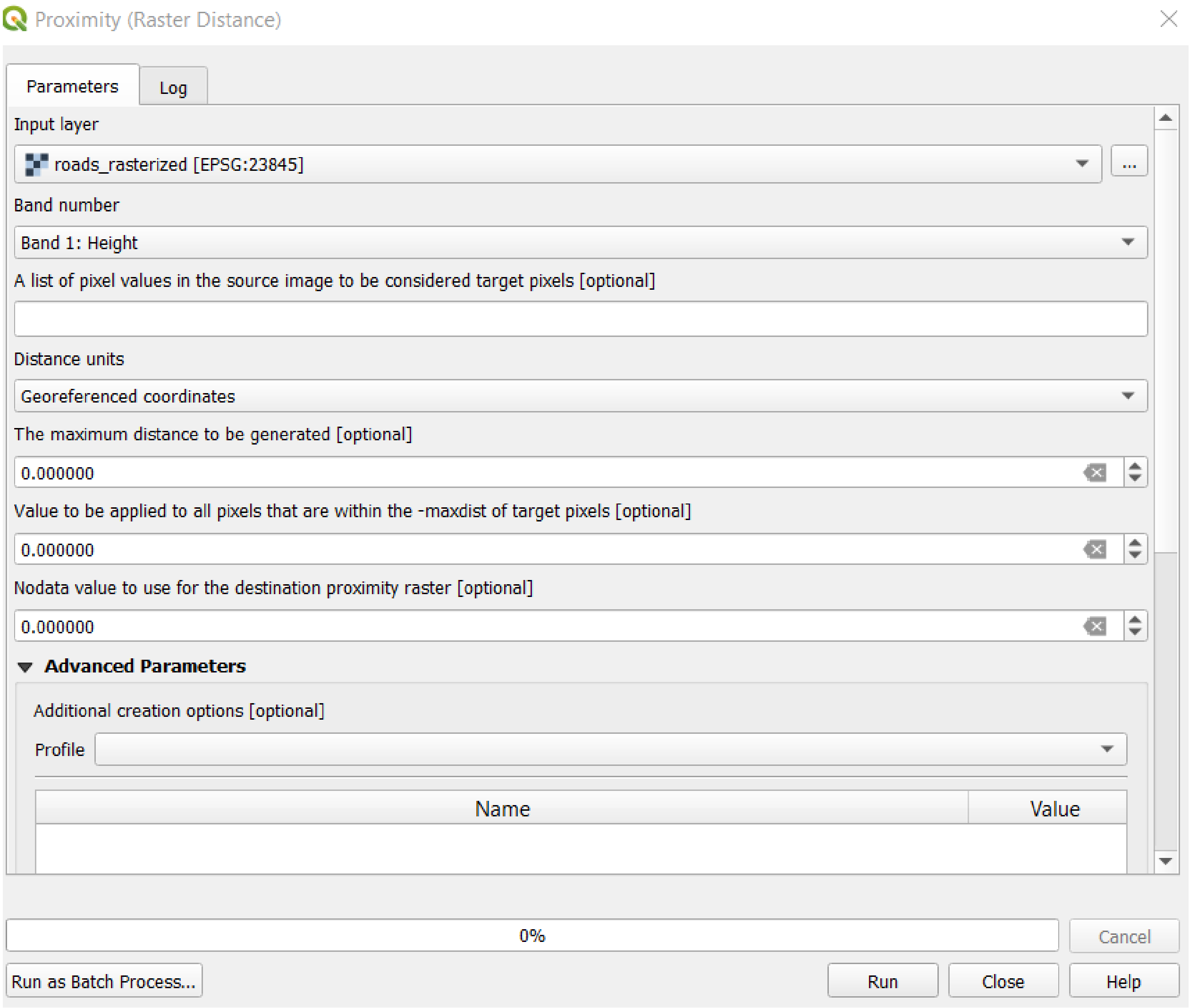
- Click on the **Run** button.
- A temporary layer will be created.
- Geopackage the layer and call it **connectingRoads_rasterized**
- **Repeat** for the rest of the dataset giving the names to each of the layers as shown below:

Layer to be rasterized	**Final Layer Name**
disaster_merged	disaster_rasterized

(Note that this layer is formed by merging the **river** and **coastline** layers)	
forest	forest_rasterized
seaport	seaport_rasterized
connectingRoads	connectingRoads_rasterized
AirportBuffer	airport_rasterized
settlements	settlement_rasterized

2.5.4 Proximity calculation

- For the menu bar, select **Raster → Analysis → Proximity (Raster Distance)**.
- For **Input layer**, select **roads_rasterized** from the drop-down list.
- For **Distance units**, select **Georeferenced coordinates** from the drop-down list.
- For **Output data type**, select *Float32* from the drop-down list.



- Click on the **Run** button.
- Geopackage the layer and name it **connectingRoads_proximity**.
- **Repeat** for the rest of the dataset giving the names to each of the layers as shown below:

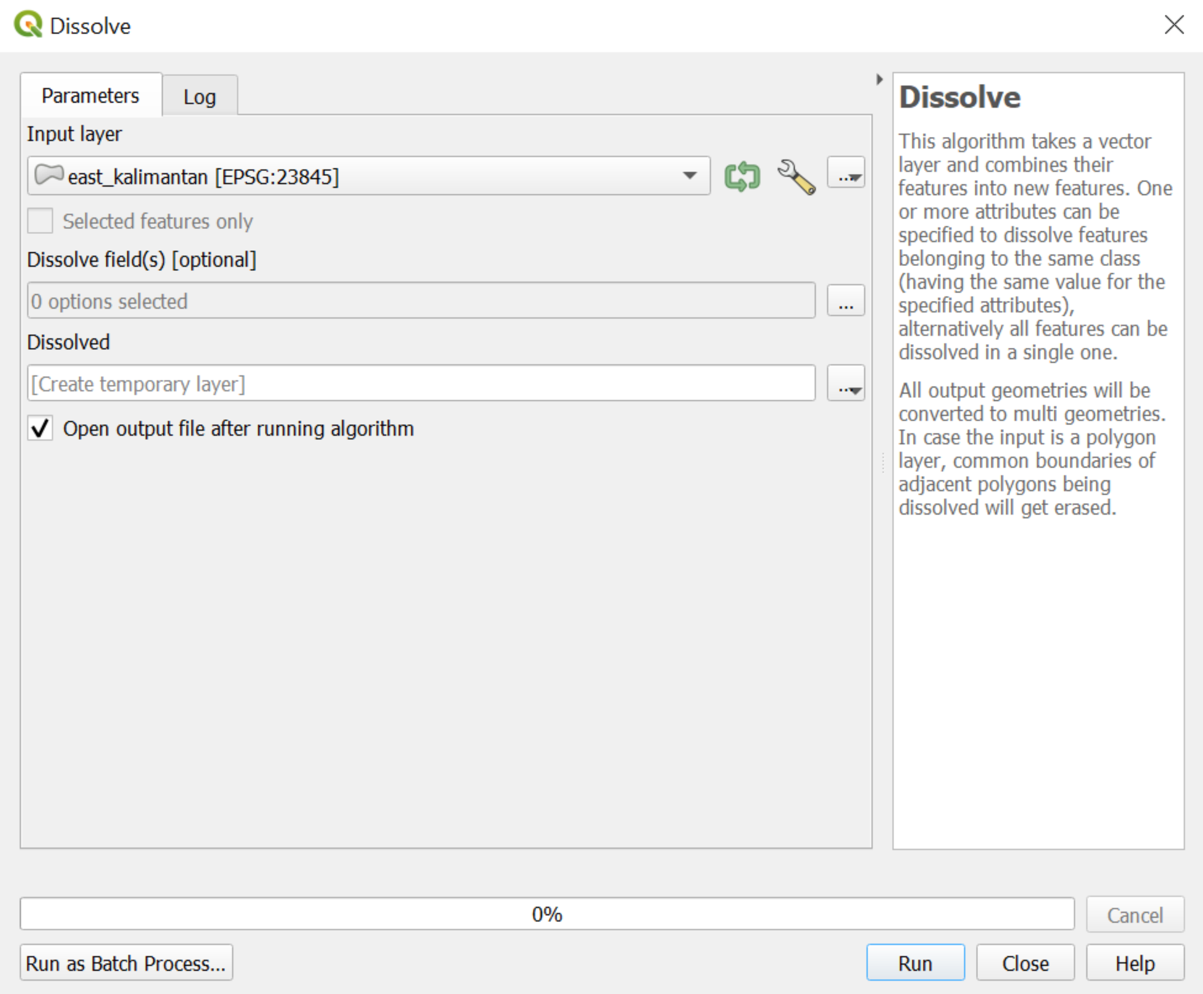
Layer to do proximity	**Final Layer Name**
disaster_rasterized	disaster_proximity
forest_rasterized	forest_proximity
seaport_rasterized	seaport_proximity
connectingRoads_rasterized	connectingRoads_proximity
airport_rasterized	airport_proximity
settlement_rasterized	settlement_proximity

2.5.5 Slope calculation

- From the menu bar, select **Raster** → **Analysis** → **Slope**.
- For **Input layer**, select **DEM_new** from the drop-down list.
- Click on the **Run** button and **Close** the dialogue window
- A temporary layer called Slope will be added.
- Set the resolution to 30m by 30m resolution.
- Geopackage layer and name it **slope30by30**.

To ensure that our slope layer only covers the study area and not the sea boundaries, we will create a dissolved vector layer for the study area.

- From the top menu bar **Vector** → **Geoprocessing Tool** → **Dissolve.**
- Input layer select **east_kalimantan.**
- Advanced options: **Do not filter (Better performance).**

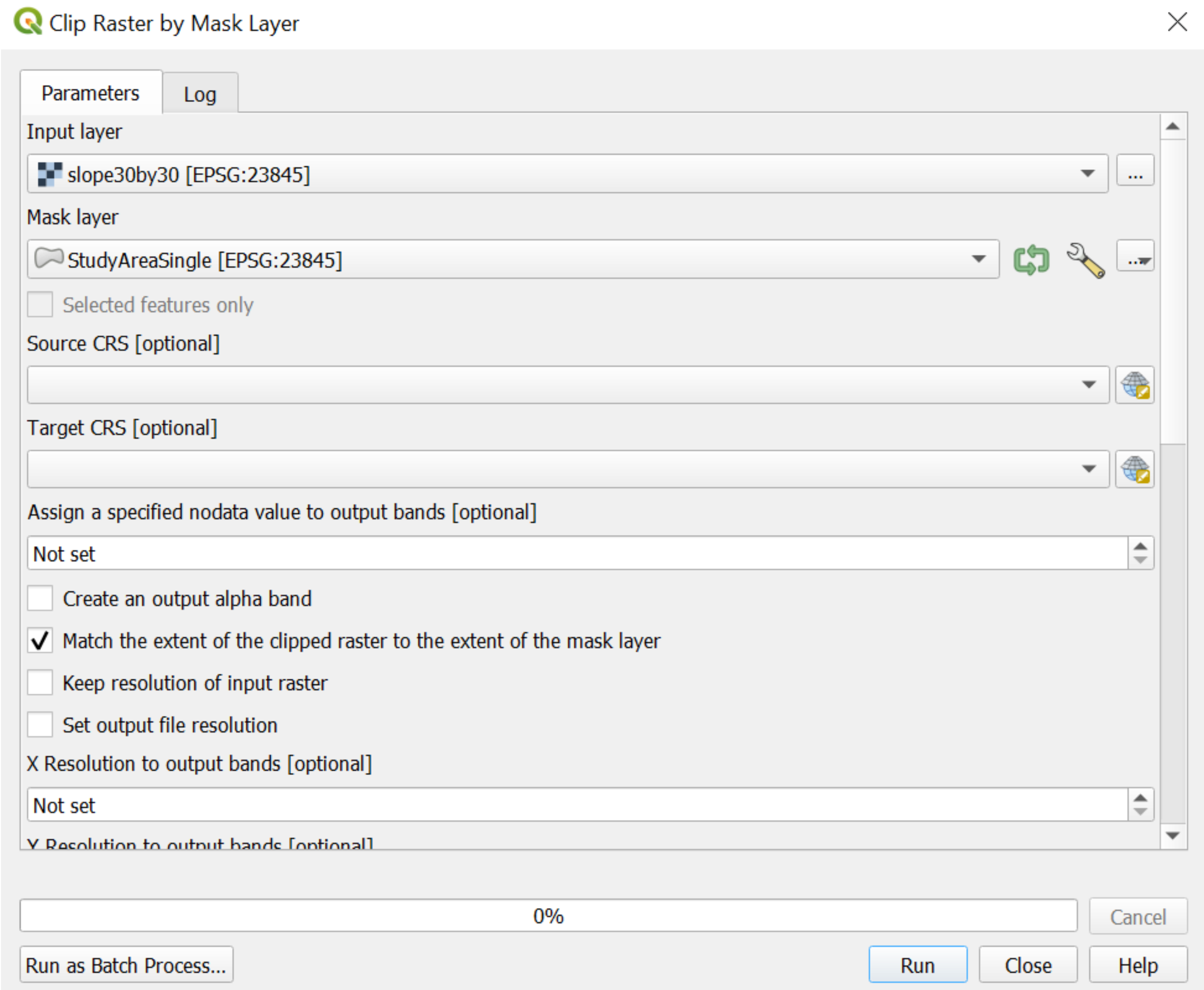


- Click on the **OK** button.

- Save to Geopackage name it **StudyAreaSingle**.

Next, we will clip raster by Mask Layer to get the raster layer of our slope in our study area

- From the top menu bar, select **Raster** → **Extraction** → **Clip Raster** by Mask Layer…
- Input layer: slope30by30
- Mask layer: StudyAreaSingle



- Click on **Run** and close the window.
- Save the Clipped(mask) layer into GeoPackage and change the resolution to 100m by 100m.
- Name it as **slopeStudyArea**.

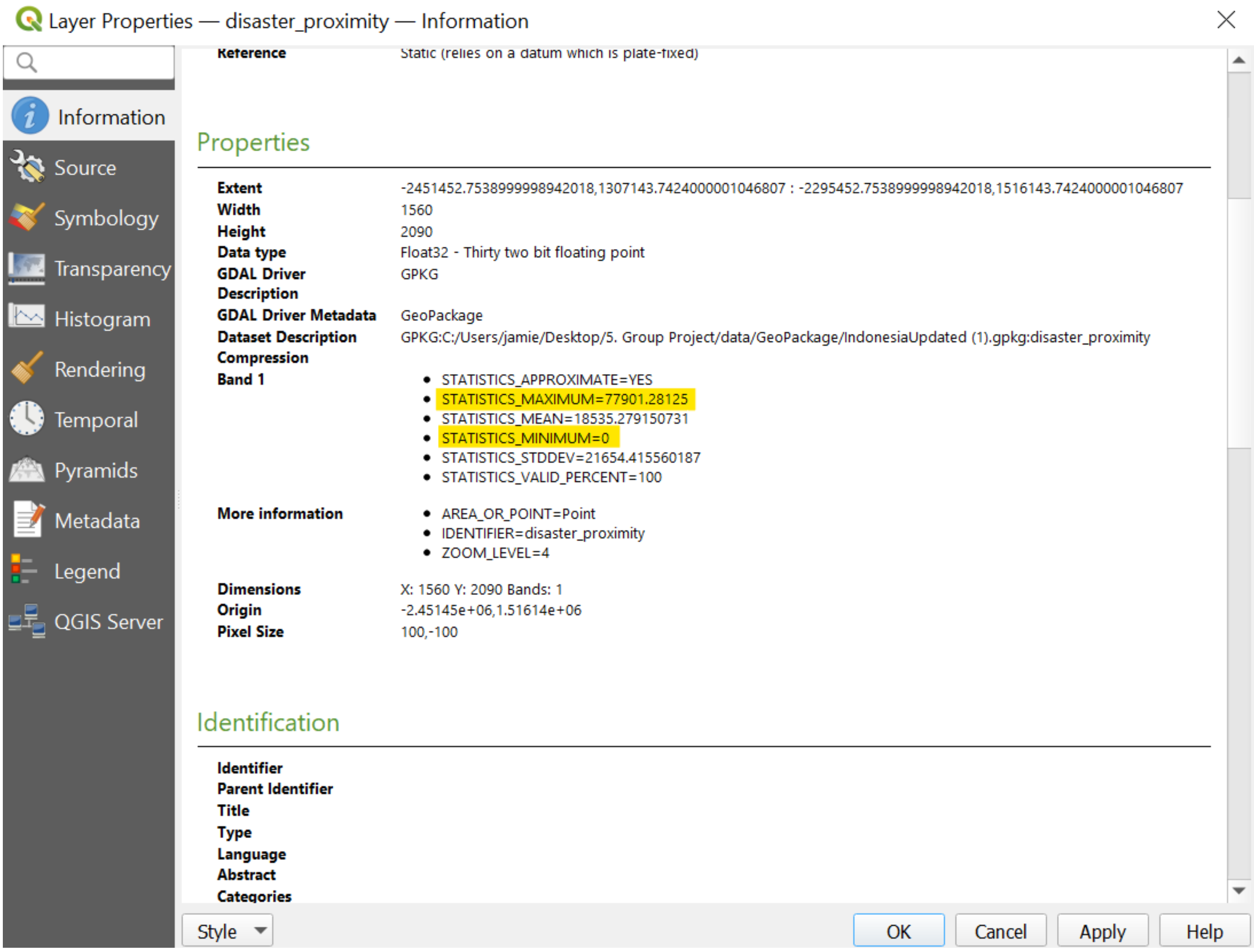
2.6 Choosing a suitable site

2.6.1 Standardising the data using Z-Score

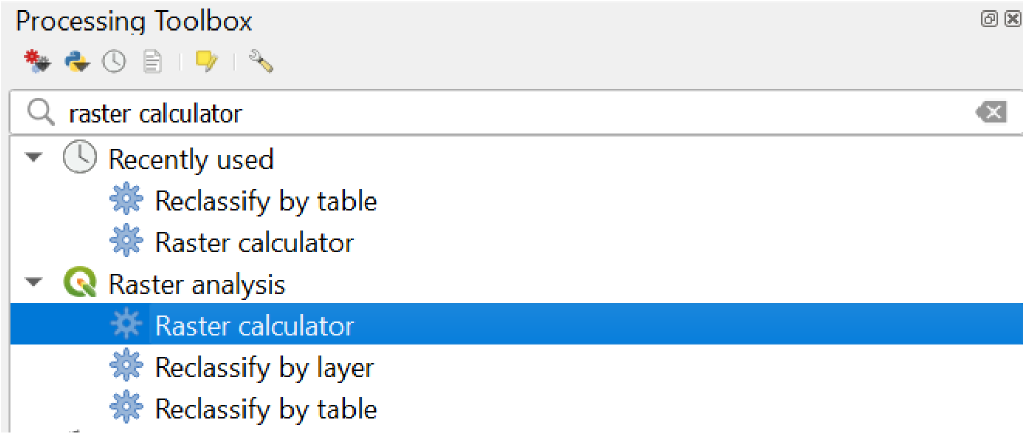
We will be using **Raster calculator** to standardise the proximity layers. The following Z-score equation is used for standardisation.

$$z = \frac{x - min(x)}{max(x) - min(x)}$$

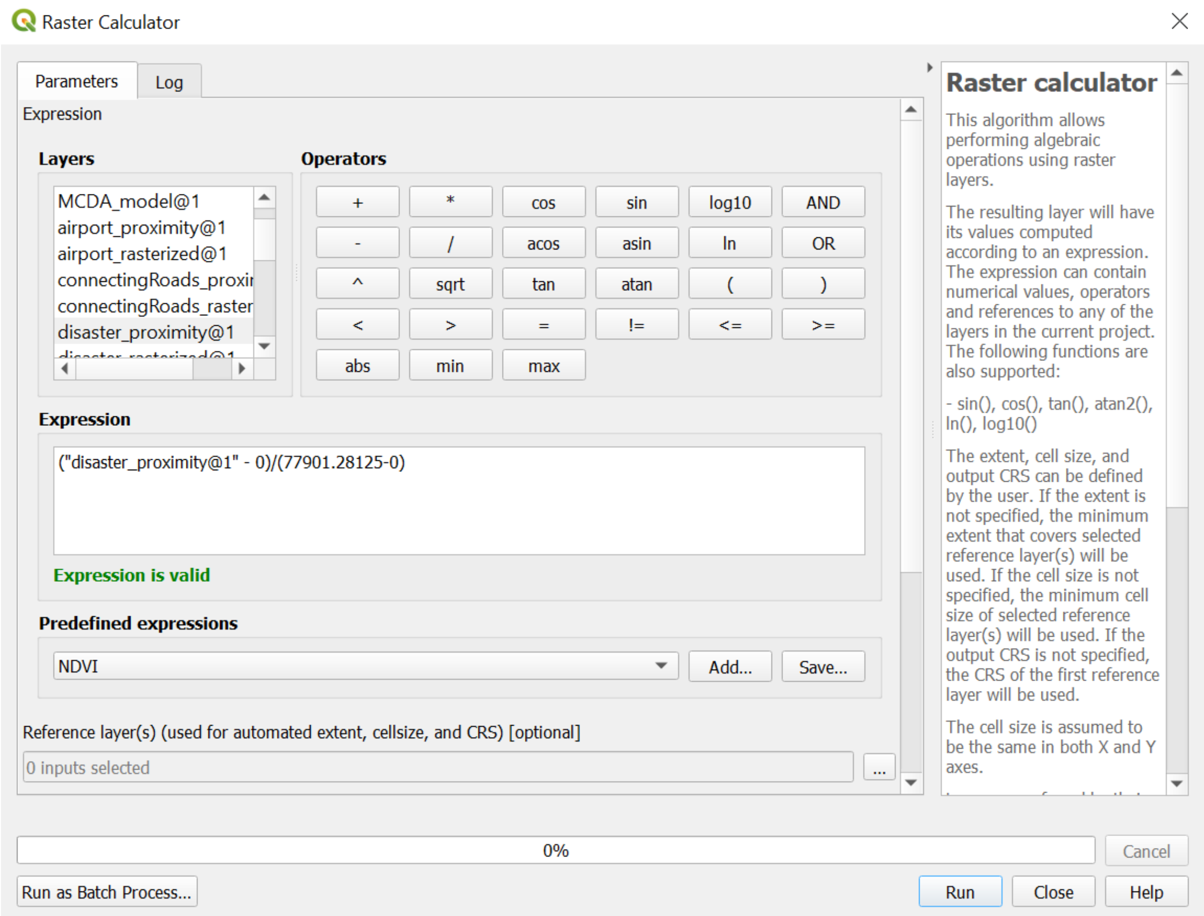
To get the minimum and maximum values used for standardisation, right click on the particular proximity layer, disaster_proxmity and navigate to the Information tab. The minimum and maximum values can be found there.



- From the top menu bar, click on Process → Toolbox
- A side pane will appear on the right.
- Double click on Raster calculator.



- Use the standardisation equation as mentioned above and key it into the expression pane as shown in the image below.



- Click on the Run button and close the window
- Export the layer as a GeoPacakge and name it **factor_disaster**.
- Repeat this for all other proximity layers

Note that for layers in which we want to be close to, we will inverse the standardisation using (1 - Zvalue). After standardizing, we save the respective results as:

Layer to perform standardization	Inverse (1-Zscore)	Final Layer Name
disaster_proximity	No	factor_disaster_new
forest_proximity	No	factor_forest
hotspots_heatmap	Yes	factor_hotspot
seaports_proximity	Yes	factor_seaport
connectingRoads_proximity	Yes	factor_connectingRoad
airport_proximity	Yes	factor_airport
slope	Yes	factor_slope
settlement_proximity	Yes	factor_settlement

2.6.2 AHP calculation

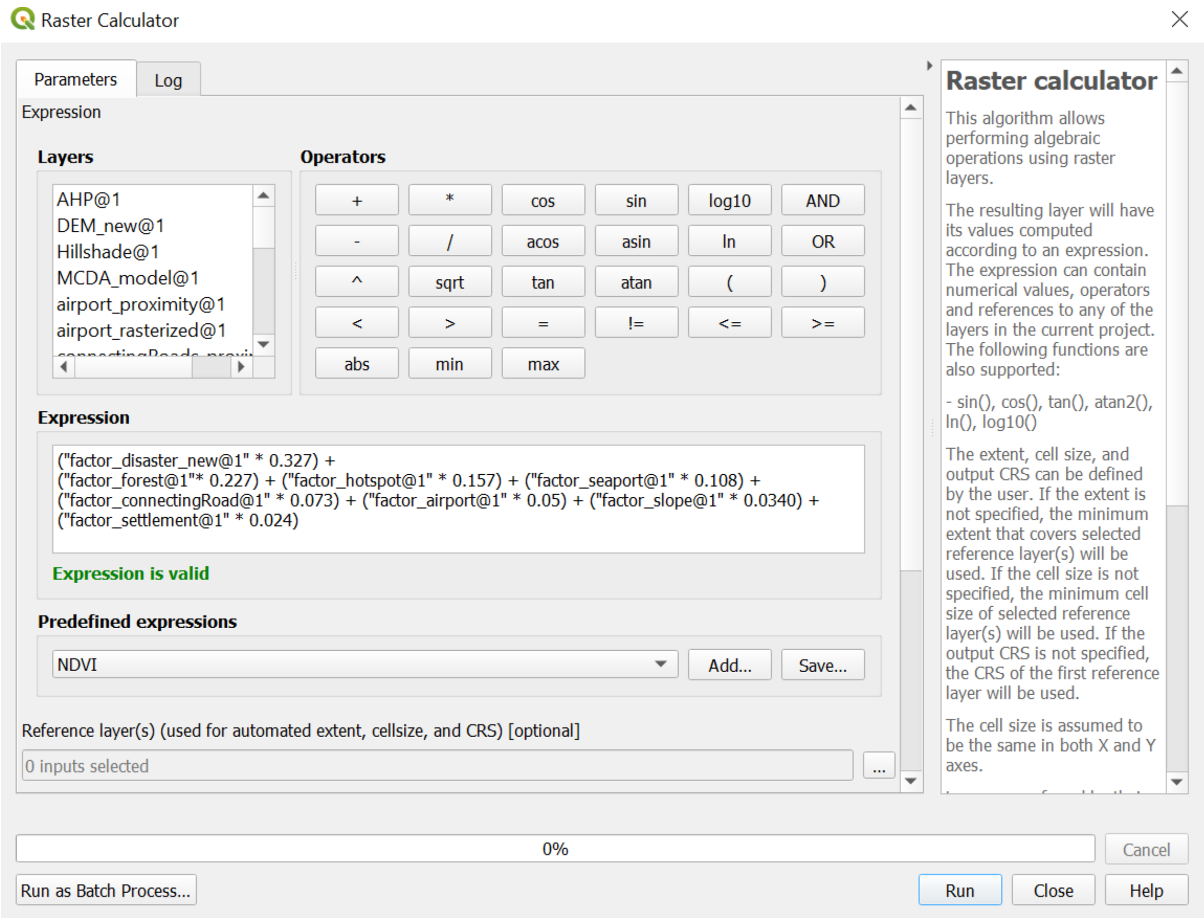
Using the Raster calculator, we will now calculate the composite factor score using the following AHP importance ranking and weights. Our team achieved a consistency score of 4% and thus we will proceed with the following AHP weightage.

Pairwise Comparison Matrix

	Natural disaster	Forest	Hotspot	Seaport	Roads	Airport	Slope	Settlements
Natural disaster	1	2	3	4	5	6	7	8
Forest	1/2	1	2	3	4	5	6	7
Hotspot	1/3	1/2	1	2	3	4	5	6
Seaport	1/4	1/3	1/2	1	2	3	4	5
Roads	1/5	1/4	1/3	1/2	1	2	3	4
Airport	1/6	1/5	1/4	1/3	1/2	1	2	3
Slope	1/7	1/6	1/5	1/4	1/3	1/2	1	2
Settlements	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1

	AHP	
1	0.327	32.7%
2	0.227	22.7%
3	0.157	15.7%
4	0.108	10.8%
5	0.073	7.3%
6	0.050	5.0%
7	0.034	3.4%
8	0.024	2.4%

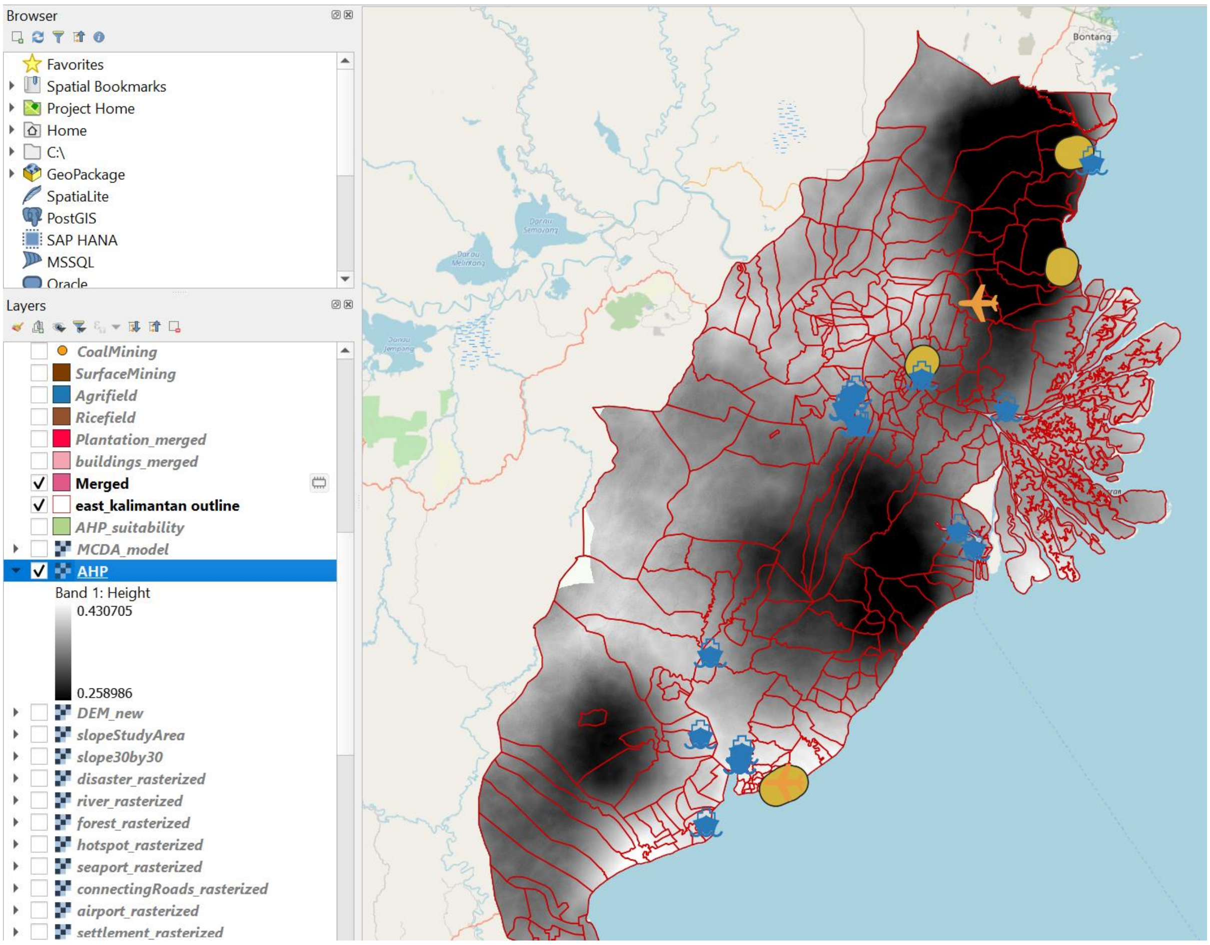
Consistency check
Consistency OK 4%



We created the AHP suitability layer with the following calculation:

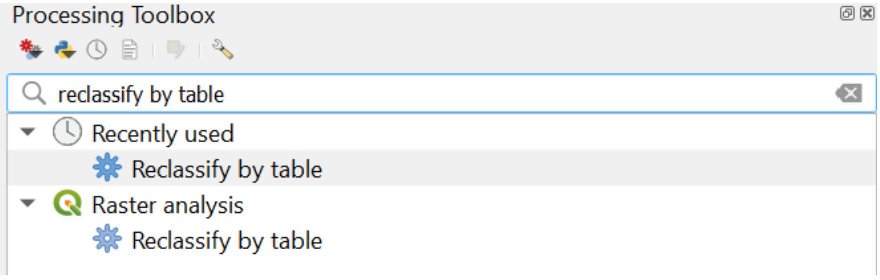
("factor_disaster_new@1" * 0.327) + ("factor_forest@1"* 0.227) + ("factor_hotspot@1" * 0.157) + ("factor_seaport@1" * 0.108) + ("factor_connectingRoad@1" * 0.073) + ("factor_airport@1" * 0.05) + ("factor_slope@1" * 0.0340) + ("factor_settlement@1" * 0.024)

- Our reference layer will be any one of the factor layers that we have
- Output CRS will be EPSG:23845 – DGN95/Indonesia TM-3 zone 54.1
- Click on **Run** and close the dialogue box after a new temporary layer is created.
- Save the temporary layer as a GeoPackage and name it **AHP**.



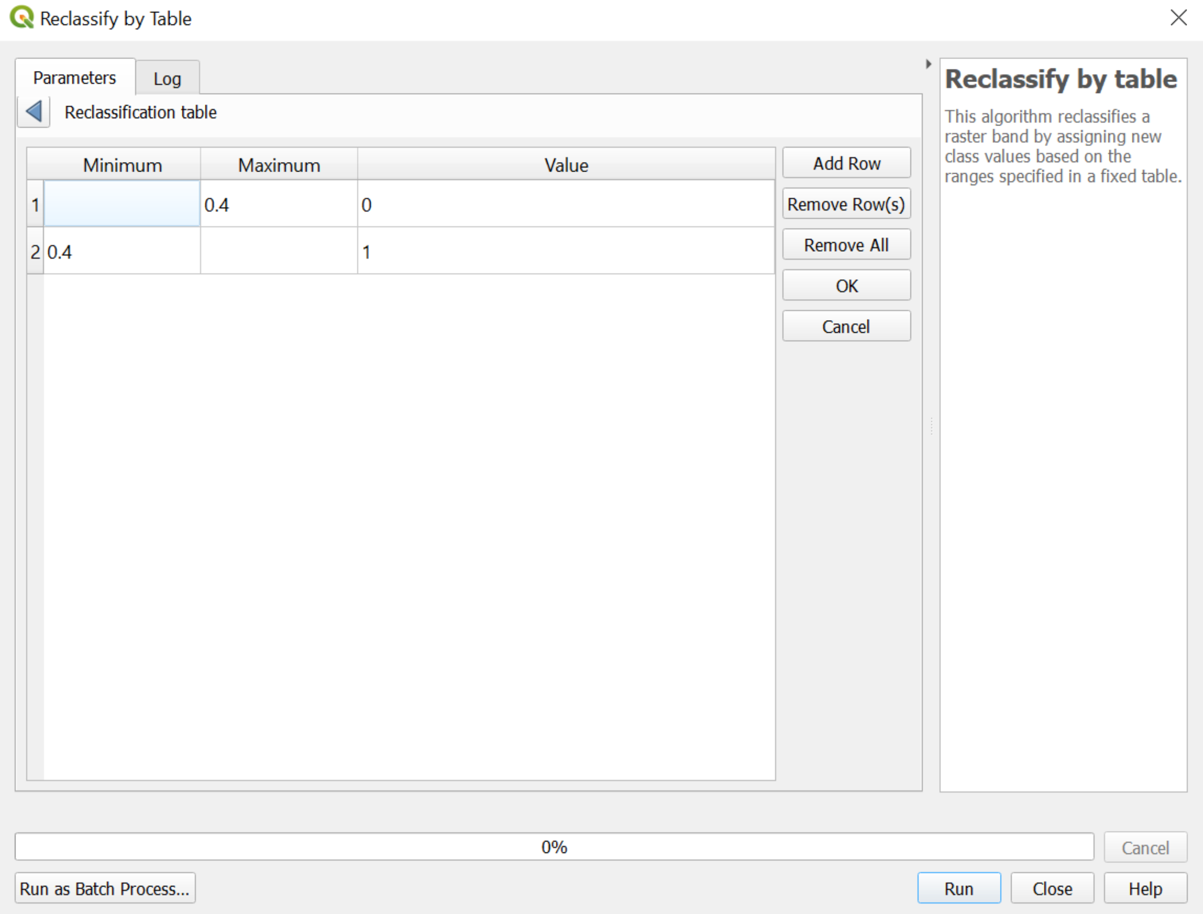
From our analysis we decided that a composite factor score of 0.4 should be used as a cut-off for suitable sites. Now, we will use the function Reclassify by table to separate the sites into suitable and not suitable.

- From the Processing Toolbox, search for **Reclassify by table** and double click on it.



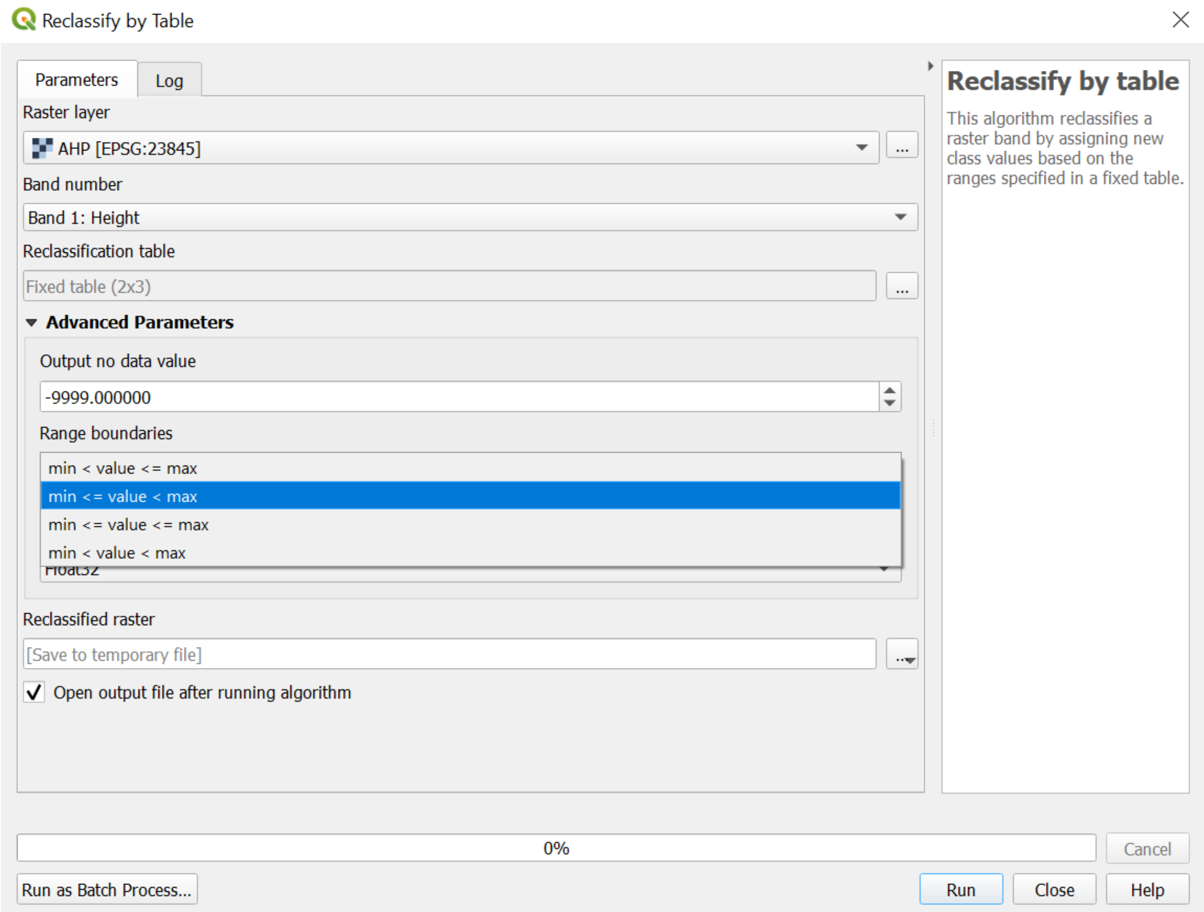
The dialogue box for Reclassify by table will appear.

- Raster layer: **AHP**
- Click on the more icon under the Reclassification table and enter the following as shown below.



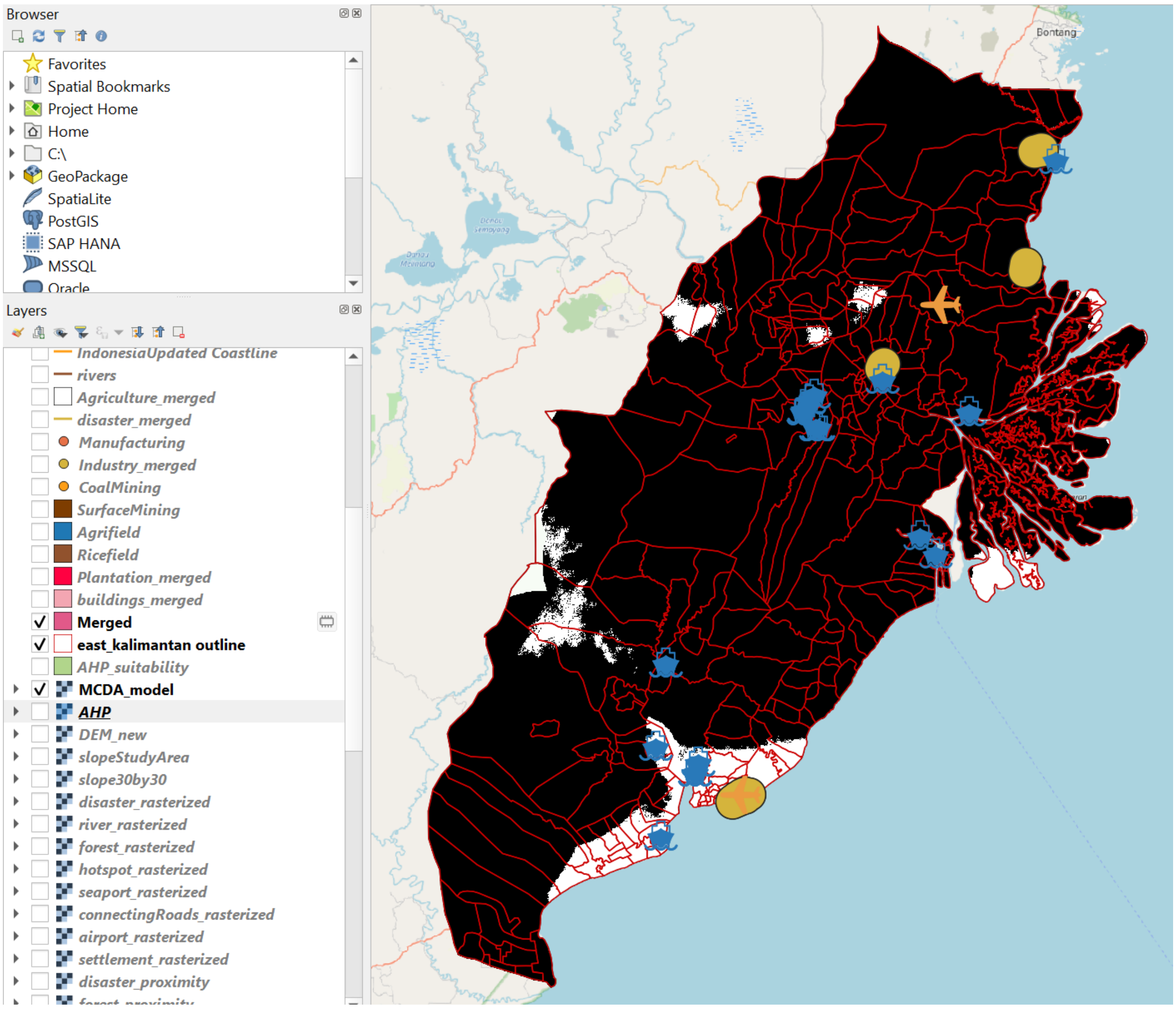
- Click **OK** to return to the previous screen
- For range boundaries select: **min<= value** < **max**

Your dialogue box should look like the screenshot below.



- Click on Run and close the dialogue box.
- Save this temporary Reclassified raster layer into the GeoPackage
- Name this layer **MCDA_model**.

The MCDA_model should look like the screenshot below. White portions indicate suitable sites while black portions indicate non suitable sites.



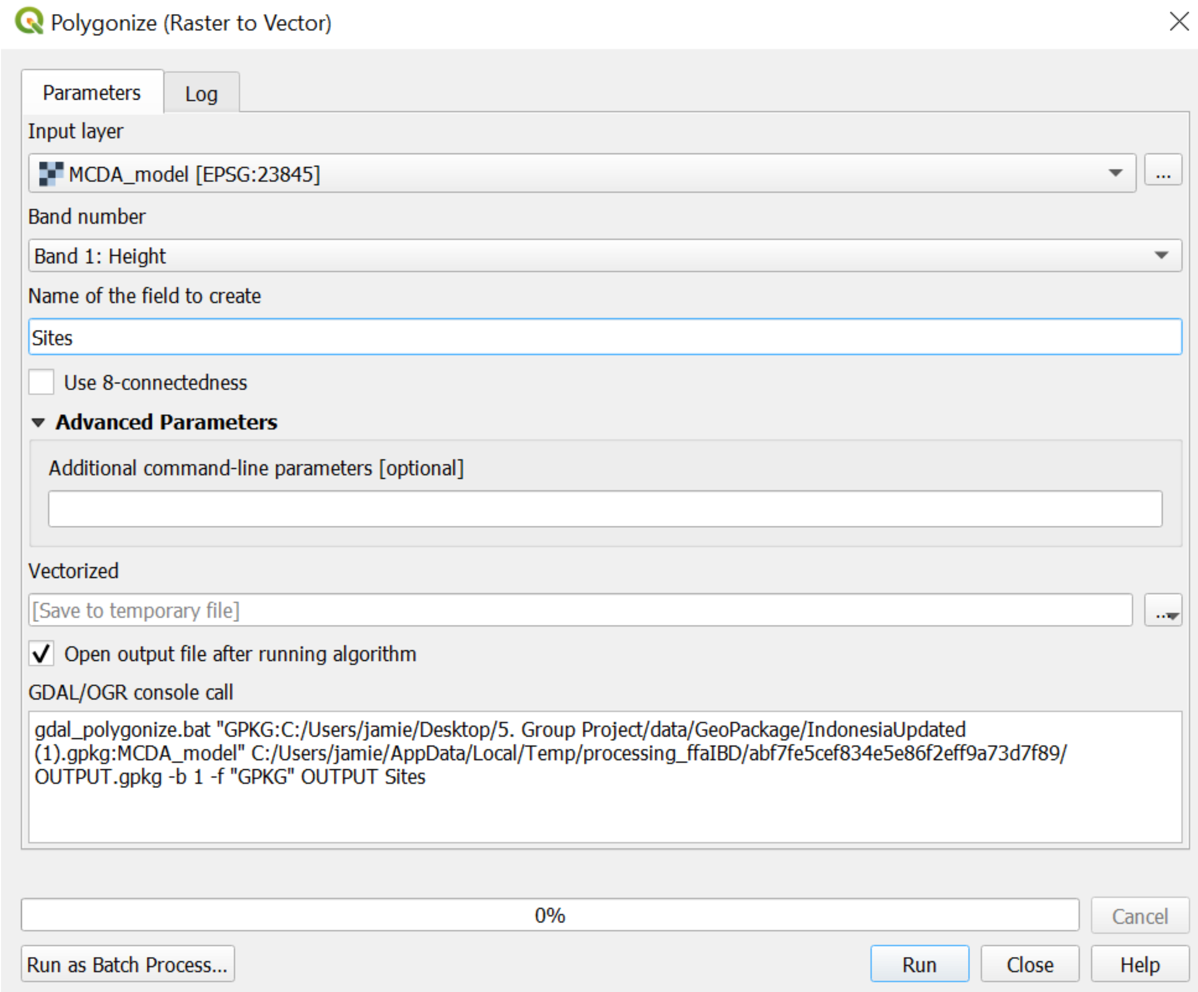
2.6.3 Vectorizing suitable sites

Now we need to convert the MCDA_model raster layer into a vector.

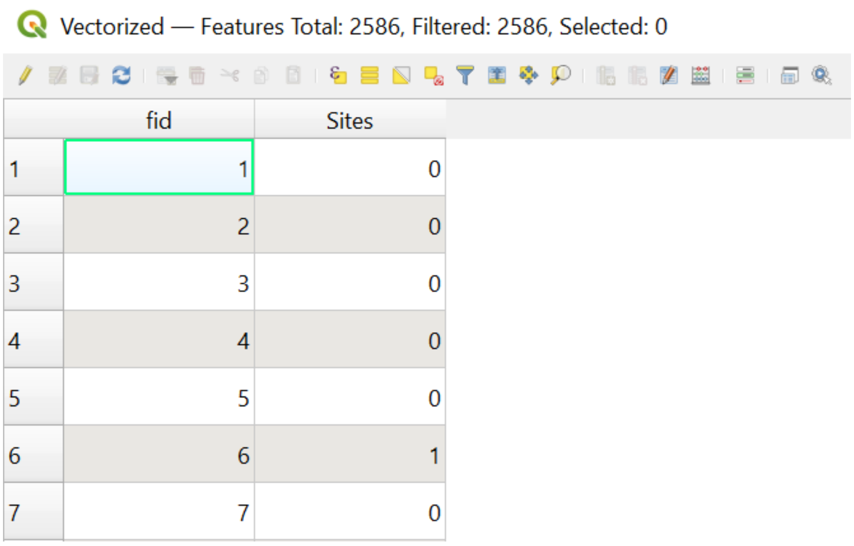
- From the top menu bar, select **Polygonize (Raster to Vector)**

The Polygonize (Raster to Vector) dialog window appears.

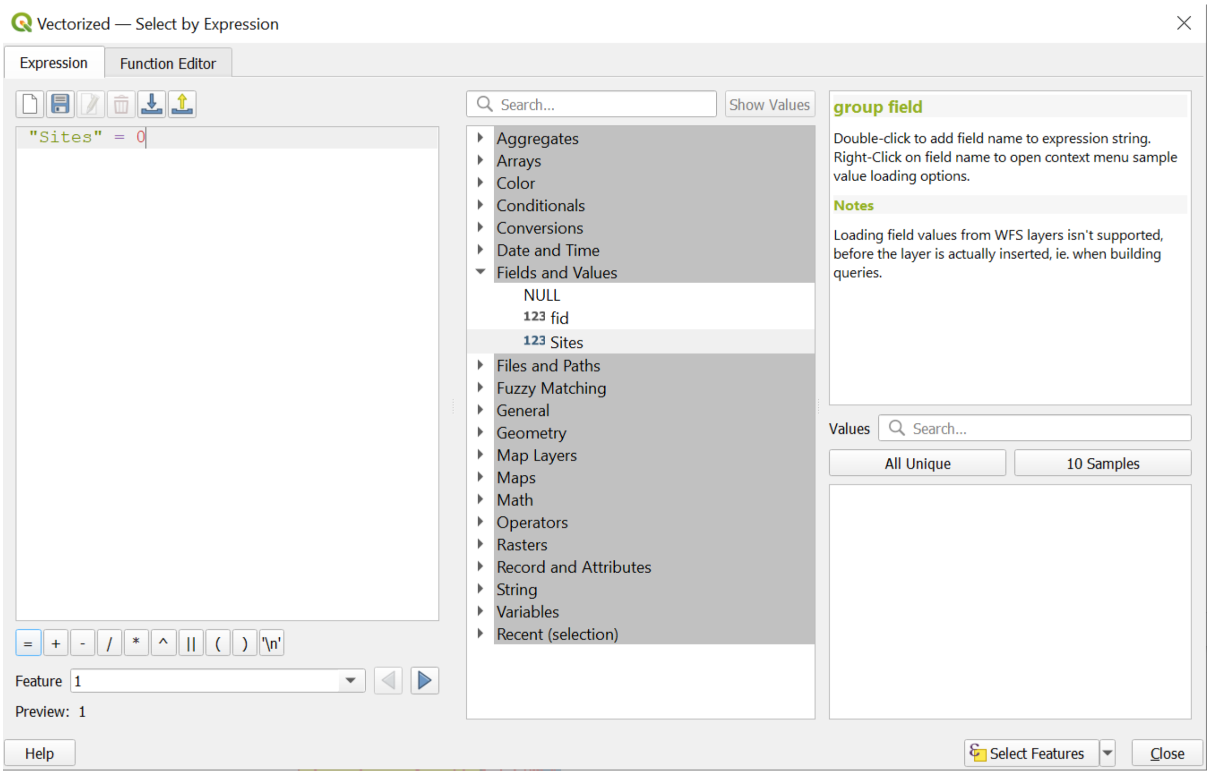
- For Input Layer, select MCDA_model from the drop-down list.
- For Name of the field to create, type *Sites*.
- Keep the checkbox in front of Use 8-connectedness uncheck.



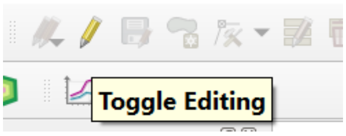
- Click on Run and close the window.
- A temporary layer called **Vectorized** will be added to the layers panel.
- Open the attribute table of this Vectorized layer.
- Note that there is a column called Sites with values 0 and 1.
- 0 indicates not suitable while 1 indicates suitable.



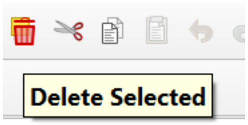
- Click on select by expression and enter the following expression into the expression box.



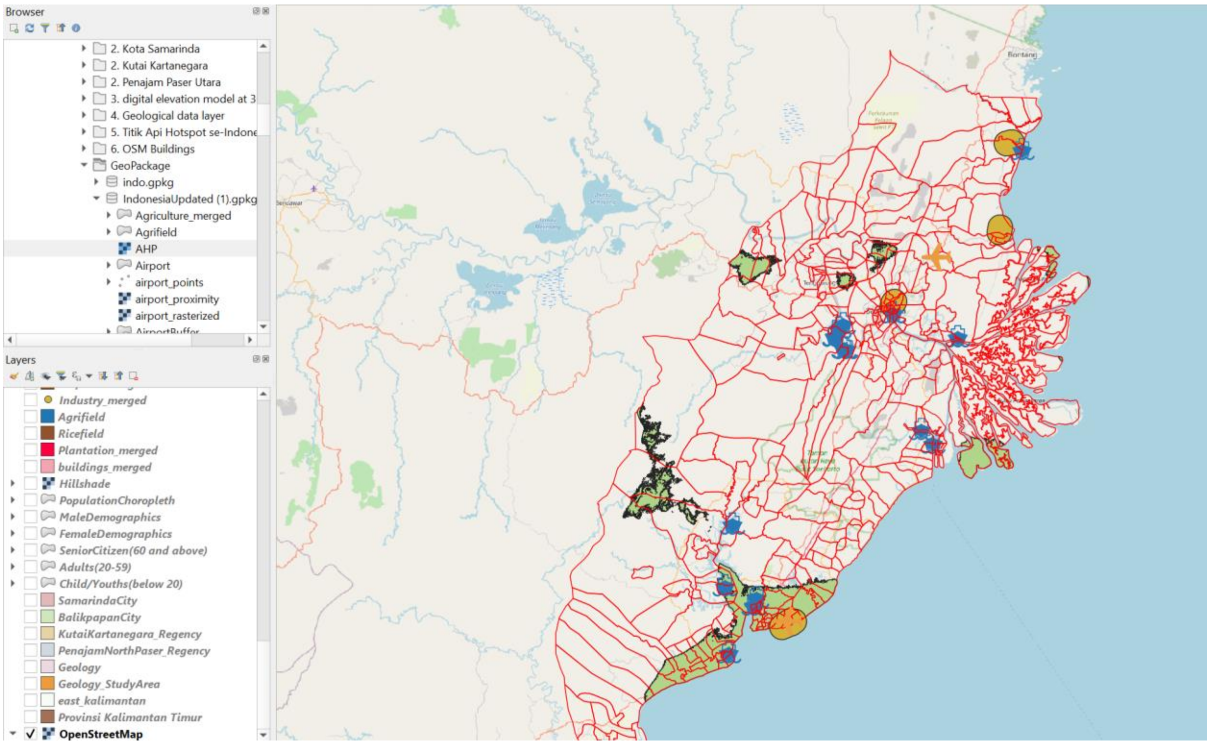
- The sites which are 0 (not suitable) are selected.
- Click on the Toggle Editing Button.



- Click on Delete Selected to remove all the non suitable sites.

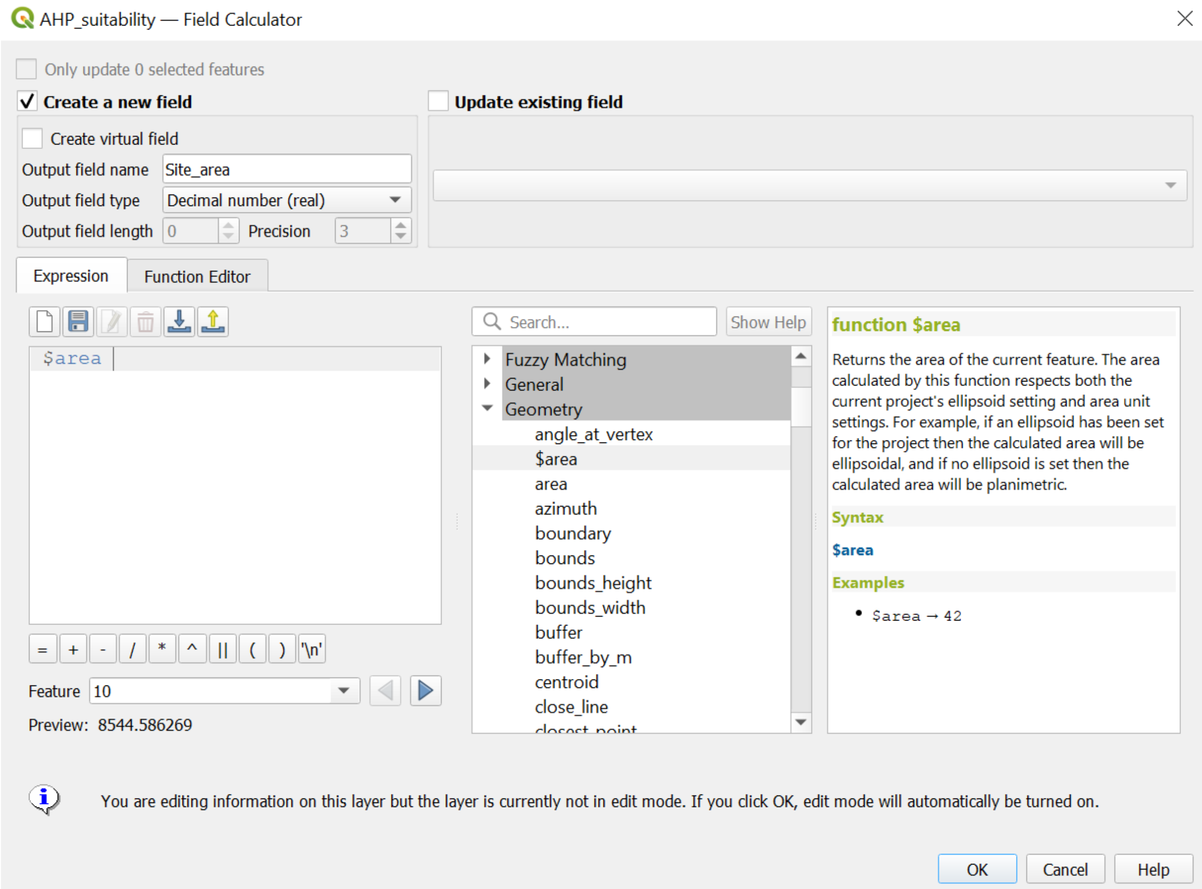


- Export the layer into a GeoPackage.
- Name this layer **AHP_suitability**.
- The suitable sites are the polygons in green as shown in the image below.



Next, we will need to calculate the area of each polygon.

- Use the Field Calculator
- Output field name: Site_area
- Output field type: Decimal number (real)
- From the Geometry drop-down menu in the middle column, double click on **$area** to add to the expression pane.



- Click on OK. Note that a new column will be added to the attribute table which includes all the areas of polygons in meters square.
- However, we want the area to be in Hectares. To do this, repeat the above steps to create a new field called **area_hectares**.
- For area_hectares, the expression should be **$area/10000** instead.

The attribute table should look like this.

AHP_suitability — Features Total: 1315, Filtered: 1315, Selected: 0

	fid	Sites	Site_area	area_hectares
1	6	1	8517.89209442...	0.85178920944...
2	8	1	8542.63344229...	0.85426334422...
3	9	1	34172.3841212...	3.41723841212...
4	10	1	8544.58626864...	0.85445862686...
5	11	1	25630.3673937...	2.56303673937...

2.7 GeoPackaged layers

GeoPackage Layer Name	Geometry	Description
Agriculture_merged	Vector - Polygon	Includes all agriculture polygons in the study area
Agrifield	Vector - Polygon	Represents **Tegalan**(dry-land) and **Ladang** (garden/bare land/ shifting land)
AHP	Raster	Raster layer of composite factor score
AHP_suitability	Vector - Polygon	Polygons of suitable sites
Airport	Vector - Polygon	Airport polygons in the study area
airport_points	Vector - Point	Airport points in the study area
airport_proximity	Raster	Proximity to airport polygons
airport_rasterized	Raster	Raster layer made from airport polygons
AirportBuffer	Vector - Polygon	Polygon representation of Airport Buffer Zone of 3.5km
AirportDissolved	Vector - Polygon	Dissolved Airport polygons in the study area
BalikpapanCity	Vector - Polygon	Polygon of Kota Balikpapan

bus_terminals_merged	Vector - Point	Bus terminal points in the study area
CoalMining	Vector - Point	Coal Mining points in the study area
Coastline	Vector - Line	Coastlines in the study area
connectingRoads	Vector - Line	Major roads in our study area
connectingRoads_proximity	Raster	Proximity to major roads
connectingRoads_rasterized	Raster	Raster layer made from connectingRoads
DEM_new	Raster	Digital Elevation Model of the study area
disaster_merged	Vector - Line	Merged river and coastline layers
disaster_proximity	Raster	Proximity to river and coastline
disaster_rasterized	Raster	Raster layer of disaster_merged
east_kalimantan	Vector - Polygon	Study area
education_merged	Vector - Point	Education points in our study area
electricity_merged	Vector - Point	Electricity points in our study area
factor_airport	Raster	Raster layer of standardised score for proximity to airport polygons

factor_connectingRoad	Raster	Raster layer of standardised score for proximity to connectingRoads
factor_disaster_new	Raster	Raster layer of standardised score for proximity to river and coastlines
factor_forest	Raster	Raster layer of standardised score for proximity to forests
factor_hotspot	Raster	Raster layer of standardised score for proximity to hotspots
factor_seaport	Raster	Raster layer of standardised score for proximity to seaports
factor_settlement	Raster	Raster layer of standardised score for proximity to settlements
factor_slope	Raster	Raster layer of standardised score for slope
FinalSite	Vector - Polygon	Final site which was chosen for task 2
forest	Vector - Polygon	Forest polygons in the study area
forest_proximity	Raster	Proximity to forests
forest_rasterized	Raster	Raster layer of forest polygons
Geology	Vector - Polygon	Geology polygon for

		Indonesia
Geology_StudyArea	Vector - Polygon	Geology polygon for the study area
healthServices_merged	Vector - Point	Health services points in our study area
Hillshade	Raster	Grayscale 3D representation of the surface
hospitals_merged	Vector - Point	Hospital points in the study area
hotspots_heatmap	Raster	Heatmap of hotspots in the study area
hotspots_merged	Vector - Point	Hotspot points in the study area
Industry_merged	Vector - Point	Industry points in the study area
KutaiKartanegara_Regency	Vector - Polygon	Kutai Kartanegara regency
Manufacturing	Vector - Point	Manufacturing points in the study area
MCDA_model	Raster	Reclassified raster of AHP. White portions indicate suitable sites while black portions indicate non suitable sites.
OpenMining	Vector - Polygon	Polygon of Surface Mining areas in the study area
OtherMining	Vector - Point	Point representation of Other

		Mining activities in study area
PenajamNorthPaser_Regency	Vector - Polygon	Polygon of Penajam North Paser Regency
phone_towers	Vector - Point	Phone tower points in the study area
Plantations_merged	Vector - Polygon	Polygons of plantations in the study area
Ricefield	Vector - Polygon	Polygon of rice fields in the study area
rivers	Vector - Line	Lines of rivers across the study area
roads_merged	Vector - Line	Lines of roads across the study area
SamarindaCity	Vector - Polygon	Polygon of Kota Samarinda
Seaport	Vector - Point	Seaport points in the study area
seaport_proximity	Raster	Proximity to seaports
seaport_rasterized	Raster	Raster layer of seaport points
Settlement	Vector - Polygon	Polygons of settlements in the study area
settlement_proximity	Raster	Proximity to settlements
settlement_rasterized	Raster	Raster layer of settlement polygons
slope30by30	Raster	Slope layer which has a

		resolution of 30m by 30m
slopeStudyArea	Raster	Slope layer of the study area
StudyAreaSingle	Vector - Polygon	A single polygon of our entire study area

3.0 Report of Survey

In this section, we will be analyzing the study area according to the following themes:

- Population and Demographic
- Economic and Businesses
- Transport and Communication
- Infrastructure
- Environment and Hazard

We will be using OpenStreetMap (OSM) to compare data points and polygons to actual land infrastructure and facilities to facilitate accuracy in our analysis.

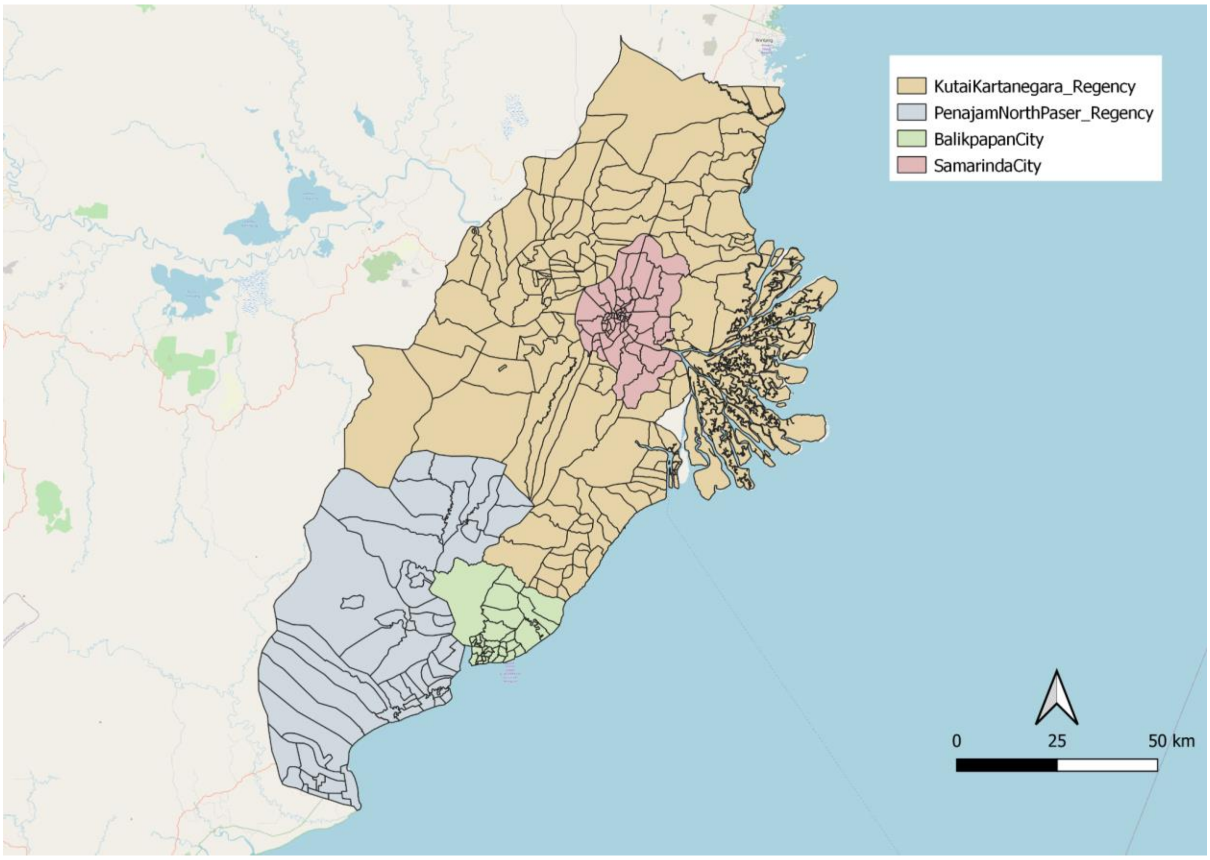


Figure 1: Map of study Area

3.1 Population Density and Demographics

3.1.1 Population Density

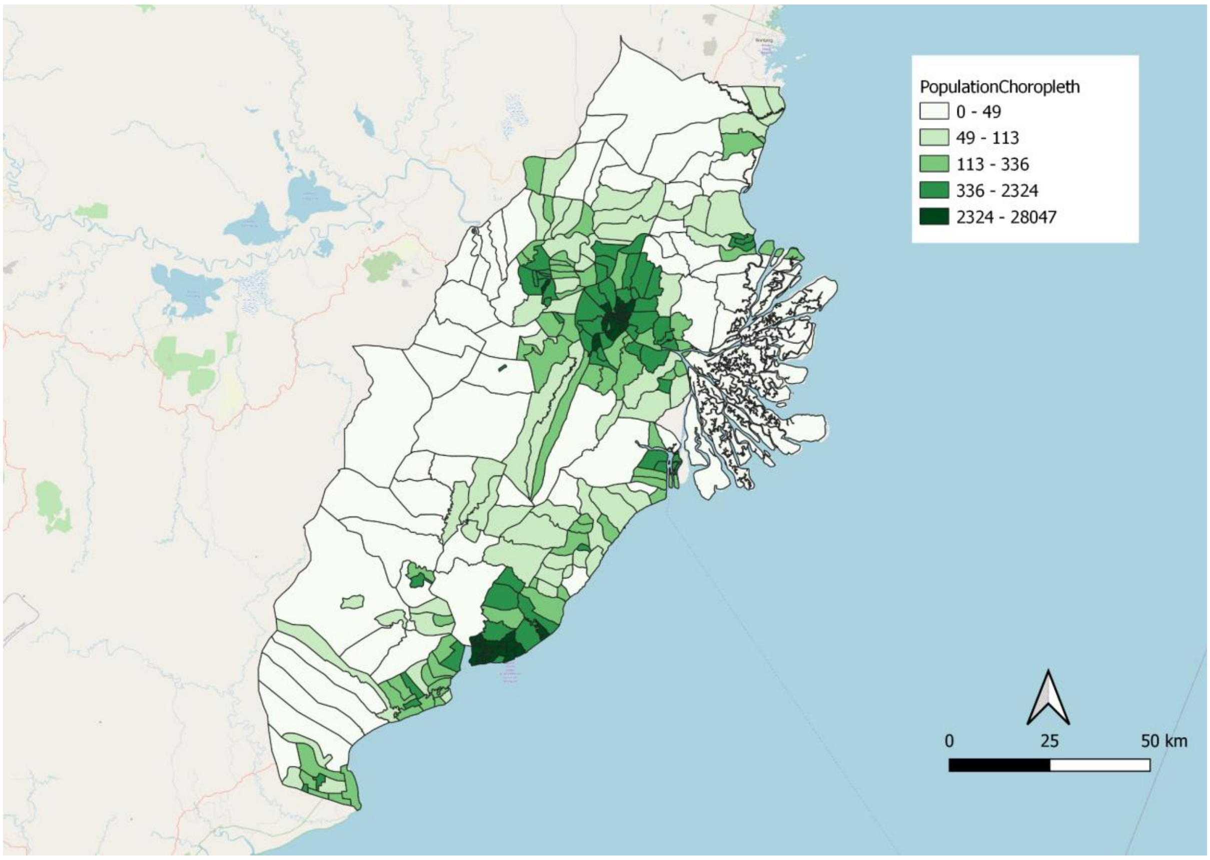


Figure 2: Population Density Map of Study Area

As our group is looking for a suitable site, we consider the population density across each sub district as one of the important factors to analyze the site suitability. Thus, using the data found in Balikpapan city, Samarinda city, North Penajam Paser regency and Kutai Kartanegara regency, we merge them altogether to map out our population density choropleth map. One interesting finding was that in city sub-districts such as Samarinda and Balikpapan, the population density tends to be higher, between 2324 to 28047 per sub district boundary. Contrastingly, we see a smaller population density across most of North Penajam Paser regency and Kutai Kartanegara regency sub-districts.

3.1.2 Gender Distribution

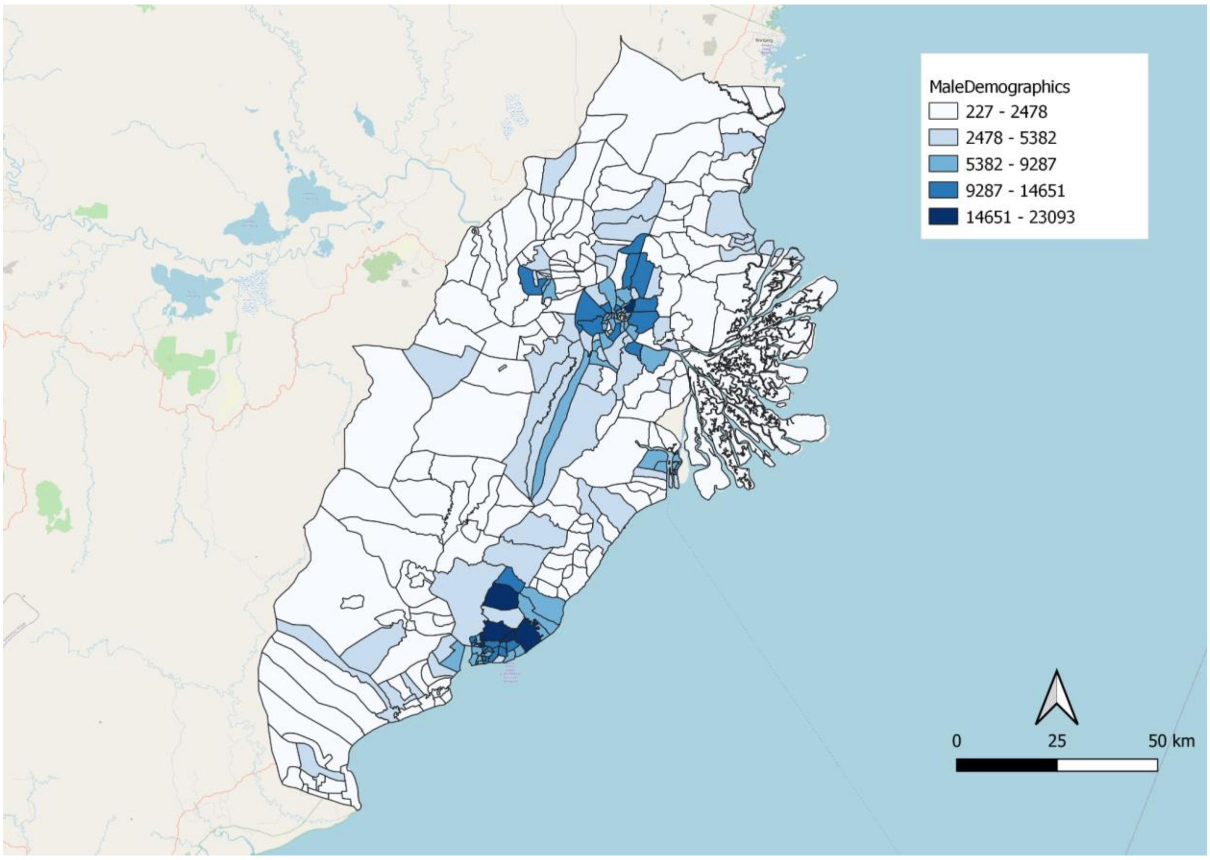


Figure 3: Male Demographics Distribution along study area

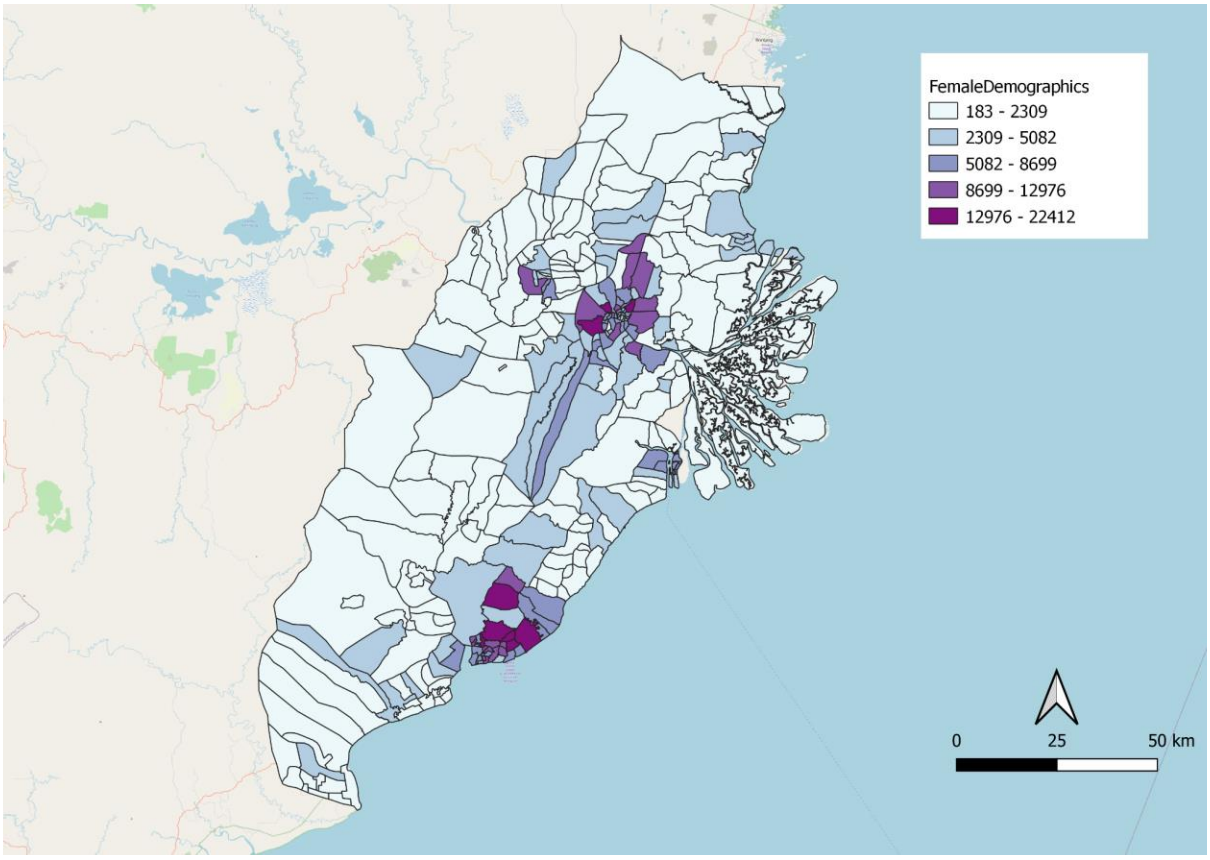


Figure 4: Female Demographics Distribution along study area

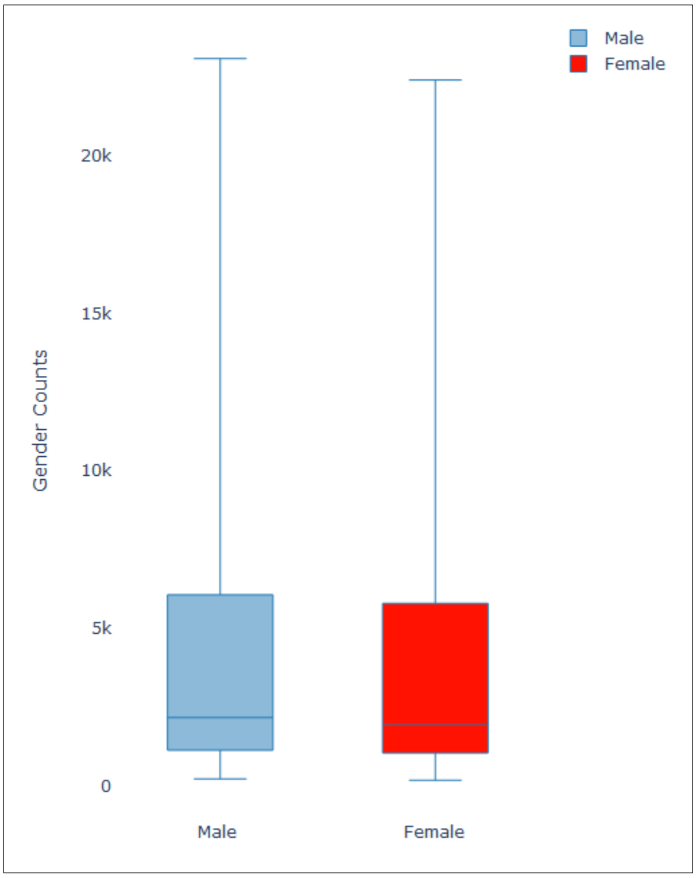


Figure 5: Gender Distribution along study area

From Figures 3, 4 and 5 above, we observed that the distribution of male to female in our study area remains somewhat equal with both showing the same gender distribution. One notable difference between figure 3 and 4 is that in Cities like Samarinda and Balikpapan, there is a higher concentration of males and females which further substantiates our earlier discussion that population density is higher in city subdistricts.

3.1.3 Distribution by age

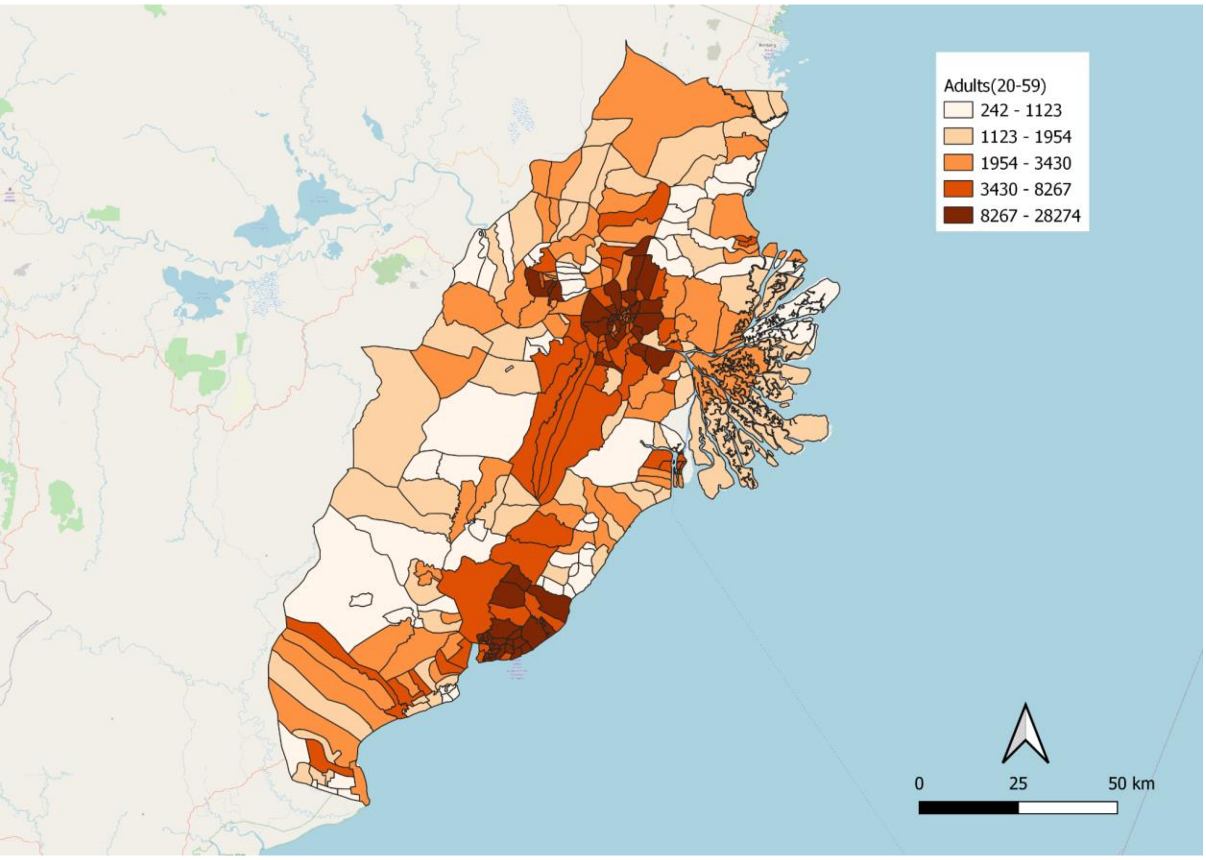


Figure 6a: Distribution of Adults aged 20-59 along study area

From the choropleth map shown in Figure 6a, we observed that a large proportion of adults are heavily concentrated around city centres like Kota Samarinda and Kota Balikpapan. This group of people is representative in terms of job opportunities and advancement for that particular state. We know that there are more job opportunities available in city centers which explains the higher representation of population in both Samarinda and Balikpapan. Furthermore, we also observed that the adult population across the Kutai Kartanegara Regency and Penajam North Paser Regency are significantly less concentrated as some of those areas are heavily related to agricultural activities.

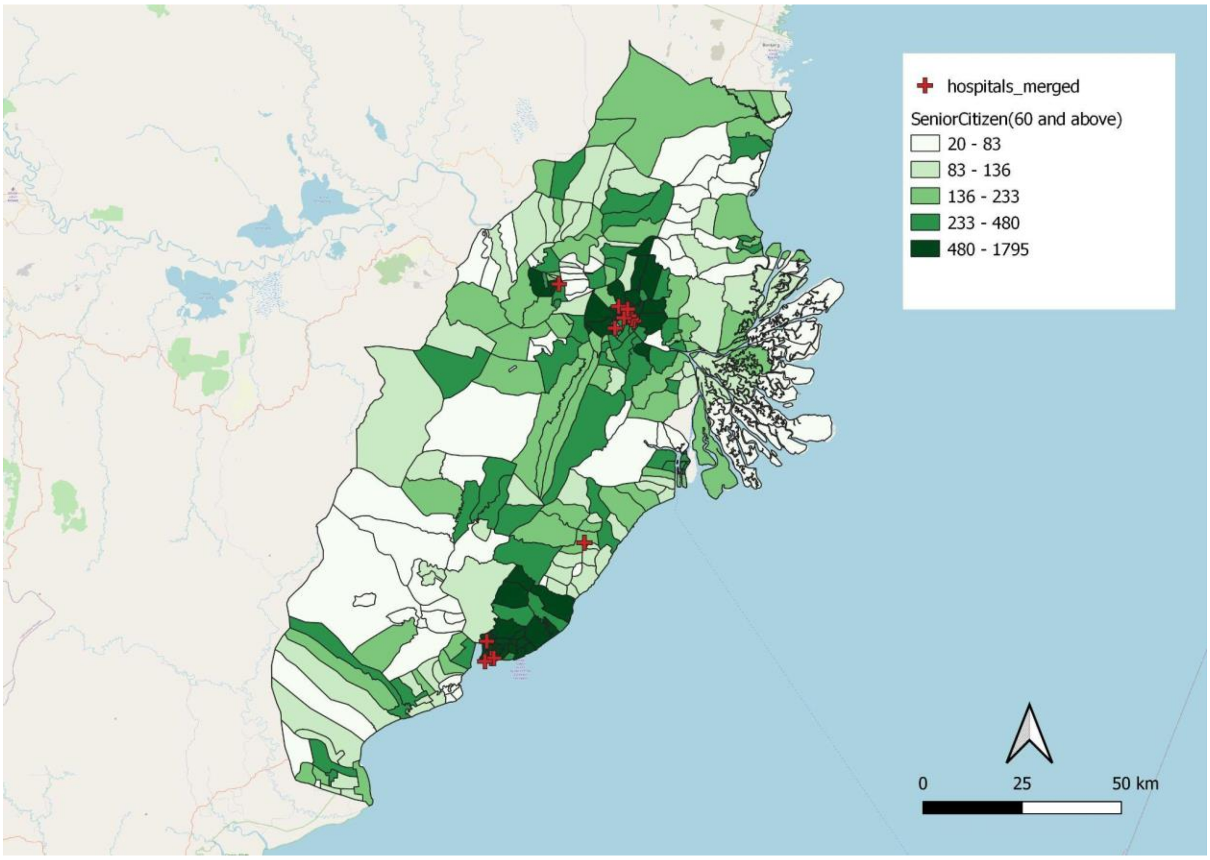


Figure 6b: Distribution of Senior Citizens aged 60 and above along study area

From the choropleth map shown in Figure 6b, we observed a similar trend where senior citizens aged 60 and above are heavily concentrated around city centres like Kota Samarinda and Kota Balikpapan. This can be attributed to reasons such as proximity to healthcare facilities, where healthcare facilities are more accessible in city centres as compared to the outskirts of the study area. In figure 6b above, we observed that hospitals are mostly situated in Samarinda and Balikpapan city, and there is a lack of healthcare facilities found in Kutai Kartanegara Regency and PenajamNorthPaser Regency. Thus, this relationship between proximity to hospital facilities and population within the senior citizens demographics are highly correlated.

3.2 Economic and Businesses

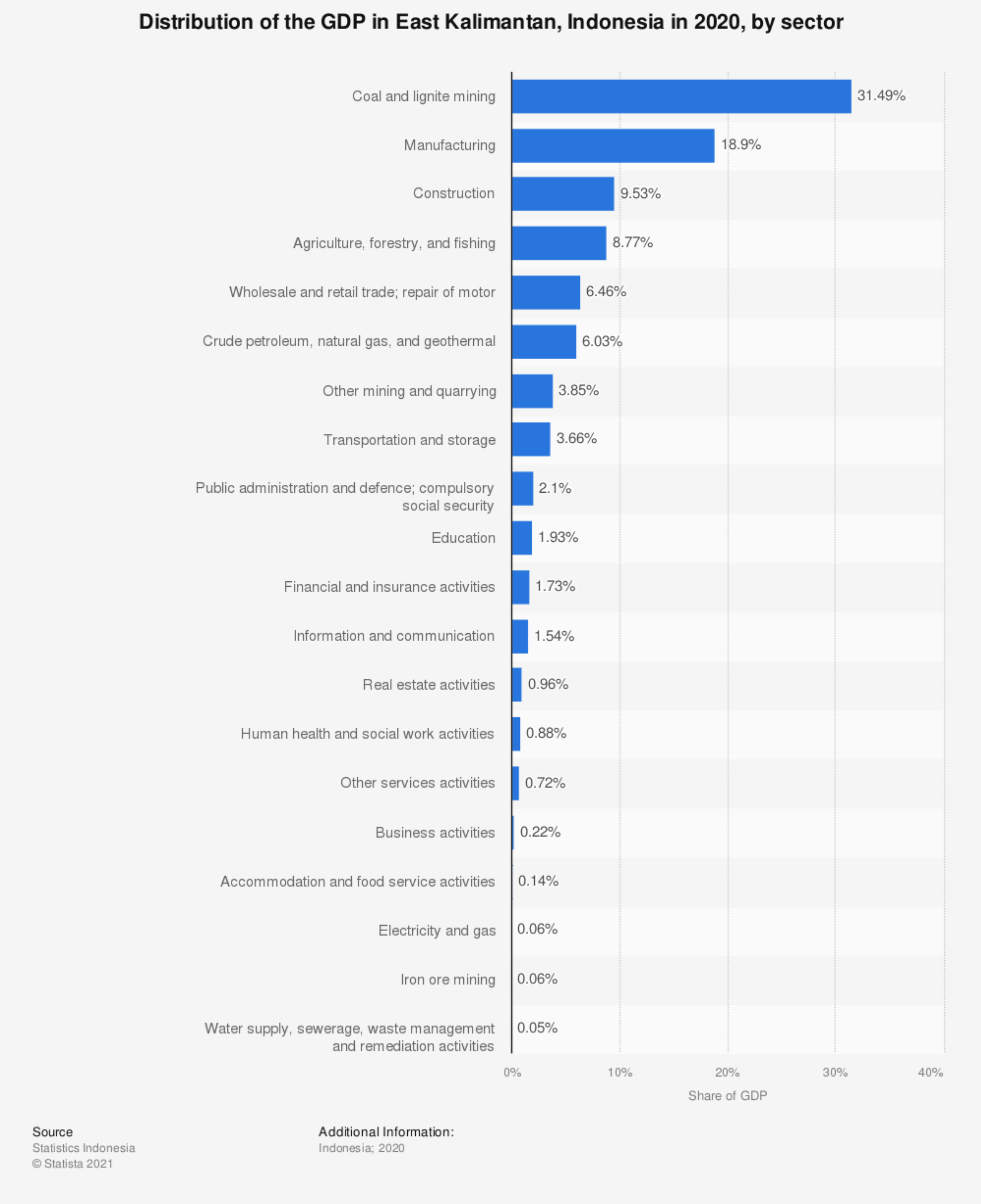


Figure 7: East Kalimantan GDP distribution by sector (Statista Research Department, 2020)

Indonesia is the largest palm oil producer in the world, while its forests make up the third largest tropical forests in the world. Additionally, Indonesia ranks among the world's top 10 coal and mining producers. In East Kalimantan, the key economic contribution to its GDP is attributed to the likes of agriculture, mining and manufacturing which we will comprehensively share in the upcoming part of the report.

3.2.1 Agriculture

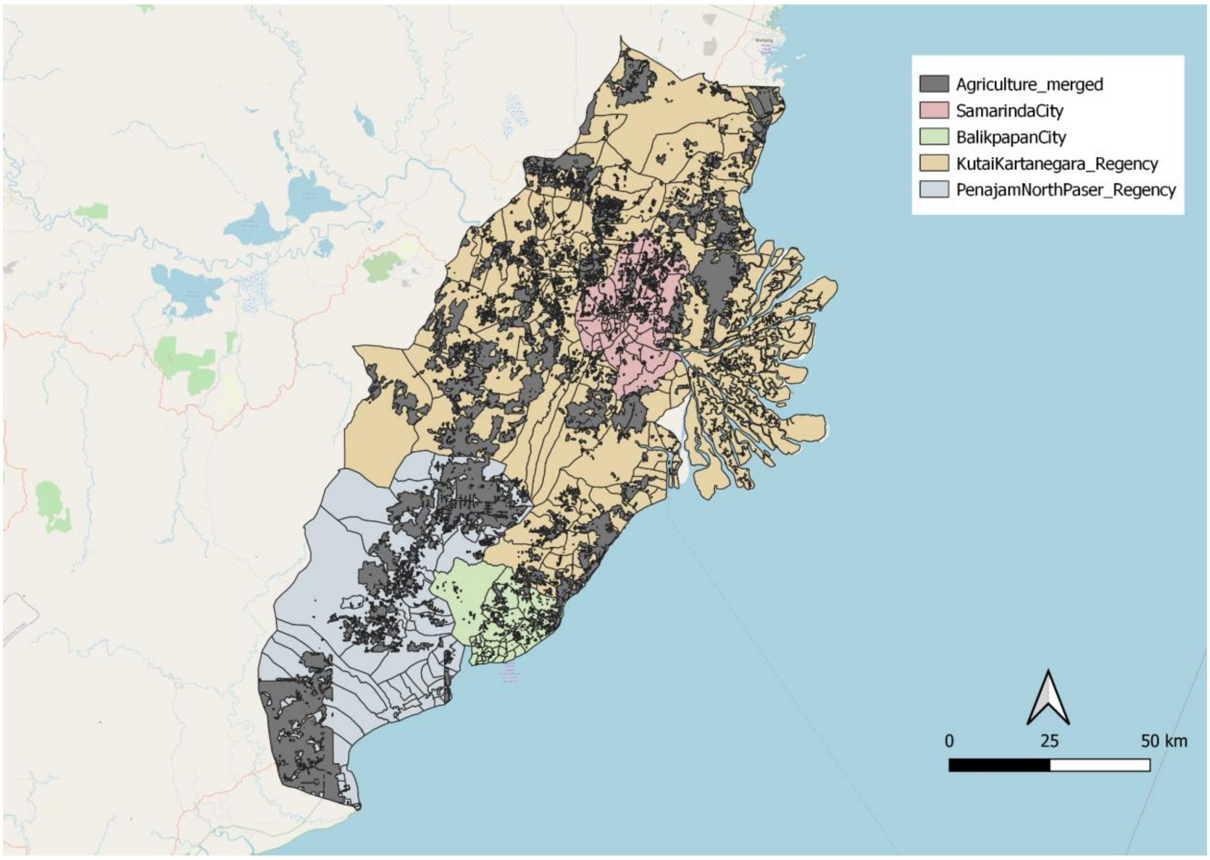


Figure 8a: Agriculture Distribution over study area

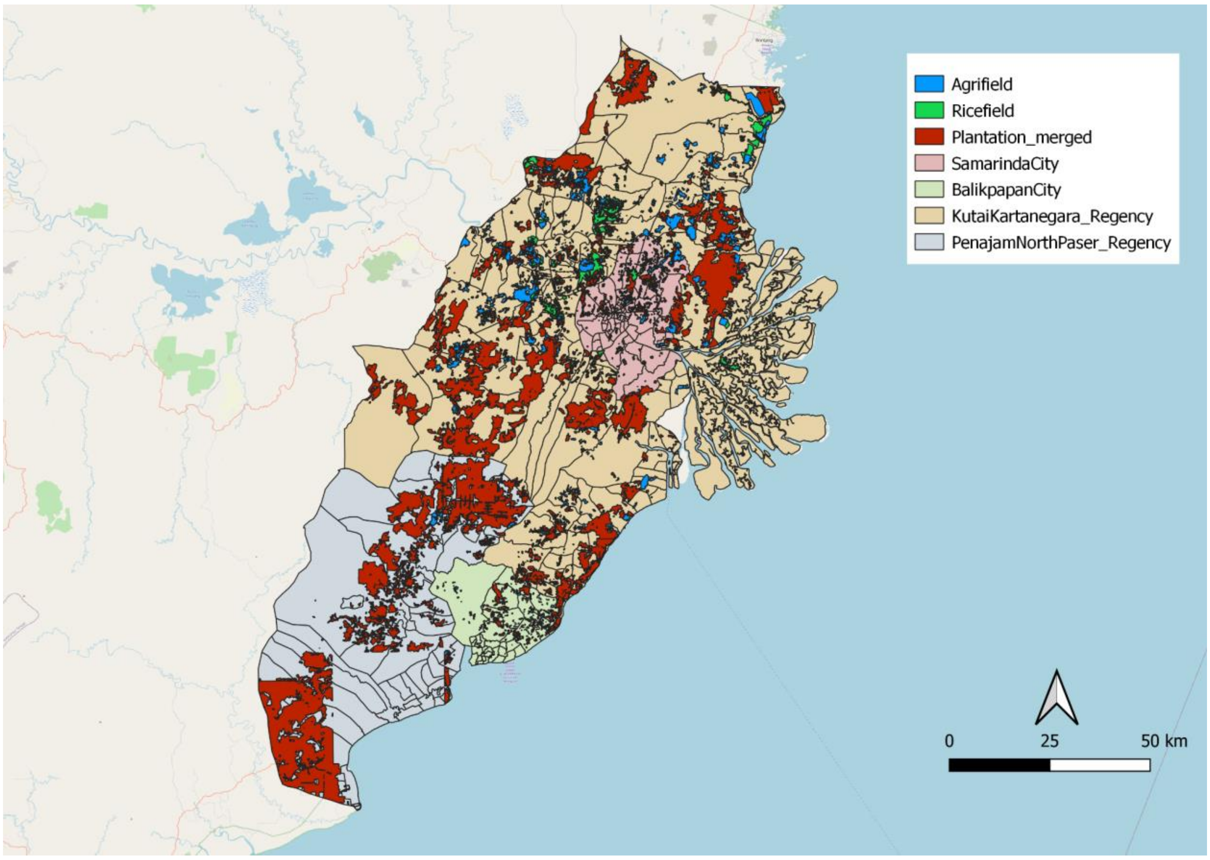


Figure 8b: Breakdown of Agriculture Distribution over study area

Figure 8a and 8b above illustrate the distribution of agricultural activities around the study area of Balikpapan City, Samarinda City, Kutai Kartanegara Regency and Penajam North Paser Regency. As Indonesia is known as the largest palm oil producer in the world, it is no surprise that we are seeing plantations forming the bulk of agriculture activities in the study area. Most of these plantations region constitutes commodities production such as palm oil and rubber which contributes most to Indonesia exports and GDP.

Food crops are cultivated in three categories of arable land in Indonesia, **Sawah** (wet-land), **Tegalan** (dry-land) and **Ladang** (garden/bare land/shifting land) ("Edu-Tourism", n.d.). Sawah is flat lowland on downhill sites or floodplains and terraced land on upper slopes. Tegalan is gently sloping land, which has no access to any irrigation system and usually located close to settlement, whereas ladang is slope land of varying steepness and altitude. Tegalan and Ladang are considered to be marginal land.

The agrifield layer represents **Tegalan**(dry-land) and **Ladang** (garden/bare land/ shifting land) which are known to be marginal land that has little or no agricultural or industrial value. We observed that agrifield is concentrated in Balikpapan, Samarinda and Kutai Kartanegara.

The rice field layer represents **Sawah**(wet-land) which contributes to part of East Kalimantan rice production. We observed that ricefield is more commonly dispersed around the northwestern site of the study area as well as a smaller proportion within Samarinda City.

3.2.2 Mining

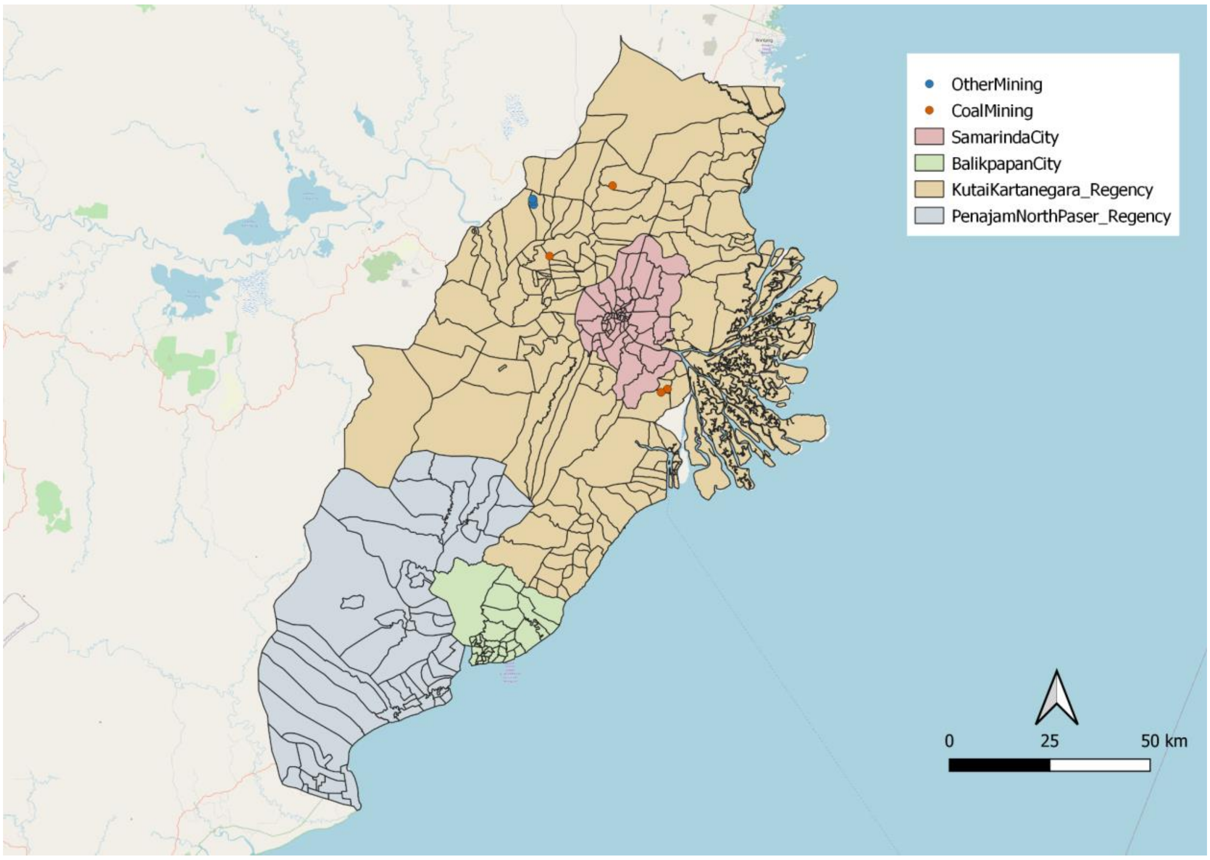


Figure 9: Coal Mining points and Other Mining points in study area

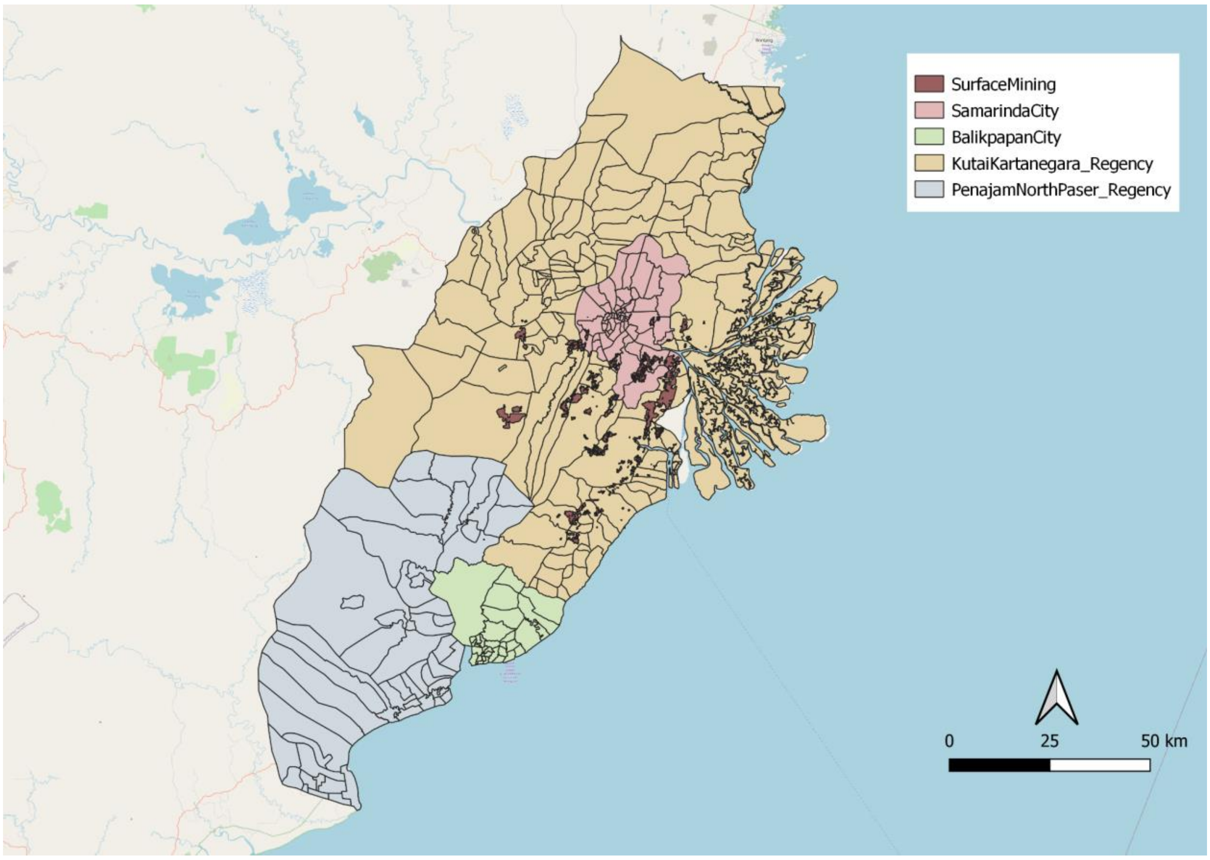


Figure 10: Surface Mining regions in study area

In East Kalimantan, mining contributes to the largest proportion in terms of GDP. From the data relating to mining that we found in our dataset, we classify them further into 3 categories which comprises Coal Mining, Other Mining and Surface Mining. We noticed that Coal Mining and other types of mining is apparent only in the Kutai Kartanegara Regency. For Surface Mining, it is only observed in the outskirts of Samarinda city and along the south-east region of Kutai Kartanegara Regency. In the study area of Penjamin Paser Utara and Balikpapan, there seems to be a lack of such land use in surface mining. Land used from mining activities could be a consideration when selecting the area for the city as it would involve additional economic cost to rehabilitate lands.

3.2.3 Manufacturing

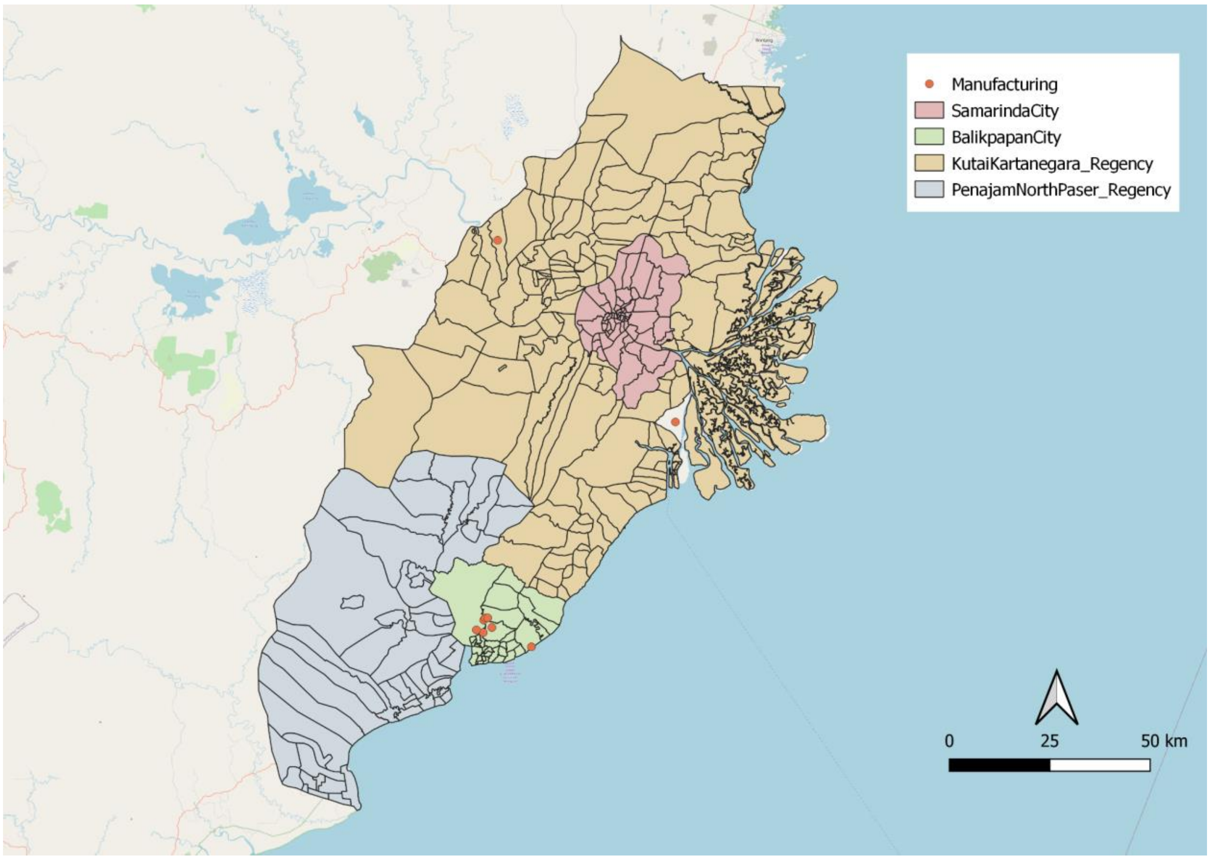


Figure 11: Manufacturing points in study area

For Figure 11, it represents the manufacturing geolocation found in our study area. We observed that Balikpapan City is more reliant on manufacturing in their economy as there are more manufacturing sites observed.

To conclude, with reference to the Agriculture layer and Industry layer which we further classify them, we are able to further understand the region's key economic sectors in the field of agriculture, mining and manufacturing. These are key considerations in allowing us to effectively find a suitable site for choosing a capital.

3.3 Transport and Communication

3.3.1 Airports, Seaports and Bus Terminals

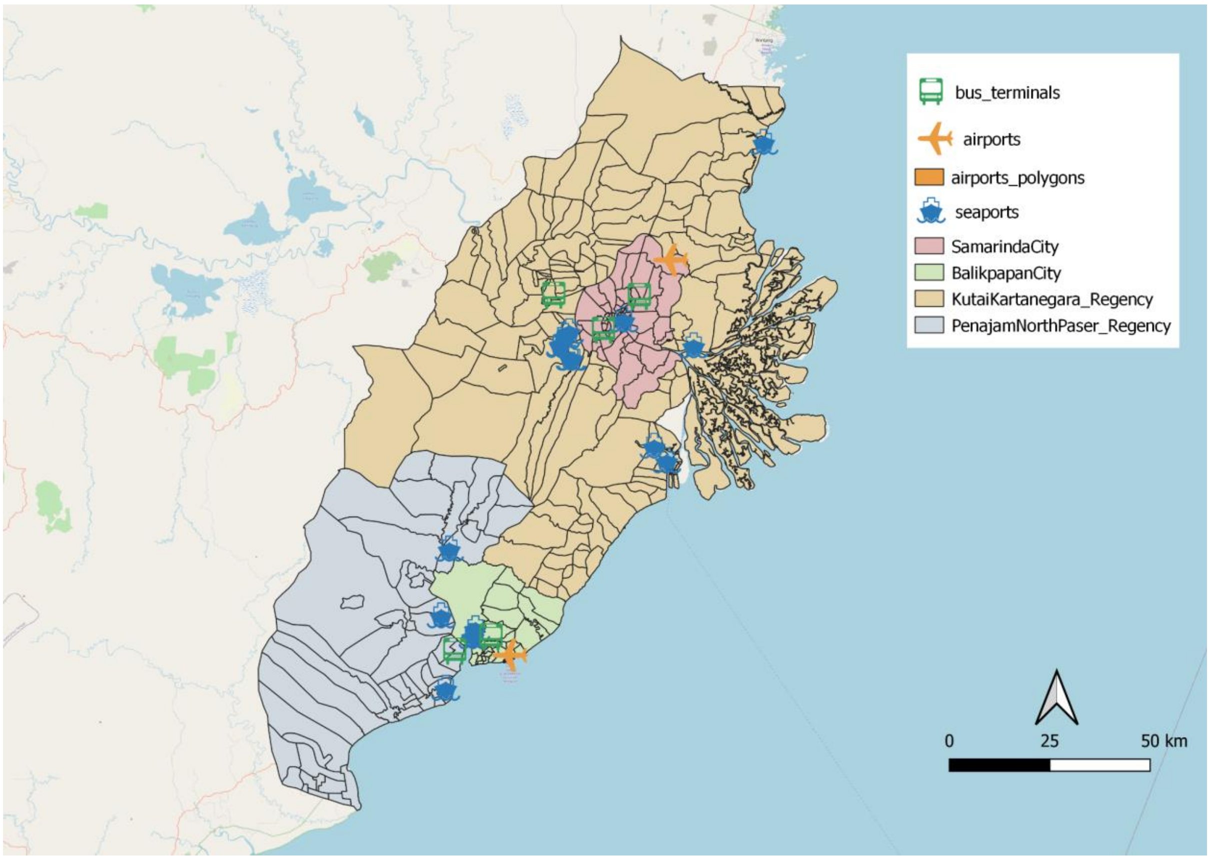


Figure 12: Distribution of Transportation services in East Kalimantan

Figure 12 illustrates the distribution of different transportation services in our study area. There are only two airports, one within Balikpapan city and the other in Penajam North Paser regency, just outside of Samarinda city. The seaports are mostly situated within or just outside of Balikpapan city and Samarinda city. Similarly, the bus terminals are also found close to Balikpapan city and Samarinda city. Collectively, the different modes of transportations are mostly situated within or near Balikpapan city and Samarinda city. Even though there are transportation services found in Penajam North Paser regency and Kutai Kartanegara regency, those services are mainly located at the edges of the two cities. This shows that most of the transportation services are found in a close vicinity to the cities.

3.3.2 Roads

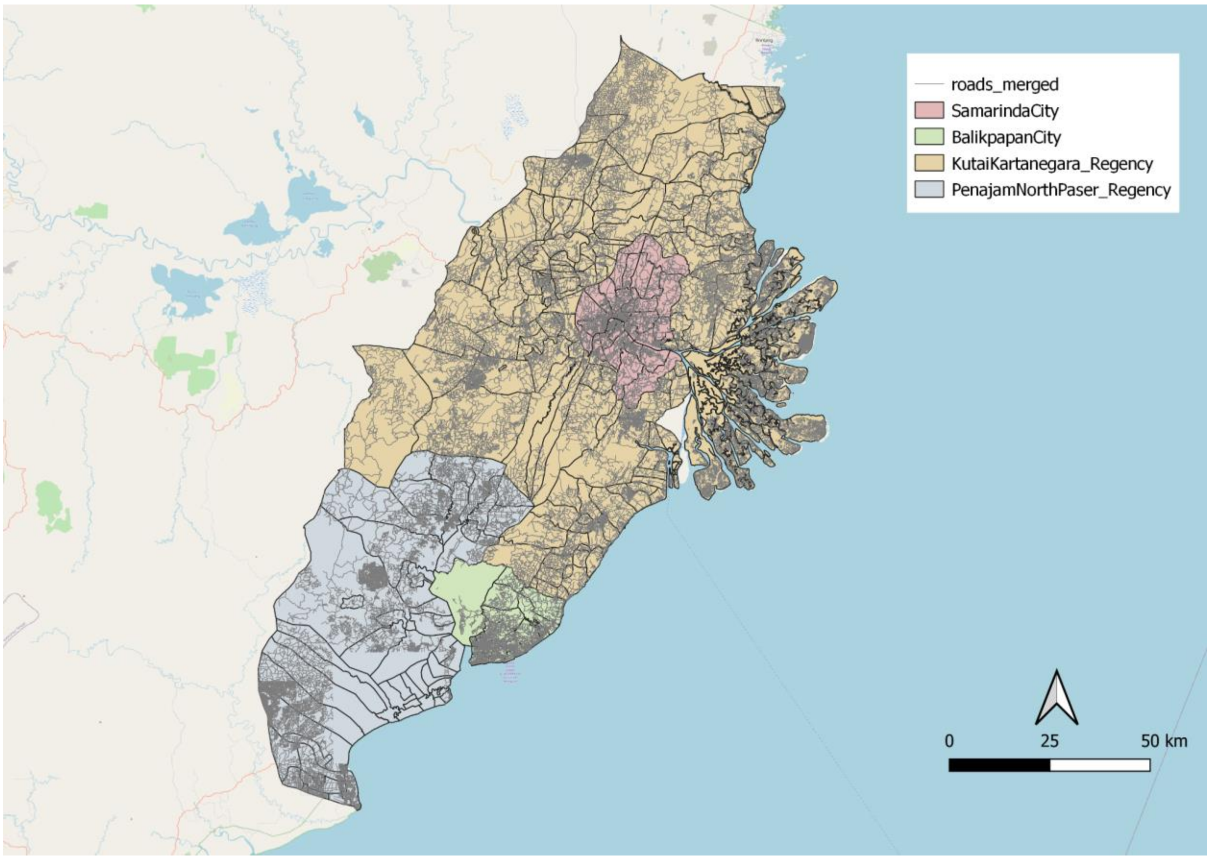


Figure 13a: Distribution of all Roads in East Kalimantan

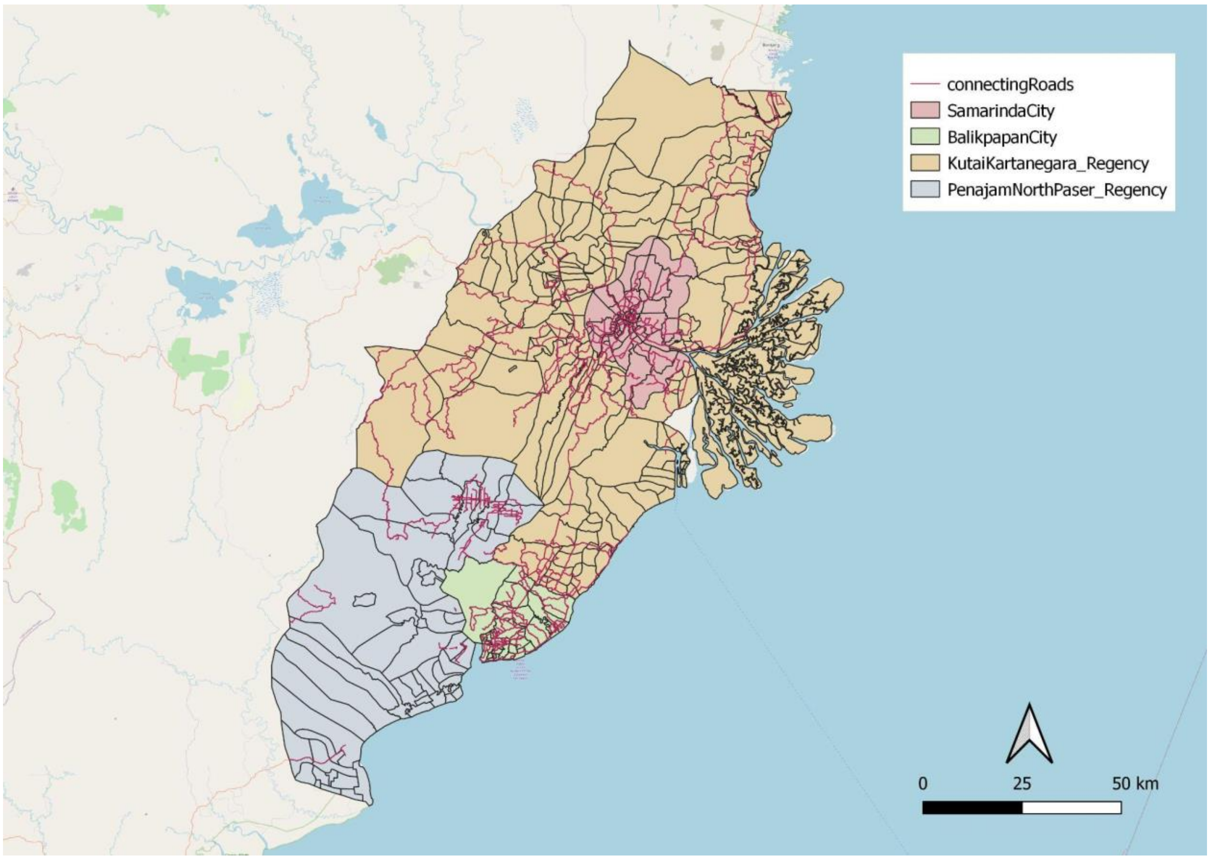


Figure 13b: Distribution of Main Roads in East Kalimantan

This map in Figure 13a and 13b shows the distribution of road networks in East Kalimantan. From the above map, we can observe that the highest concentration of roads are found within Balikpapan city and Samarinda city. This further indicates that the cities have a higher concentration of transportation facilities as compared to the regencies.

3.3.3 Phone Towers

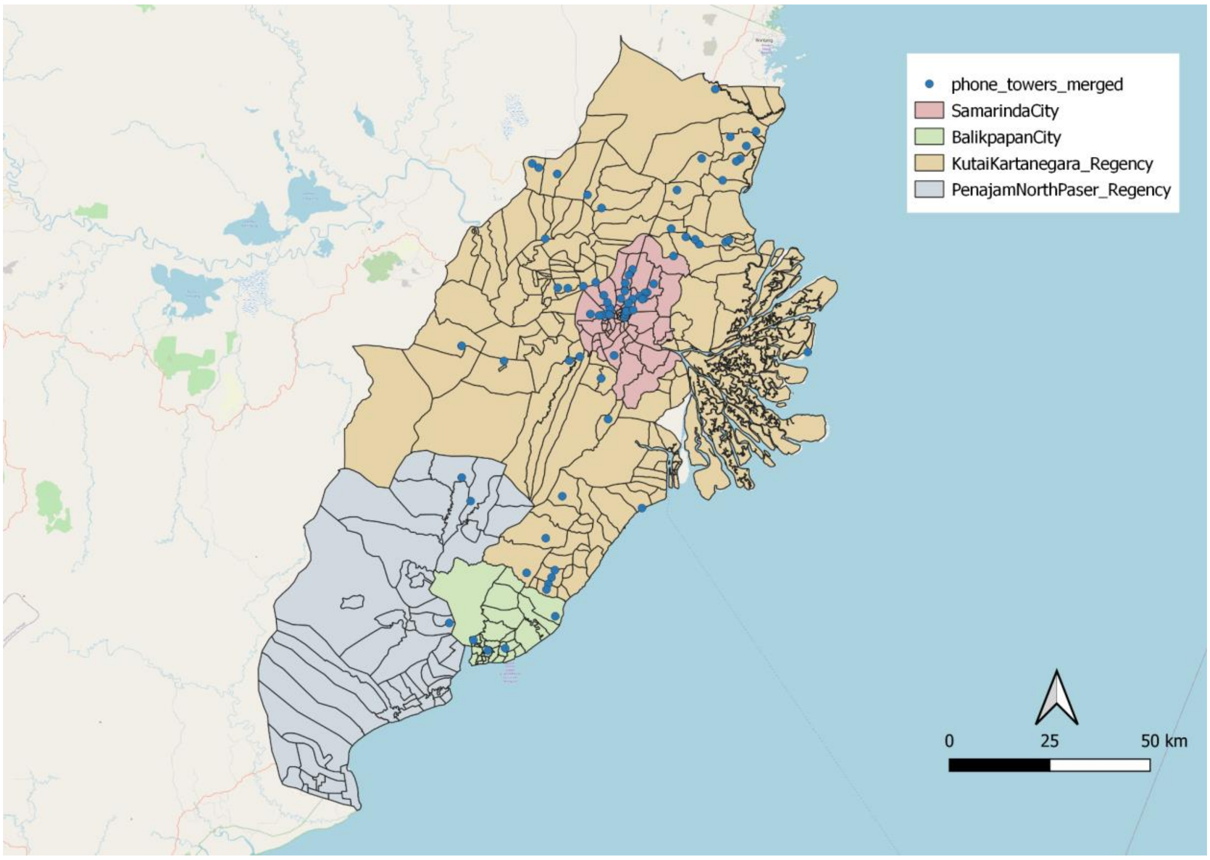


Figure 14: Distribution of Phone Towers in Our Study Area

Figure 14 shows the distribution of phone towers in our study area. There is a large concentration of phone towers in Samarinda. Phone towers are electronic wireless equipment that allows the surrounding area to utilize wireless devices such as radios and cell phones. The distribution of phone towers indicates good connectivity between the different regions, allowing for good communication.

3.4 Infrastructure

3.4.1 Electricity towers and power

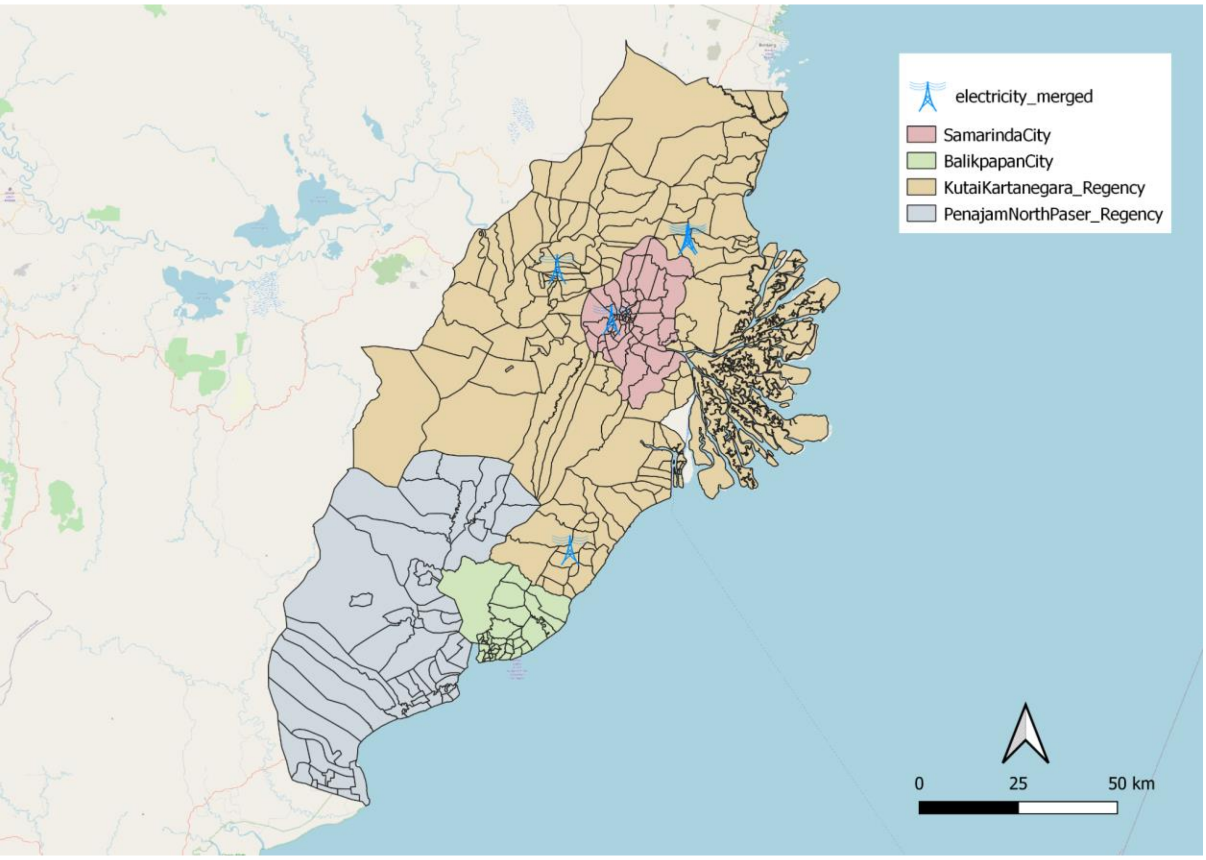


Figure 15: Distribution of Electrical Towers in Our Study Area

Electrical points are more prominent in Kota Samarinda and Kutai Kartanegara.These facilities provide infrastructure to further develop the country. It can be observed that the distribution of electrical towers are not evenly spread out as most of them are located in Kota Samarinda. This could be due to the fact that Kota Samarinda is the capital of East Kalimantan, and more modern buildings are located there.

3.4.2 Hospitals and healthcare services

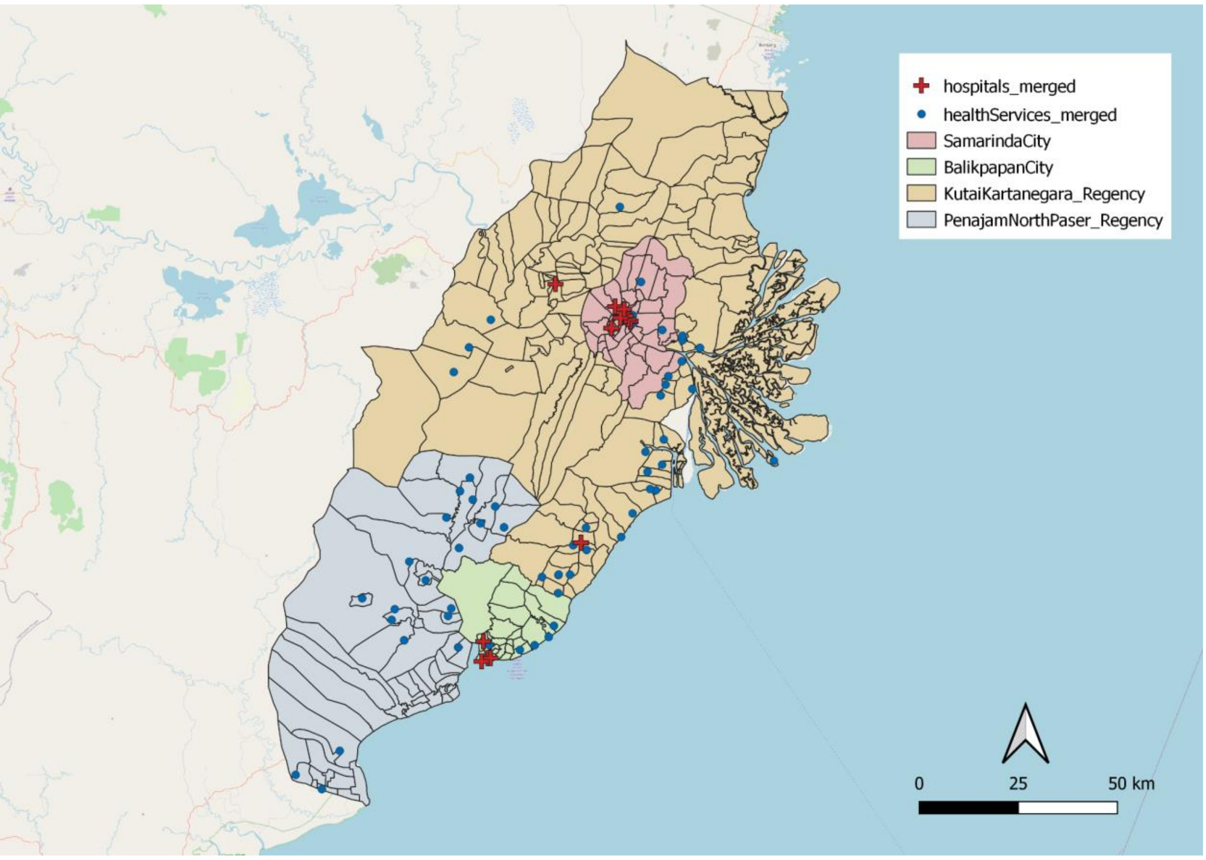


Figure 16: Distribution of hospitals and healthcare services

Figure 16 shows the distribution of hospitals and healthcare services. Hospitals are symbolised with a red cross while healthcare services are symbolised with a blue point. These are essential services as they prevent diseases, improve wellbeing and quality of life for citizens. However, we can see that some areas do not have access to any healthcare services as the points are sparsely scattered. On the other hand, we observed that most hospitals are situated within Balikpapan city and Samarinda city. Therefore, choosing a site nearer to areas with many healthcare facilities will be ideal.

3.4.3 Educational institutions

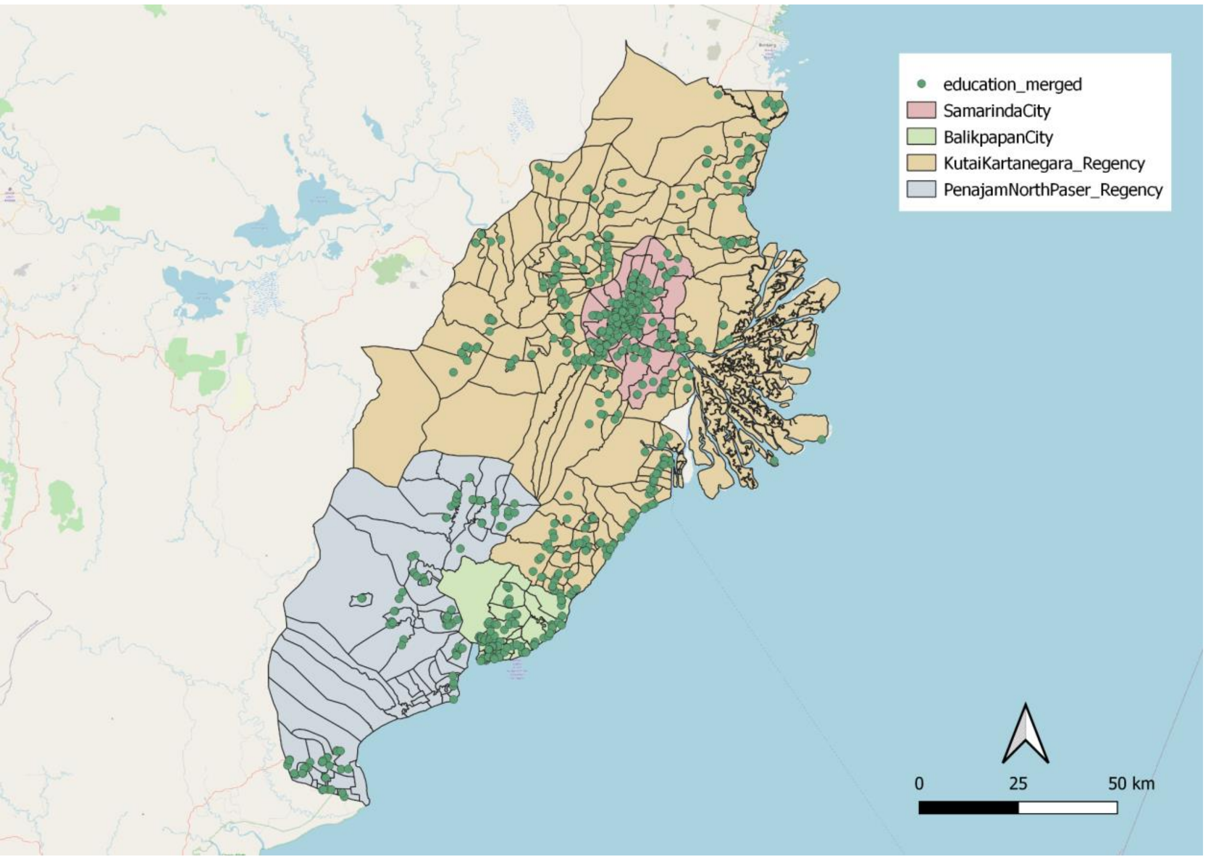


Figure 17: Distribution of educational institutions

Similarly, Kota Samarinda and the coastline of Kota Balikpapan are densely populated with educational institutions. They are not evenly distributed. This might be due to the fact that Kota Samarinda and Kota Balikpapan have a higher population density.

3.5 Environment and Hazard

We will be looking at fire hotspots, rivers, coastlines and forests to evaluate the environment and its hazards.

3.5.1 Fire hotspots

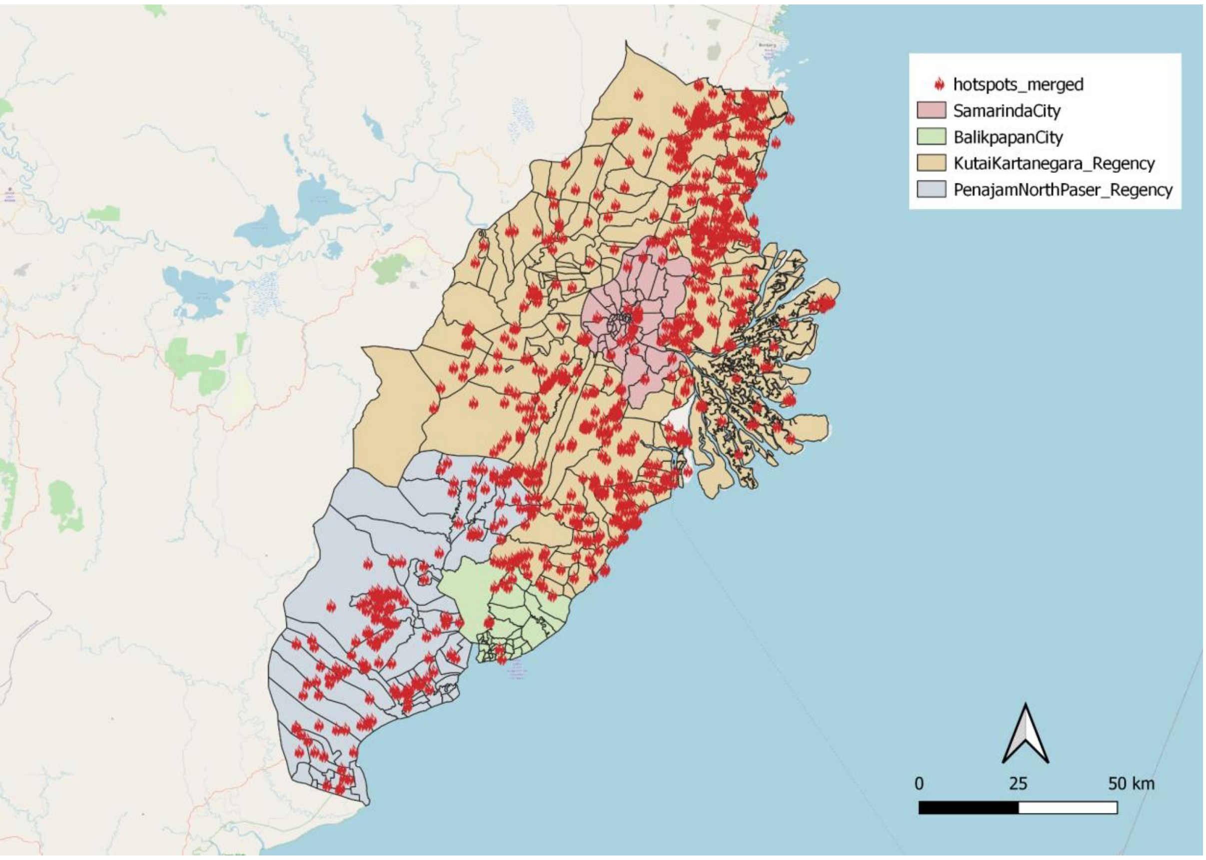


Figure 18: Distribution of fire hotspots

After clipping fire hotspot data to the study area, it is observed that hotspot points are consistently scattered throughout the whole study area except Loa Kulu and Sepaku (extreme left of study area). It can also be observed in figure 18 that the top most section of the study area is the most densely populated with fire hotspots. Therefore, when choosing the capital area, we should avoid hazardous portions of the study area.

3.5.2 Rivers

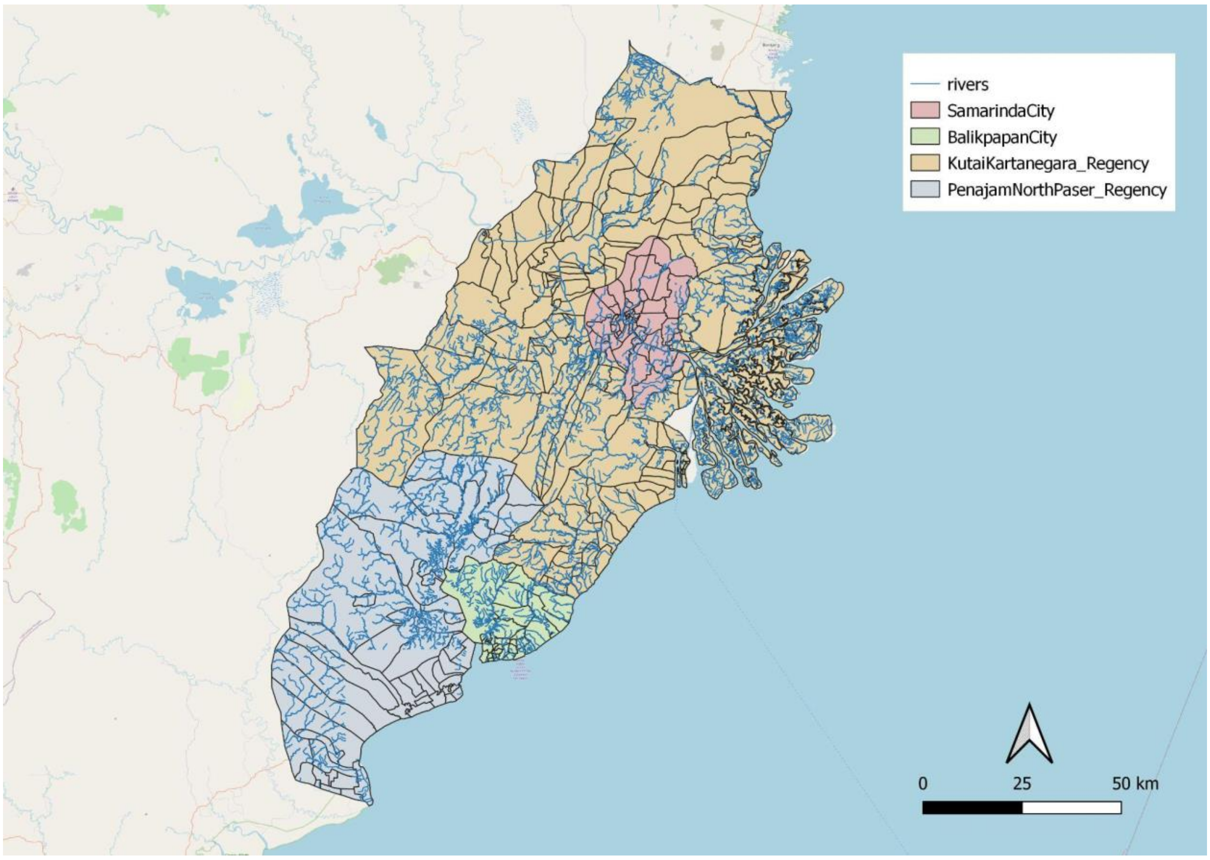


Figure 19: Distribution of rivers

Rivers run through the 4 regions. As it was mentioned in task 2 that our area should avoid major rivers, we took this into consideration. However, it is quite obvious that rivers are very prominent throughout the whole of East Kalimantan.

3.5.3 Coastlines

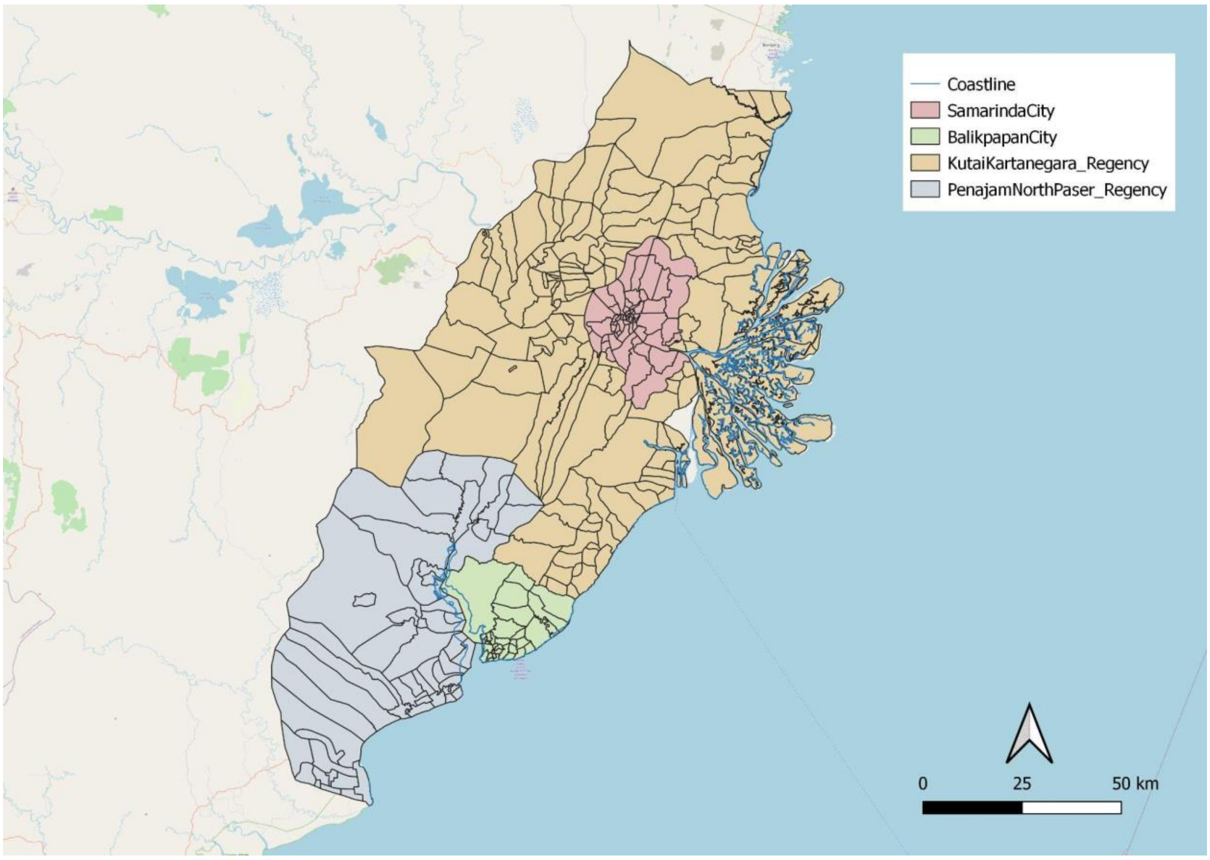


Figure 20: Distribution of coastlines

It was also mentioned in task 2 that coastlines should be avoided when choosing a site as it could pose risks resulting from natural disaster. Indonesia For instance, tsunamis occur in Indonesia. By avoiding coastlines, we are mitigating the chances of high casualties and fatalities should a tsunami take place.

3.5.4 Forest

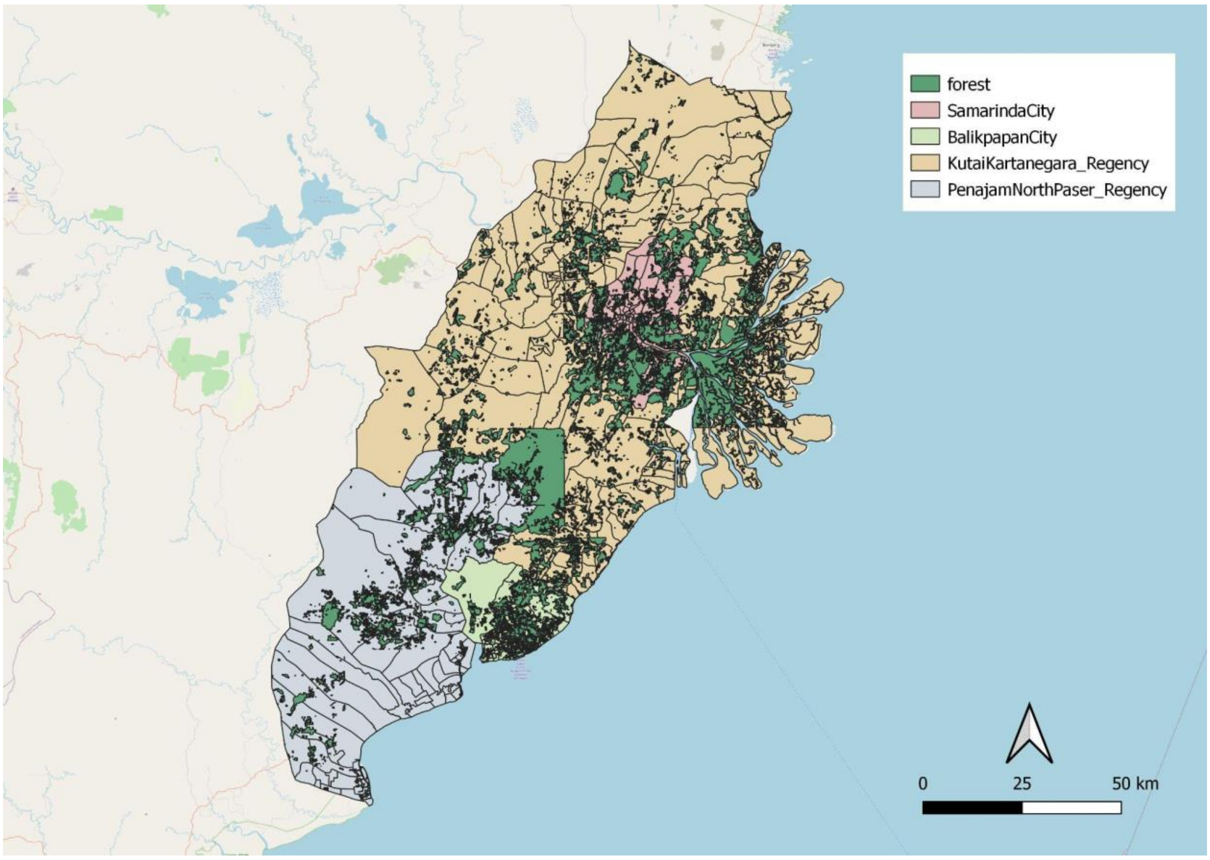


Figure 21: Distribution of forests

Task 2 mentioned that the new area should avoid natural forests. Figure 21 shows the distribution of forests. In this day and age where climate change is a real problem, we should preserve forests as and when we can. By choosing a site that is far from forests, it reduces the need for deforestation, thus preserving the environment.

4.0 Site Selection

4.1 Preliminary Analysis: Geology Layer

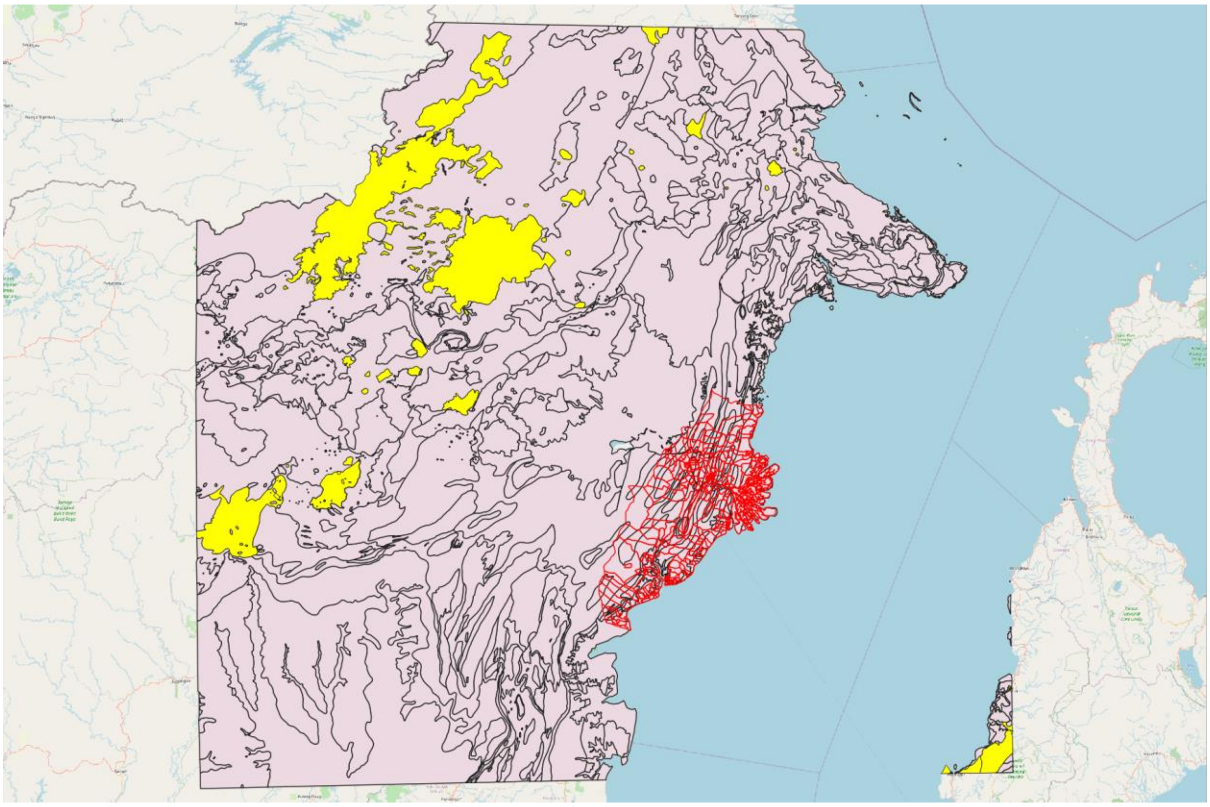


Figure 22: Distribution of Volcanoes in East Kalimantan

Legend:

- Yellow: Volcanic areas
- Red Outline: Study area
- Pink: Geology overview in East Kalimantan

In our site selection, we looked for potential natural disaster risk areas such as sea coasts, major rivers and volcanoes. Upon analysis, we found out that there were no volcanoes within our study area as indicated in the image above. Therefore, the study area is safe from volcanic hazards and activity.

4.2 AHP Analysis

Before performing site selection, we will have to first conduct Analytical Hierarchical Process (AHP) analysis to determine which criterias should be prioritized for decision making.

By keeping the following goal in mind, we will explain our reasons for choosing the weightings for each criteria.

> Goal: To create a new **province-level planned city**, and the capital will be relocated to a more central location within Indonesia. The plan is part of a strategy to reduce developmental inequality between Java and other islands in the Indonesian archipelago and to reduce Jakarta's burden as Indonesia's primary hub.

A primary hub is defined as a main hub for airlines. By operating an additional hub, it will take away the pressure from Jakarta being the sole primary hub in Indonesia. The implementation of a new hub will bring in more business to Indonesia, boosting tourism and export sectors.

	AHP		Consistency check
1	0.327	32.7%	Consistency OK
2	0.227	22.7%	4%
3	0.157	15.7%	
4	0.108	10.8%	
5	0.073	7.3%	
6	0.050	5.0%	
7	0.034	3.4%	
8	0.024	2.4%	

Figure 23: AHP scores

Pairwise Comparison Matrix

	Natural disaster	Forest	Hotspot	Seaport	Roads	Airport	Slope	Settlements
Natural disaster	1	2	3	4	5	6	7	8
Forest	1/2	1	2	3	4	5	6	7
Hotspot	1/3	1/2	1	2	3	4	5	6
Seaport	1/4	1/3	1/2	1	2	3	4	5
Roads	1/5	1/4	1/3	1/2	1	2	3	4
Airport	1/6	1/5	1/4	1/3	1/2	1	2	3
Slope	1/7	1/6	1/5	1/4	1/3	1/2	1	2
Settlements	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1

Figure 24: Pairwise comparison matrix

We set n = 8 for the number of factors to be used in our AHP calculation and ranked these factors in decreasing order of importance. The final consistency showed a result of 4% which we thought was a suitable score. We used these values to compute the AHP site suitability layer in our QGIS project. Additionally, we took into account the amount of data we have for each of the factors, as a lack of data will not produce an accurate site suitability result. We will now justify why we think each factor should be ranked as so. The factors and our respective rankings are:

1. Natural disaster
    a. Since the main goal of choosing a site is to create a new province-level city, we feel the most important factor for consideration is safety since many people will be visiting or permanently staying in this area. Should there be any natural catastrophes, casualties will be high.
    b. We will be analysing this by looking at fire hotspots, coastlines and rivers.
2. Forest
    a. If the chosen area is near forests, a lot of land pre-planning will need to be done. Especially in a time where global warming is a real issue, we should not support more deforestation for industrial purposes. To preserve the environment, we should select areas that are more barren.
    b. We will analyse this by comparing site areas with OpenStreetMap.
3. Forest fire
    a. Forest fire can also be seen as a type of natural disaster. However, it is more predictable. It can be gauged through ambient temperatures. It is still very dangerous as the fumes resulting from forest fires can negatively impact the health of citizens. It also kills off the flora and fauna. We also have many data points on forest fires, which is why we think that ranking it first will be significant, as we need to avoid hotspot points.
    b. We will be analysing this through forest hotspots from our datasets.
4. Seaport
    a. Indonesia is the world’s largest exporter of mining resources. Therefore, we conclude it is more important than airports since mining resources are generally transported with cargo ships. An article reported that “With exports of oil, gas and coal steadily increasing, the province was responsible for a major portion of the country’s export output with a value of US$37.97 billion. As of October 2012, its export output value stood at $27.71 billion.” Furthermore, Balikpapan is labelled as “a seaport city on the east coast of East Kalimantan,” meaning that they rely more heavily on seaports. (International Trading Institute, n.d.)
    b. We will analyse this through rasterized points of seaports. This is because we lack the polygon representation of seaport polygons.
5. Road transport
    a. We ranked this after airport/seaport because airports and seaports help connect Indonesia to the world. Road transport is more so for domestic travelling

purposes. It is still important as citizens need to be able to efficiently move within the country.

b. We will be analysing this through the rasterized layer for road transport.

6. Airport
   a. Airports are still important because they bring in tourists to Indonesia. This boosts Indonesia’s economy. Additionally, they can also be used to export sensitive and perishable goods.
   b. We will analyse this through rasterized polygons for airports. Polygons are more accurate.
7. Slope
   a. Although it is important to note that our selected site should avoid steep slopes due to higher development cost from the involvement of more cut-and-fill, we felt that slope does not outweigh the above mentioned factors.
   b. We will analyse this using the slope layer that we created so that we can analyze steep slope areas to avoid.
8. Settlement
   a. By planning a provincial area, many people would flock to this area to live since it is accessible. Hence, a suitable area would be one near current urban settlement areas and not major ones which are already densely populated.
   b. We will be analysing this through the use of a choropleth map created with population attributes. Additionally, we will cross reference with Indonesia's OpenStreetMap to analyze the complexity of buildings.

5.0 Site suitability

5.1 Narrowing down the suitable sites

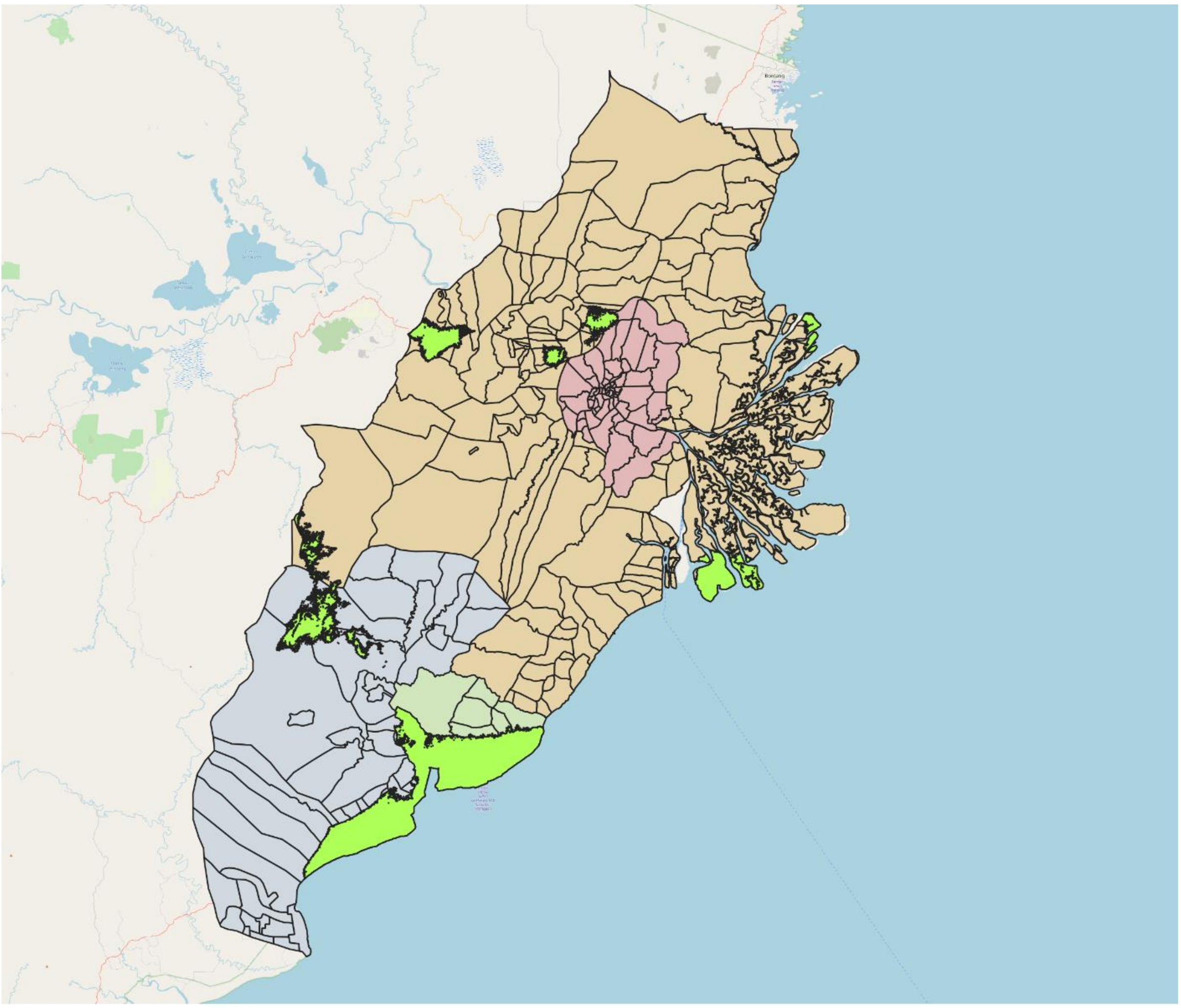


Figure 25: Suitable sites

After performing AHP analysis, we have derived a layer with suitable sites highlighted in green as shown in figure 25. To narrow down these areas, we first check if each of these suitable sites meet the size requirements. As we have calculated the area of each of these polygons in hectares, we can simply use the identify tool to confirm whether or not the polygons are within 4500 to 5500 hectares.

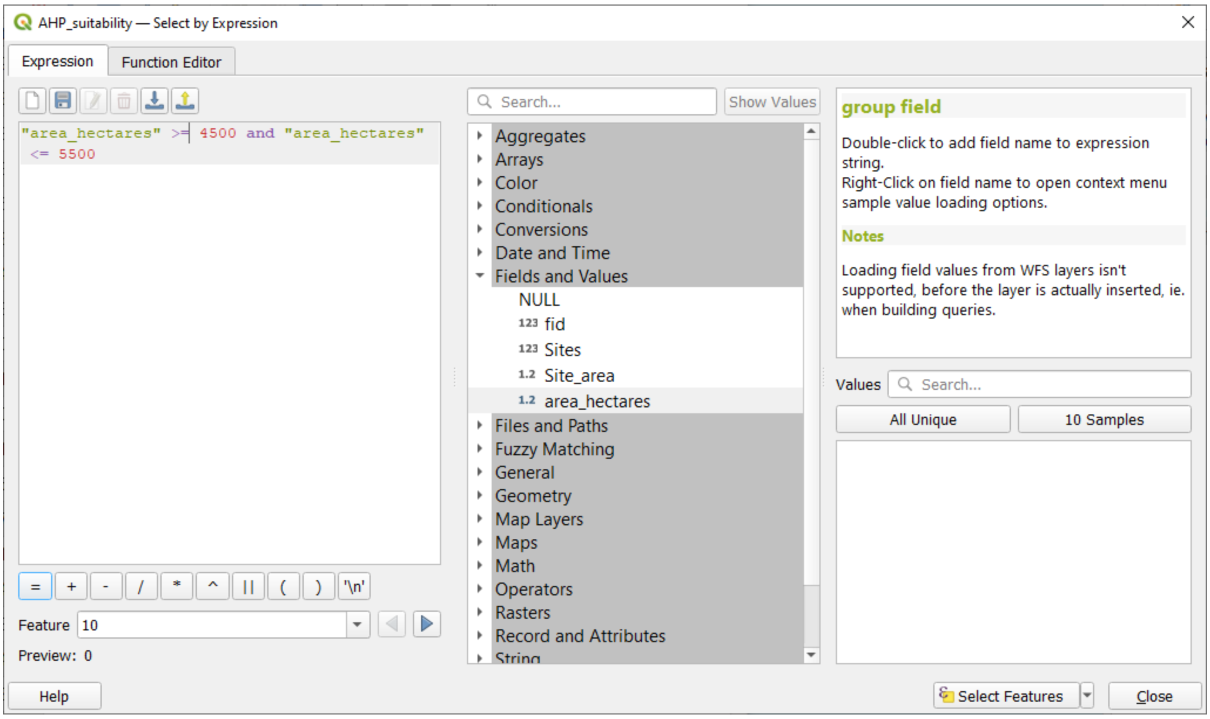


Figure 26: Selecting polygons with appropriate size

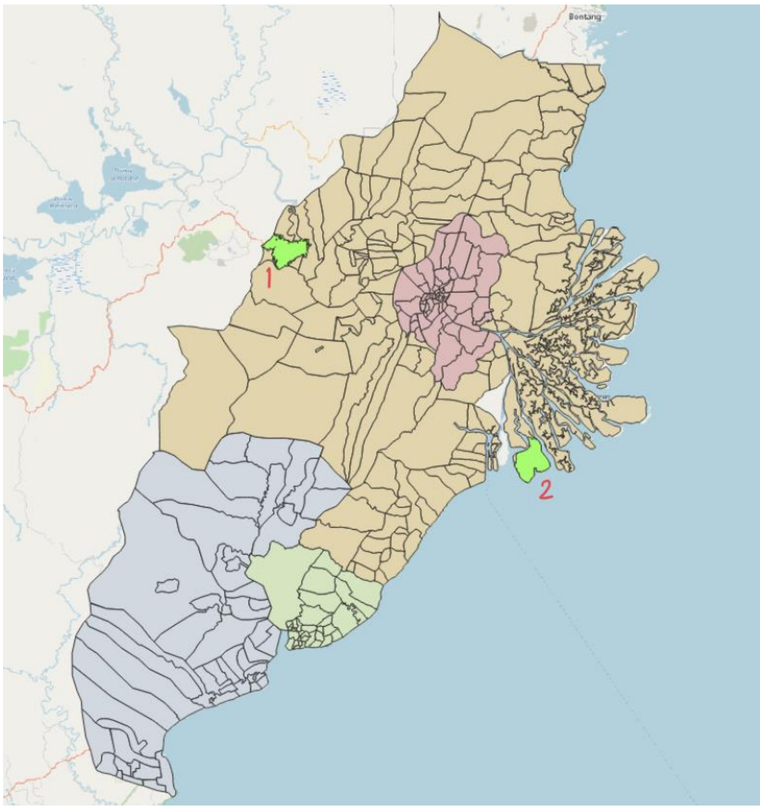


Figure 27: Polygons with appropriate size

By using the select expression function, we can key in the following to determine which polygons meet the size criteria. As seen in figure 27, we have narrowed down the suitable sites to just 2 locations. For simplicity purposes, we will be calling the site on the **far left “1”** and the site on the **far right “2.”**

5.2 Comparing the sites

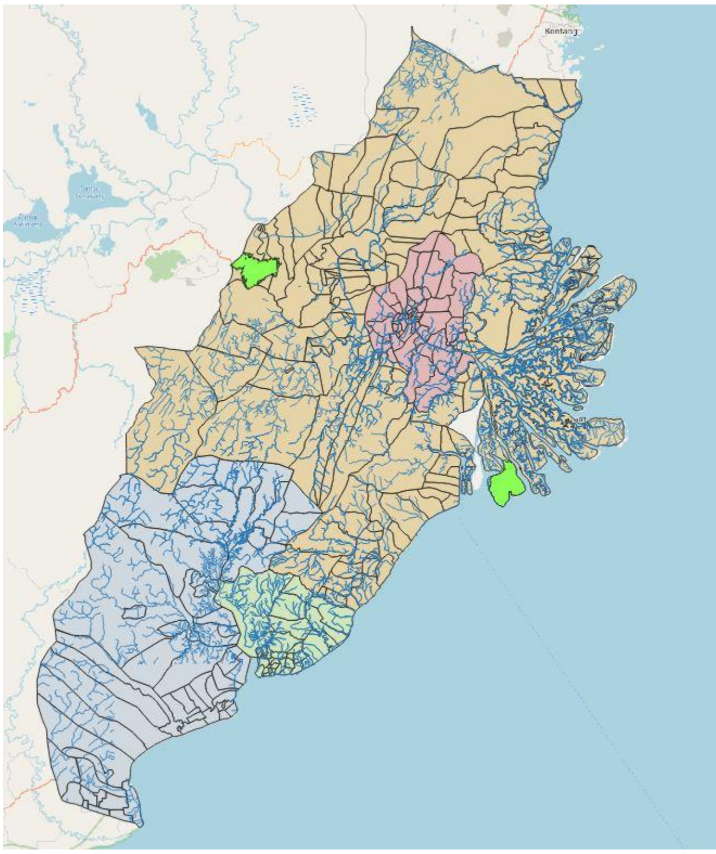


Figure 28: Sites and natural disaster

While both sites are relatively far away and safe from fire hotspots, site 1 is more preferable as it is away from the coastlines and rivers.

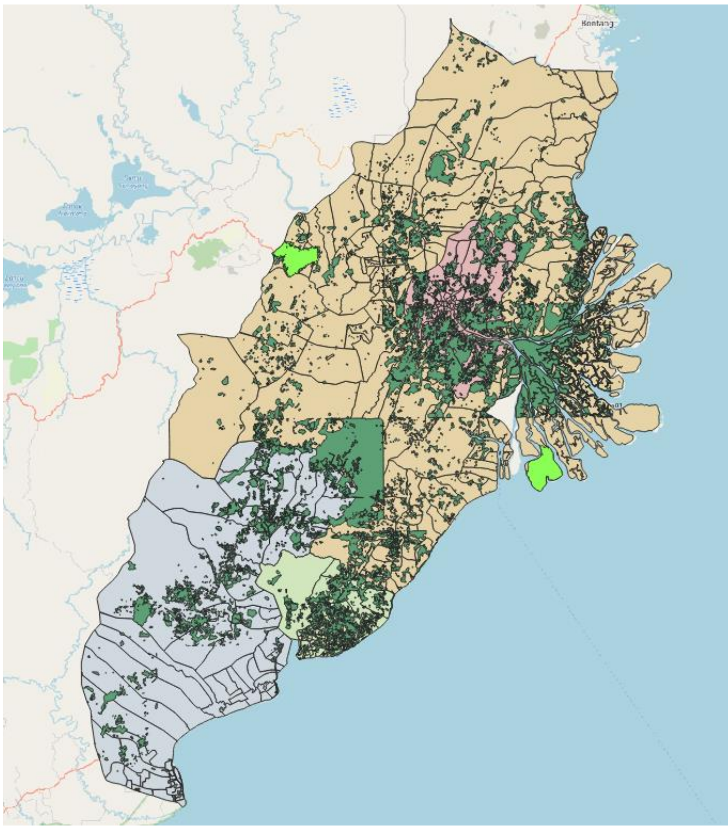


Figure 29: Sites and forests

Both sites are far away from forests. However, site 2 has more forest surrounding it. This may mean that the forests have to be cleared to improve accessibility to that area. Therefore, site 1 is more favourable.

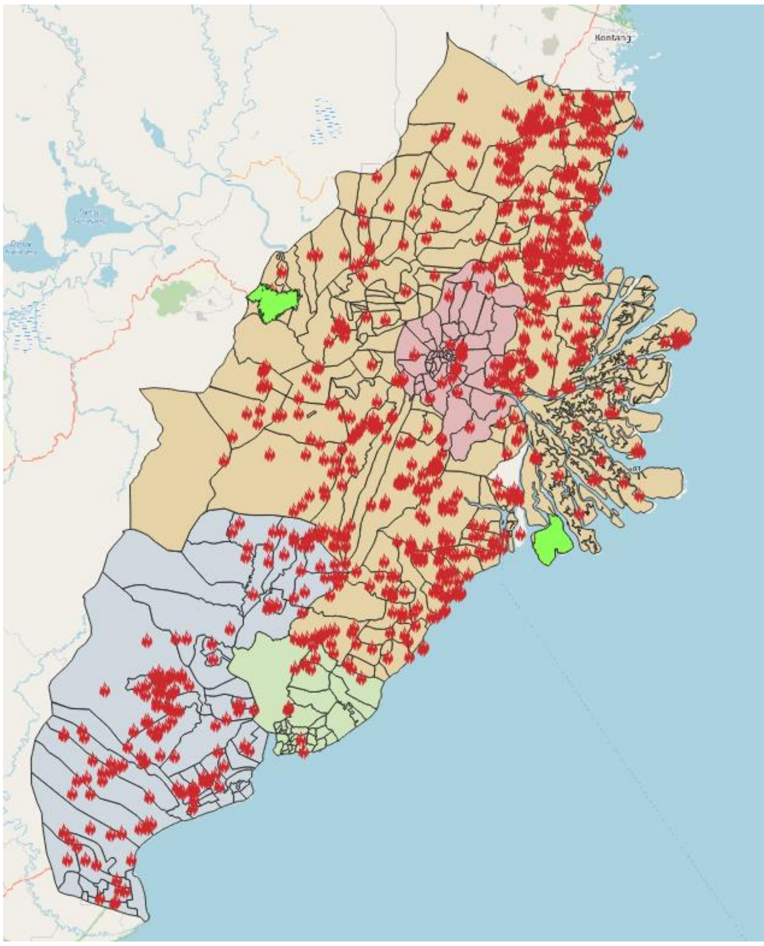


Figure 30: Sites and hotspots

Both sites are safe from fire hotspots as they are far away from them.

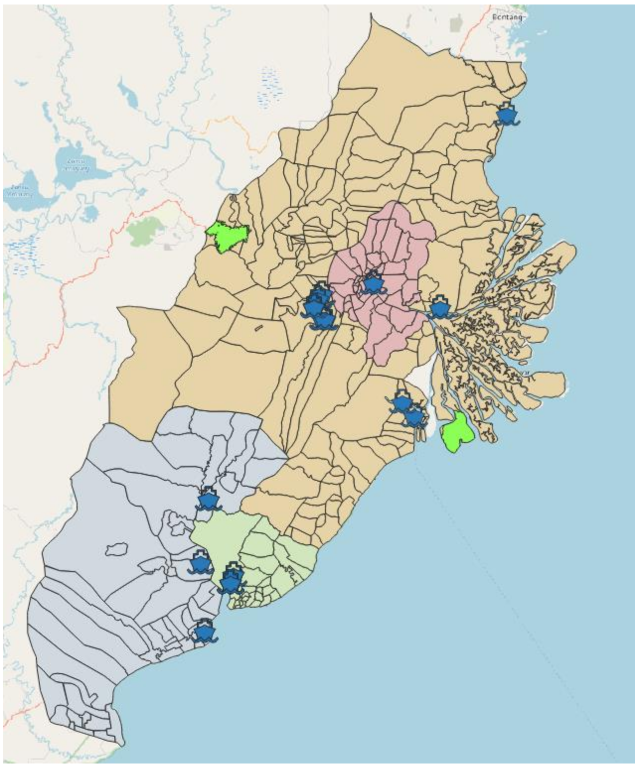


Figure 31: Sites and seaports

From Figure 31, Site 2 is more favourable as it is nearer to seaports. This allows for more efficient transportation as workers in site 2 will not have to travel as much to get to seaports.

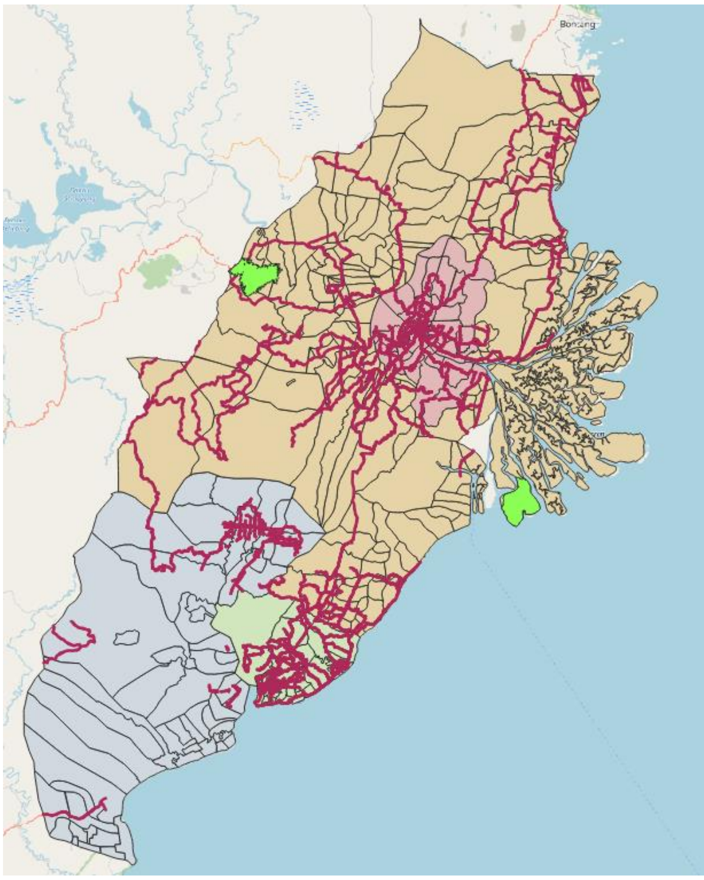


Figure 32: Sites and road transport

The lines in red show connecting roads for East Kalimantan. Site 2 does not have any connecting roads leading to it, which makes it inaccessible. This might also be due to the face that the entrance to site 2 is blocked by forests as shown in figure 29.

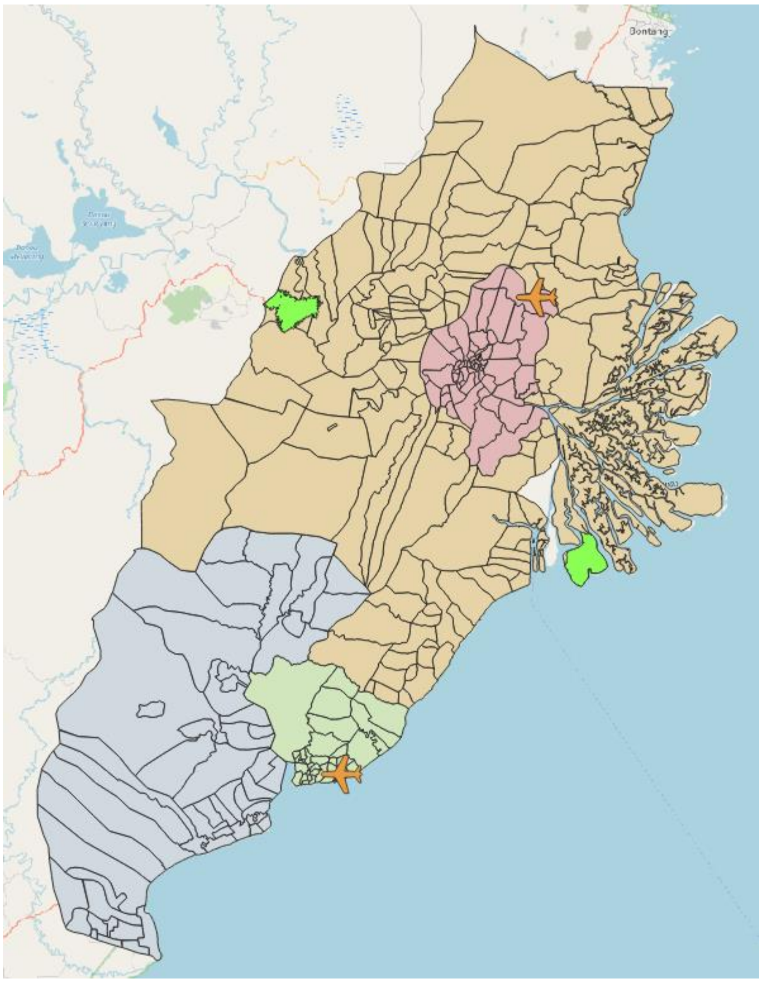


Figure 33: Sites and airports

Both sites are not very near to the airport points. However, because site 2 does not have connecting roads, it makes it even more difficult to access airports. Therefore, site 1 is preferred.

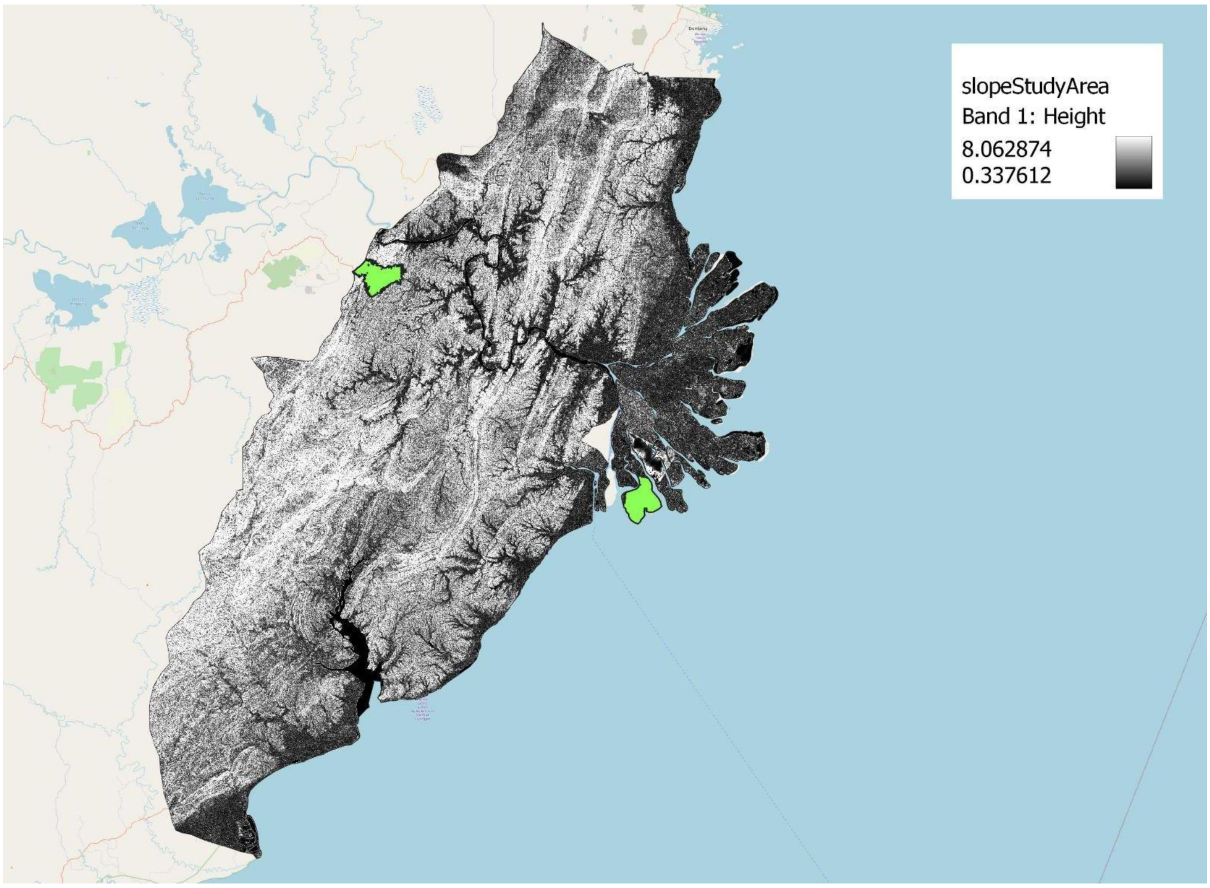


Figure 34: Sites and slope

White areas represent steeper slopes compared to darker areas. Based on this map, site 2 is more preferred because it has a gentler slope. Places with steeper slopes result in higher development cost due to the cut and fill.

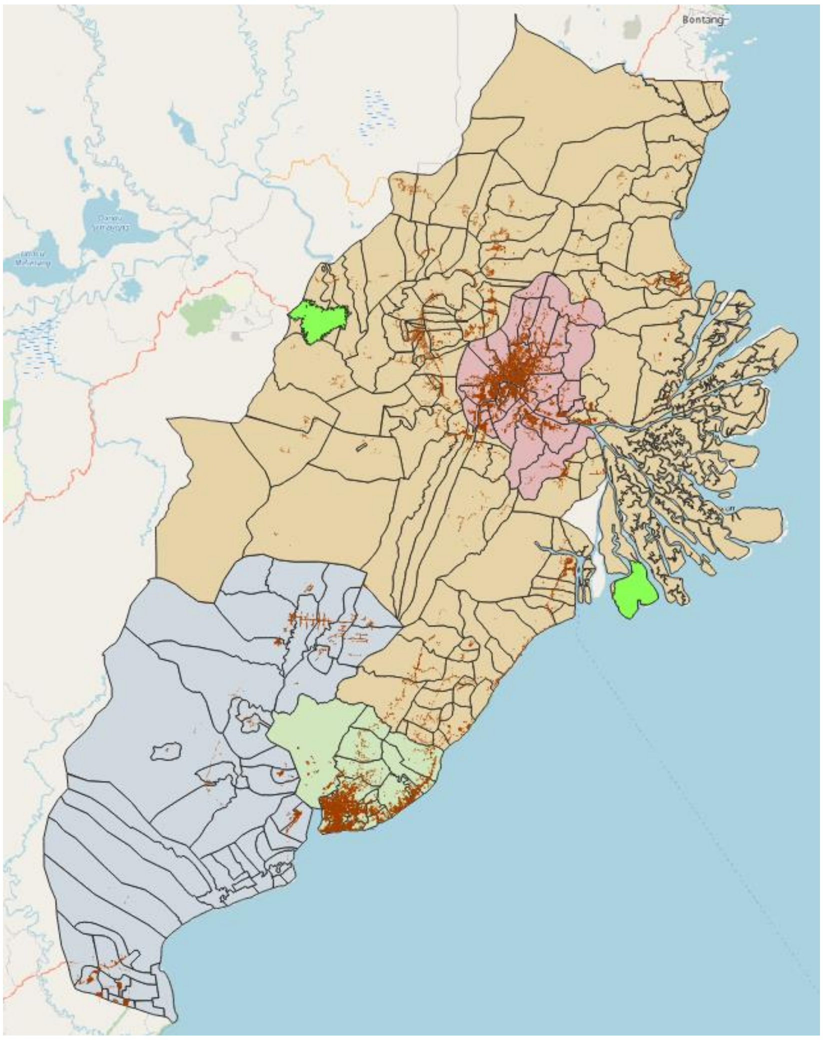


Figure 35: Sites and settlements

As part of the requirements, the site should be near urban settlement areas but not located directly at major settlement areas. This is true for both sites as they are not currently in highly populated areas. However, in terms of accessibility, site 1 is preferred as it has connecting roads, making it nearer to current settlement areas as compared to site 2. The ease of access thereby makes site 1 "nearer" to these settlements.

5.3 Site overview and conclusion

The table below shows our thought process. By comparing both sites with each attribute, we are able to find the most optimal solution.The highlighted boxes represent the site with the more preferred characteristic.

Site	1	2
Natural disaster	Far away from coastline and rivers	Closer to coastline and rivers
Forest	No forest blocking entrance to the area	Forest blocking entrance to area
Forest fire	Far away from hotspots	Far away from hotspots
Seaport	Further from seaports	Nearer to seaports
Road transport	More accessible	Less accessible
Airport	More accessible to airports	Less accessible to airports
Slope	Steeper slope	Gentler slope
Settlement	Nearer to settlement areas	Further from settlement areas
Size	5452 hectares	5373 hectares
Total highlighted	7	3

Apart from size, all other factors in the table are ranked in order of decreasing weight as per our AHP analysis. Hence, attributes higher up should be prioritized for consideration. For example, even though site 2 has a gentler slope, selecting site 2 will lead to tradeoffs such as lower accessibility and higher chances of fatalities due to it being prone to natural disasters.

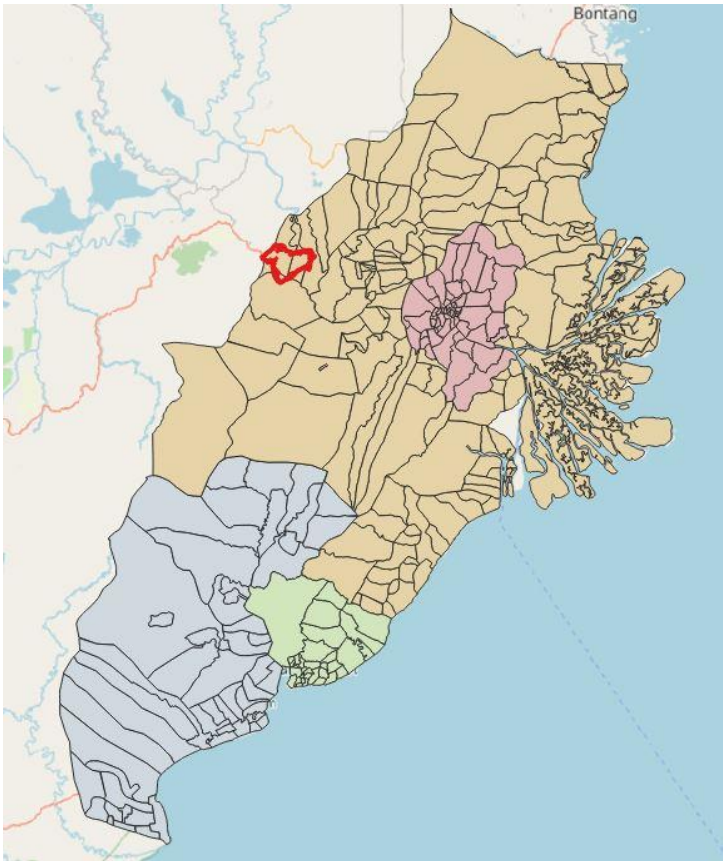


Figure 36: Final selected site

In totality, site 1 has 7 preferred attributes while site 2 only has 3. Therefore, site 1 is our chosen site as shown in figure 36.

6.0 Future Work and Conclusion

QGIS has proven to be a powerful and cost effective application for analysts. With many plugins in their repository, we are able to manipulate data and produce web pages for professional use.

Narrowing down such a huge map to several sites has been challenging. It is important to first identify constraints and limitations when performing map study. We could have also analysed additional factors such as gross domestic product (GDP) and potential business ventures that Indonesia can undertake to make sure their new province thrives. For instance, by planning out what new activities the selected site could do will create clear goals when building its infrastructure.

As our AHP consistency score is 4%, we could have tried out more AHP permutations to get an even lower consistency score. This would provide us even more suitable sites for analysis.

Additionally, it would be good if we were able to get external help from someone fluent in Bahasa Indonesia. As attributes in the data are mainly in that language, we were unable to translate all attributes due to the language barrier. Therefore, there might be minor inconsistencies as we might have missed a few layers, which might have affected the final AHP site suitability results.

In future, we hope that the skills we gained from Geographic Information Systems for Urban Planning will be put to good use, so that we can derive deeper insights for better urban planning and analysis.

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