Flood impact assessment on road network and healthcare supply - Jakarta, Indonesia

[WP] Master Thesis

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Objectives

- Road network assessment regarding:
  - Centrality (Betweenness and Closeness)
  - Best accessible / main roads and most central places
- Healthcare supply assessment:
  - Healthsite amenity spatial distribution and accessibility
- Flood impact on road network and healthcare supply
  - Floodprone: Preparation and theoretical impact
  - 2013 Flood: Reaction and actual impact

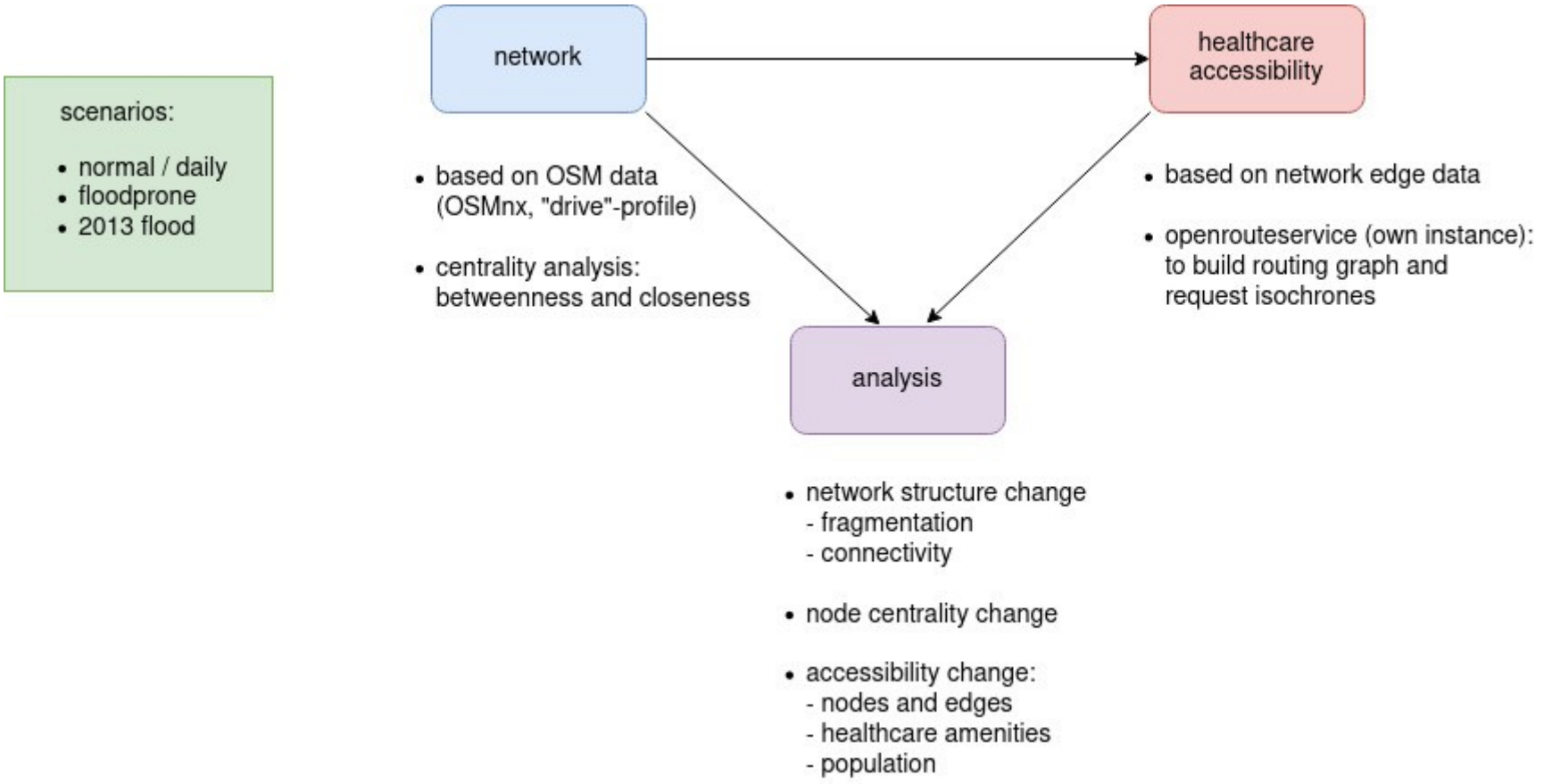
Tools

- Python 3
  - OSMnx: download and build OSM network graph
  - Networkx: for better handeling
  - NetworKit: Centrality analysis
  - Openrouteservice: Isochrone request and accessibility anaylsis
- QGIS: Visualisation

Data

- OSM:
  - Network graph
  - Healthcare amenities: clinic, doctors, hopital, pharmacy
- HOT Indonesia:
  - Floodprone layer
  - 2013 flood layer: 4 week timeframe → used: total flood affected area
- WorldPop population raser:
  - Year: 2020
  - Resolution: 3 arc (approx. 100m at the equator); WGS84

Workflow


scenarios:
• normal / daily
• floodprone
• 2013 flood
network
healthcare accessibility
• based on OSM data (OSMnx, "drive"-profile)
• centrality analysis: betweenness and closeness
• based on network edge data
• openrouteservice (own instance): to build routing graph and request isochrones
analysis
• network structure change
- fragmentation
- connectivity
• node centrality change
• accessibility change:
- nodes and edges
- healthcare amenities
- population

Network graph

- Directed
- Edge-weighted:

$$duration = \frac{road\ length}{speed\ limit}$$

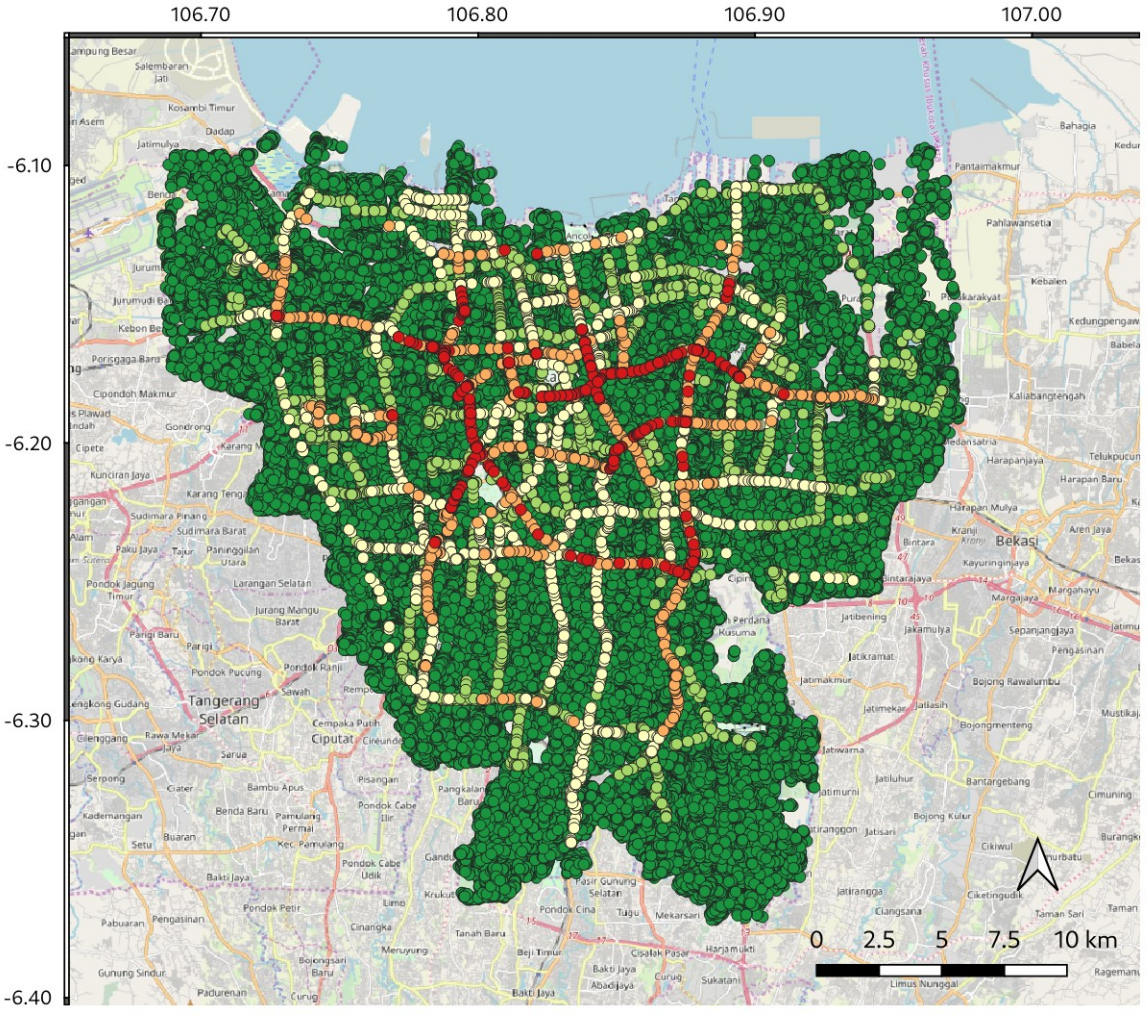
, where *road length* is the OSM edge length in km and
speed limit the allowed drive speed limit for the specific road type
  - road type: OSM attribute
  - speed limit: defined by openrouteservice

- Node-based

- Normal scenario: connected
- Floodprone and 2013 flood scenario: disconnected

Network Centrality

- Tool: NetworKit (networkit.github.io)
- Betweenness:
  - Measures number of times a node lies on the shortest path between other nodes
  - Most used nodes → main roads, best accessible roads
- (Harmonic) Closeness:
  - Measures the average distance to every other node in the graph
  - Most central nodes
  - Harmonic Closeness can also be used for disconnected graphs



Note:

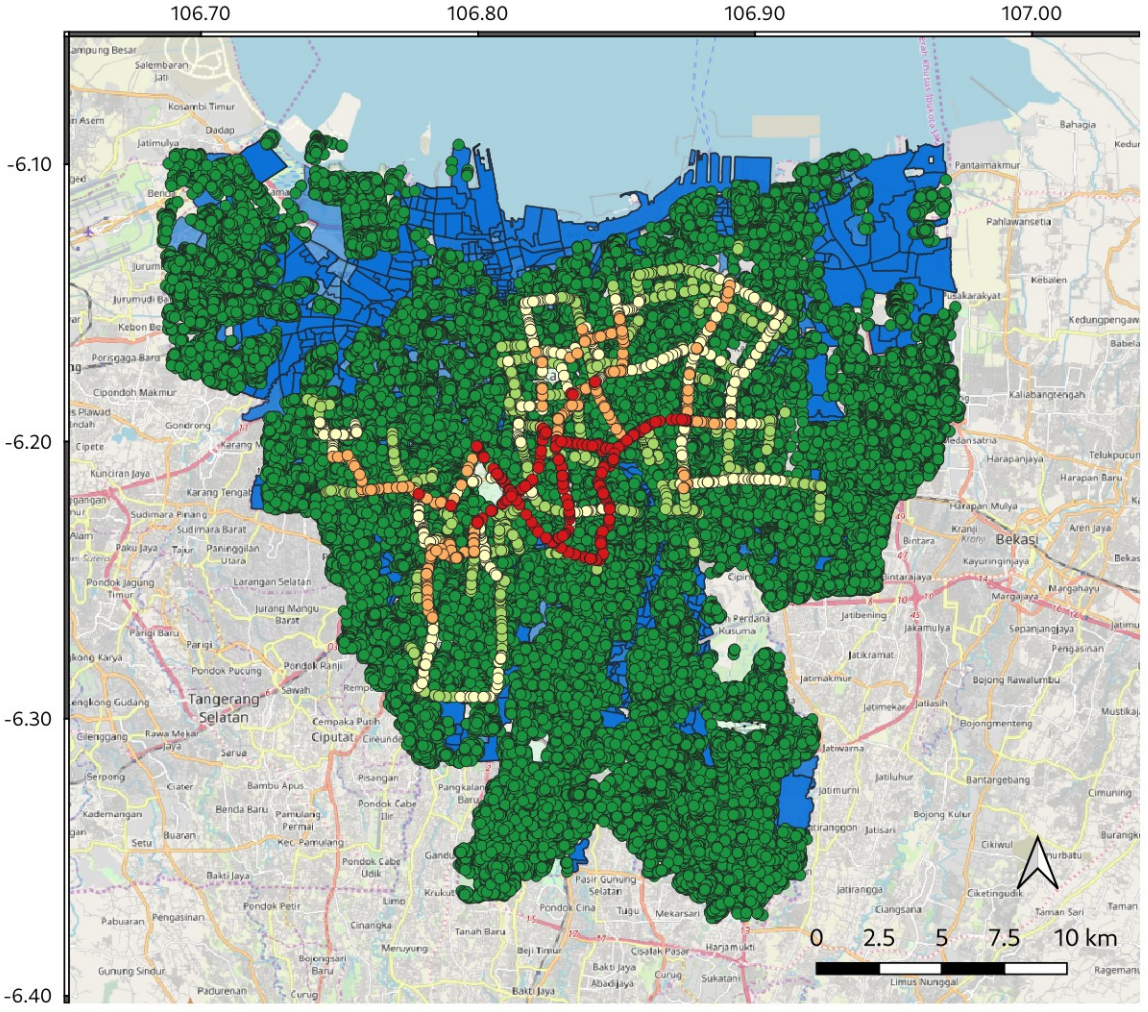
Betweenness values are normalized

→ red: most passed nodes on shortest path between other nodes; main roads, best accessible roads

Betweenness Centrality
-
normal / daily scenario

nodes_btwn
- 0 - 0.000088
- 0.000088 - 0.000297
- 0.000297 - 0.000614
- 0.000614 - 0.001122
- 0.001122 - 0.002677

OSM Standard



Note:

Floodprone and flood centrality value gradations are adapted to the normal / daily scenario, except the last border value.

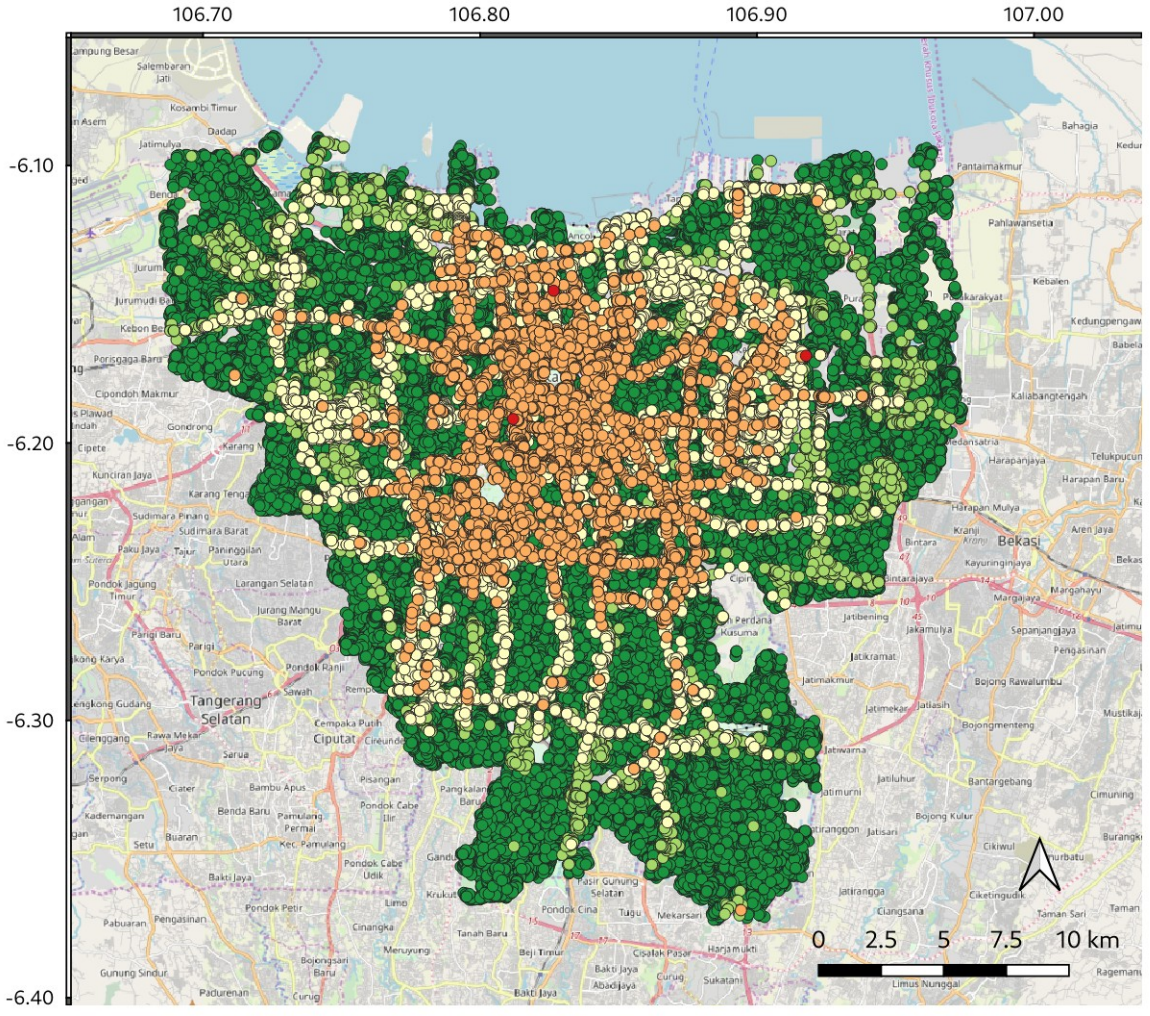
→ Decrease of overall betweenness centrality
→ Traffic shift: Redefinition of most passed nodes

Betweenness Centrality
-
2013 flood scenario

nodes_btwn
- 0 - 0.000088
- 0.000088 - 0.000297
- 0.000297 - 0.000614
- 0.000614 - 0.001122
- 0.00112 - 0.00304

flooded

OSM Standard



Note:

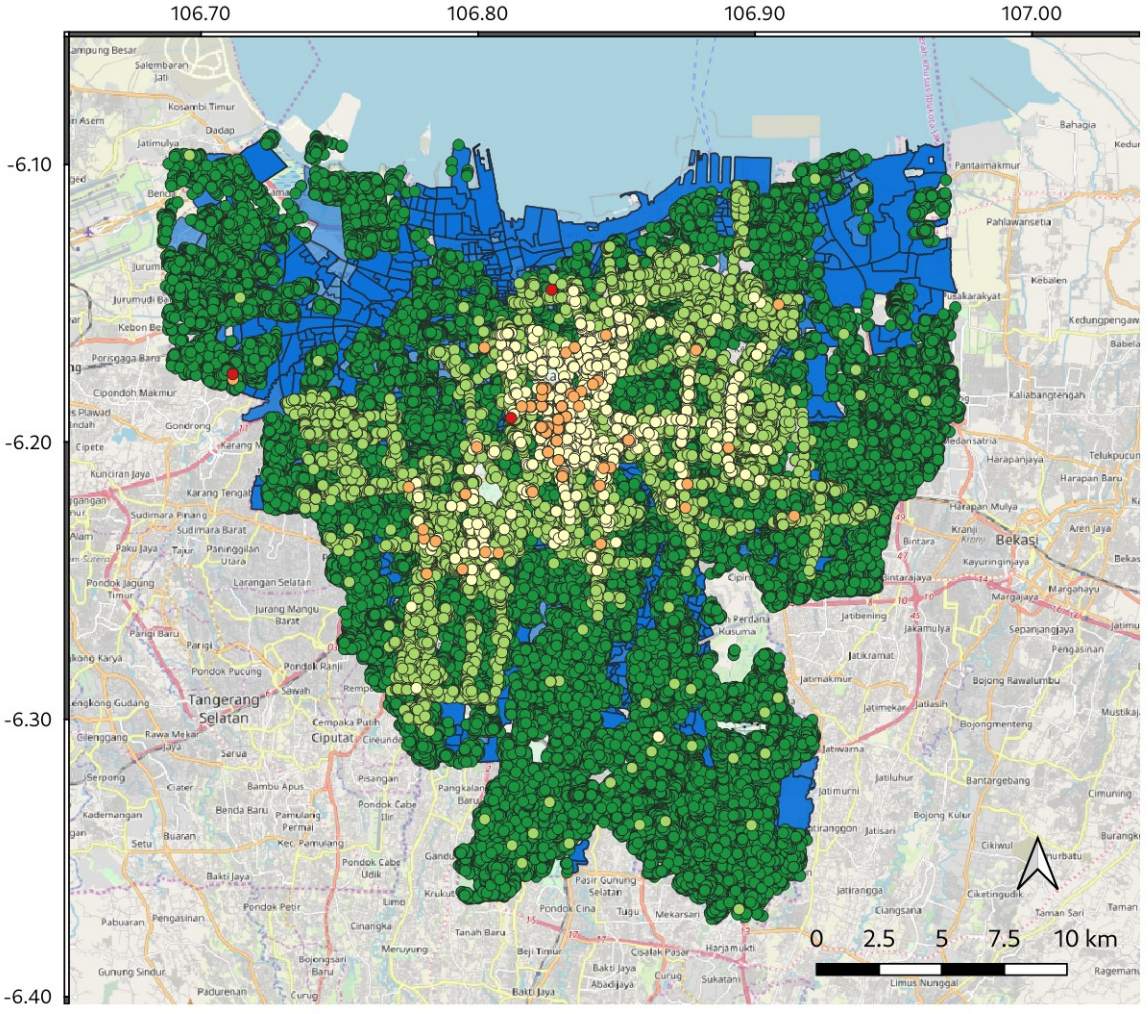
→ red: most central nodes; minimum average distance to every other node in the graph

→ Main roads are recognisable

Closeness Centrality
-
normal/daily scenario

nodes_harmcls
- 0 - 0.35
- 0.35 - 0.85
- 0.85 - 1.09
- 1.09 - 1.81
- 1.81 - 12.29

OSM Standard



Note:

→ Decrease of overall closeness centrality

→ Maintaining of most central nodes

Closeness Centrality
-
2013 flood scenario

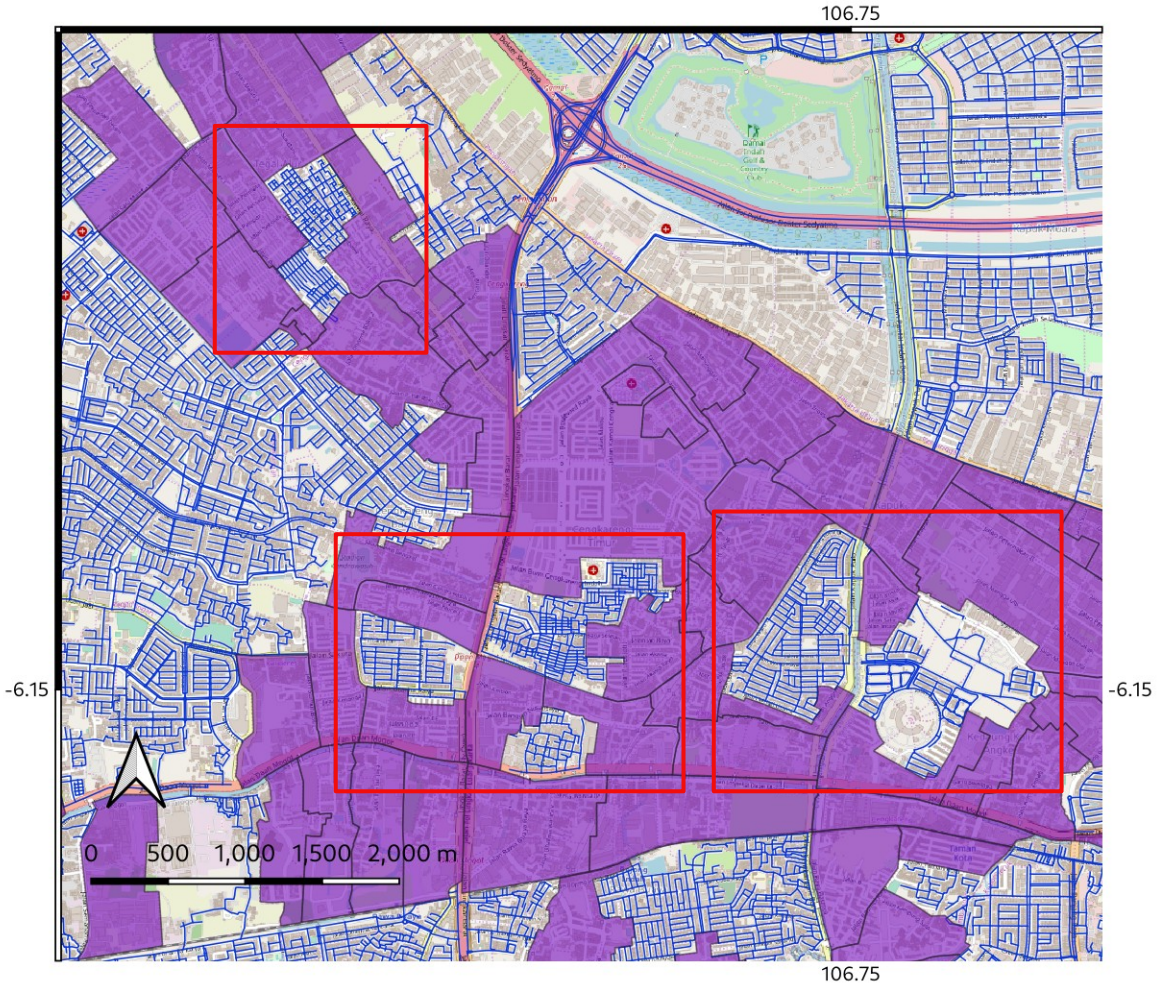
nodes_harmcls
- 0 - 0.35
- 0.35 - 0.85
- 0.85 - 1.09
- 1.09 - 1.81
- 1.81 - 2.631

flooded

OSM Standard

Identify subgraphs

- Subgraphs are not interconnected → not accessible among each other
- Identify subgraphs with network analysis:
  - NetworKit: e. g.: class ConnectedComponents to determine the connected components and associated values for an undirected graph

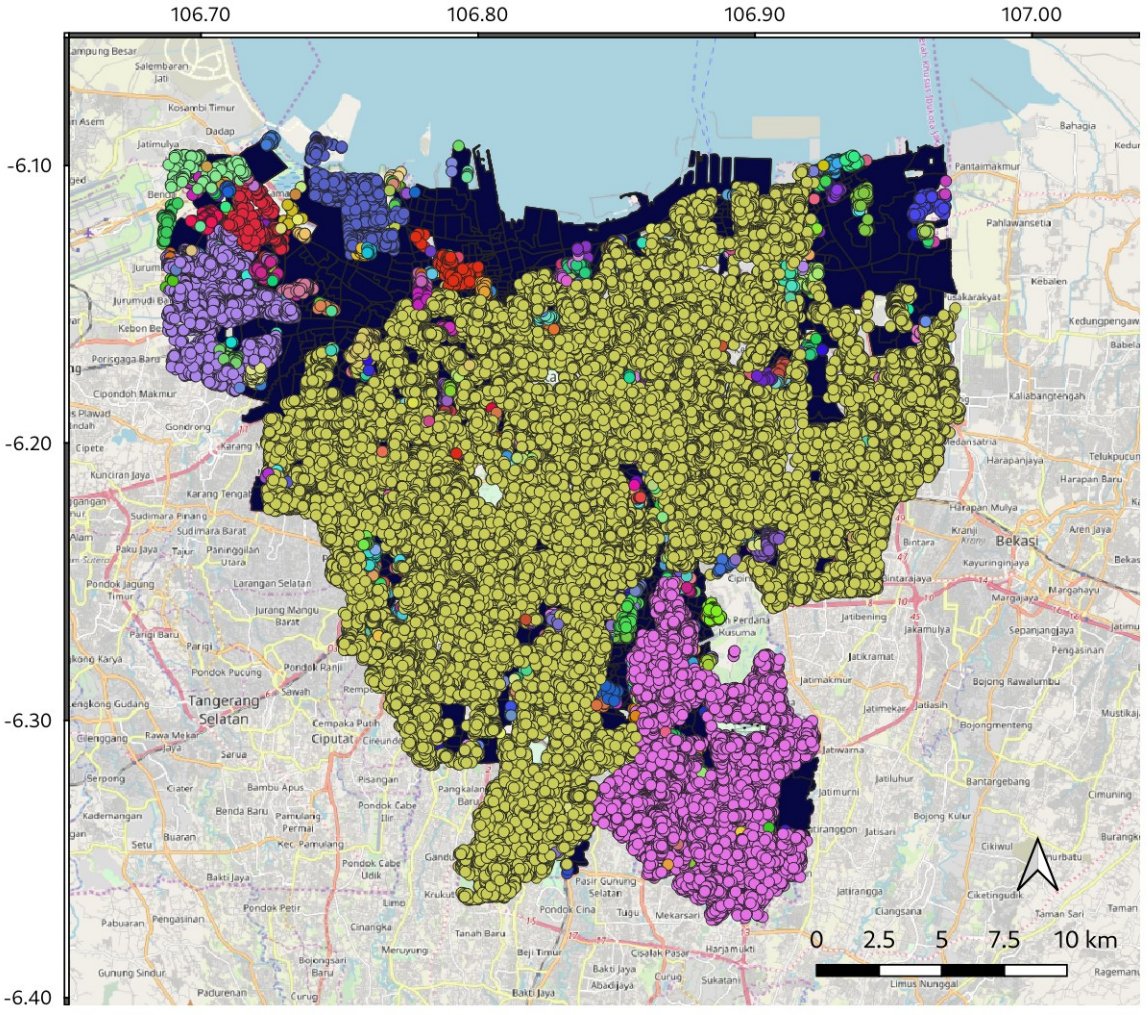


Note:

Isolated subgraphs are not longer connected to the main graph
→ Fragmentation

Isolated areas

floodprone
edges/roads
OSM Standard



Note:

Visualisation of connected node groups

→ Flood divides graph into one main graph (yellow), medium sized subgraphs (purple: bottom right, bluish: top left) and small subgraphs.

Single coloured nodes: not connected to a larger subgraph

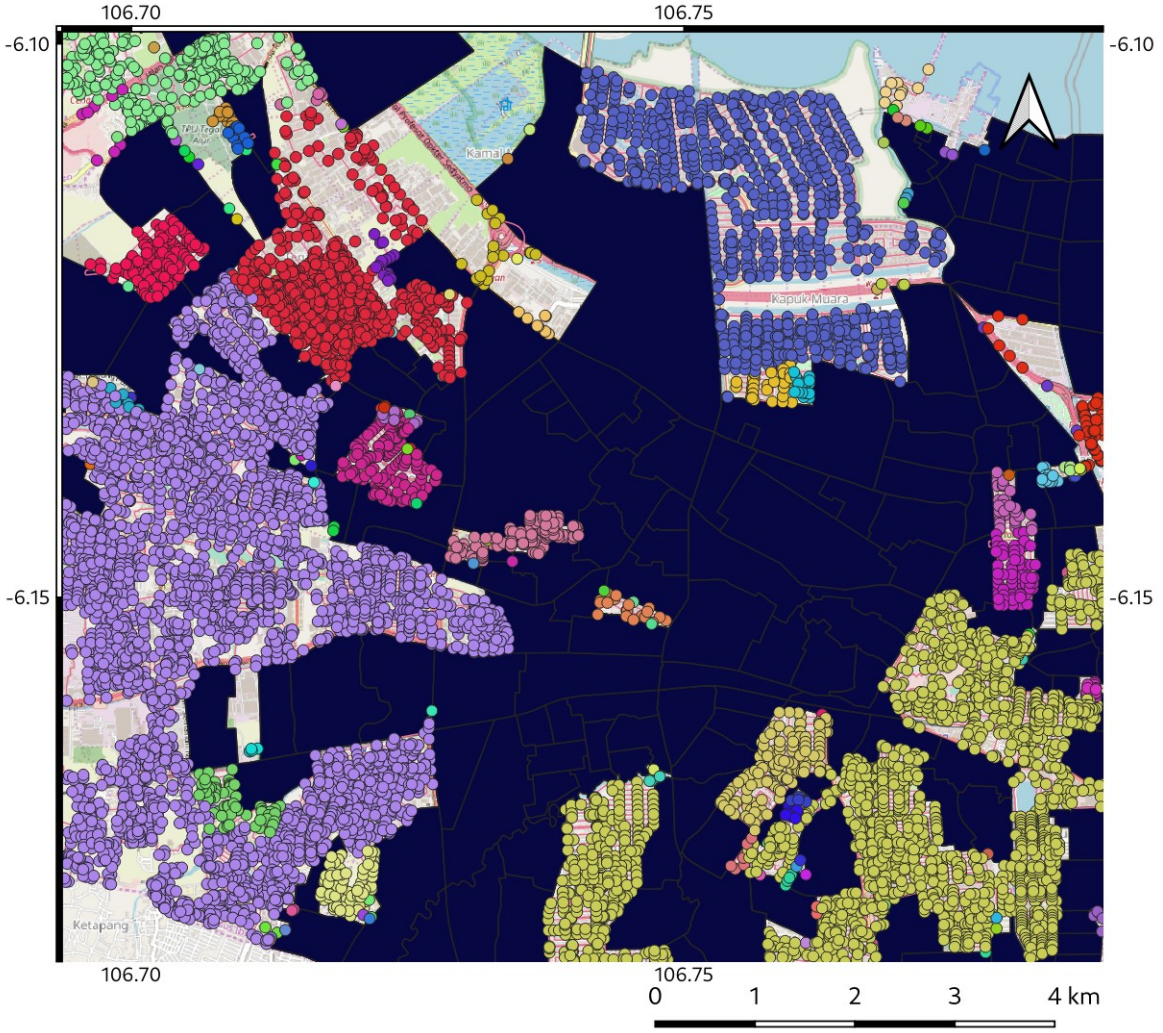
Used: undirect graph → spatial graph / no consideration of e.g. one-way streets

Connected components
-
Flooded scenario

component e.g.
- 1
- 2
- 3
- 4
- 5
- 6
- 7

flooded

OSM Standard



Note:

Top right extract of complete map.

→ Only same coloured and nearby situated nodes are connected and therefore mutually accessible.

Connected Components
-
Flooded Scenario

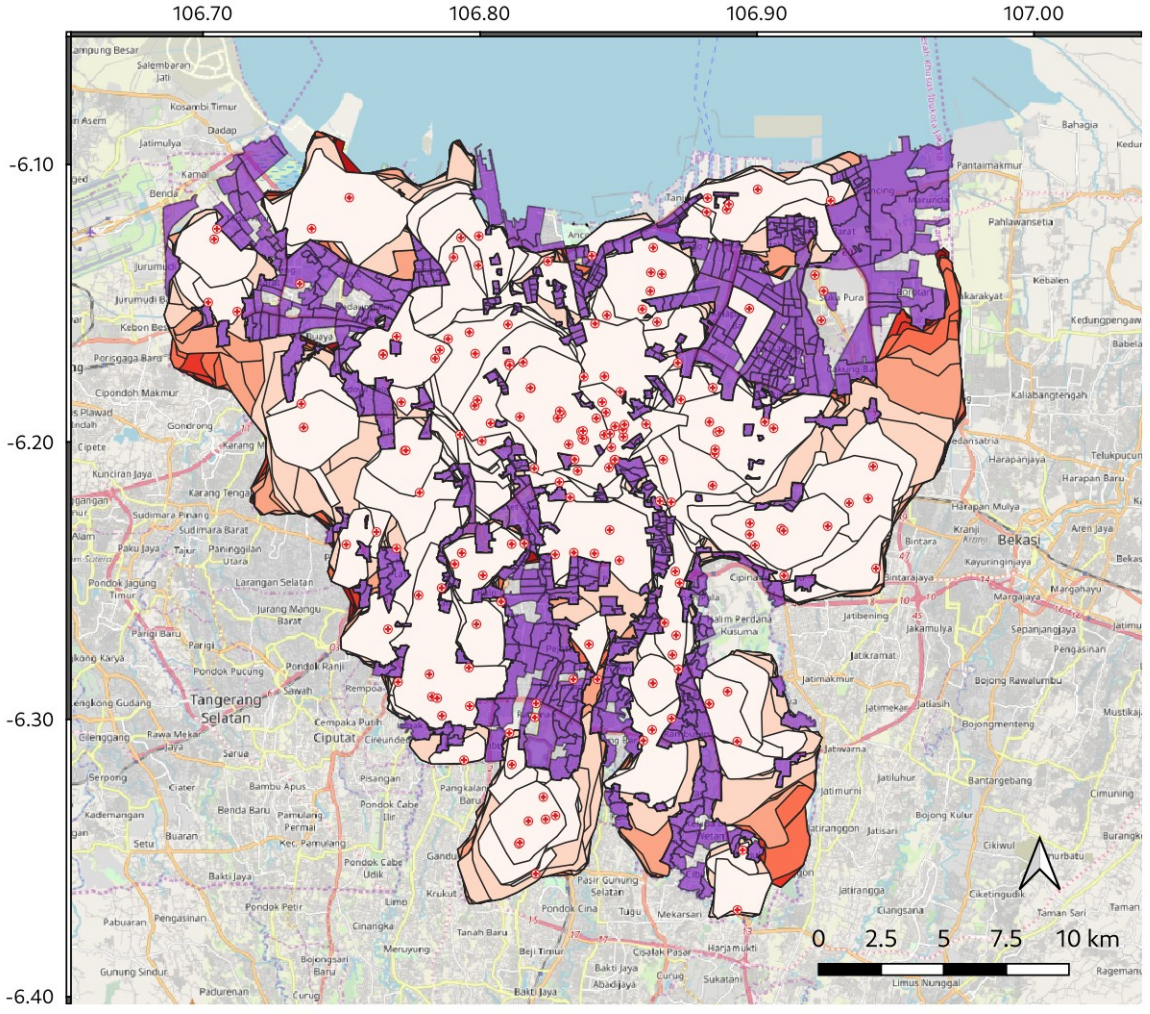
edges
flooded

components e.g.
1
2
3
4
5
6

OSM Standard

Openrouteservice

- Build three own instances using network graphs as base data:
  - Normal
  - Floodprone
  - 2013 flood
- Healthsite accessibility using isochrones:
  - Healthsite amenities as location
  - driving-car profile
  - 30 minute range, 5 min interval



Example:

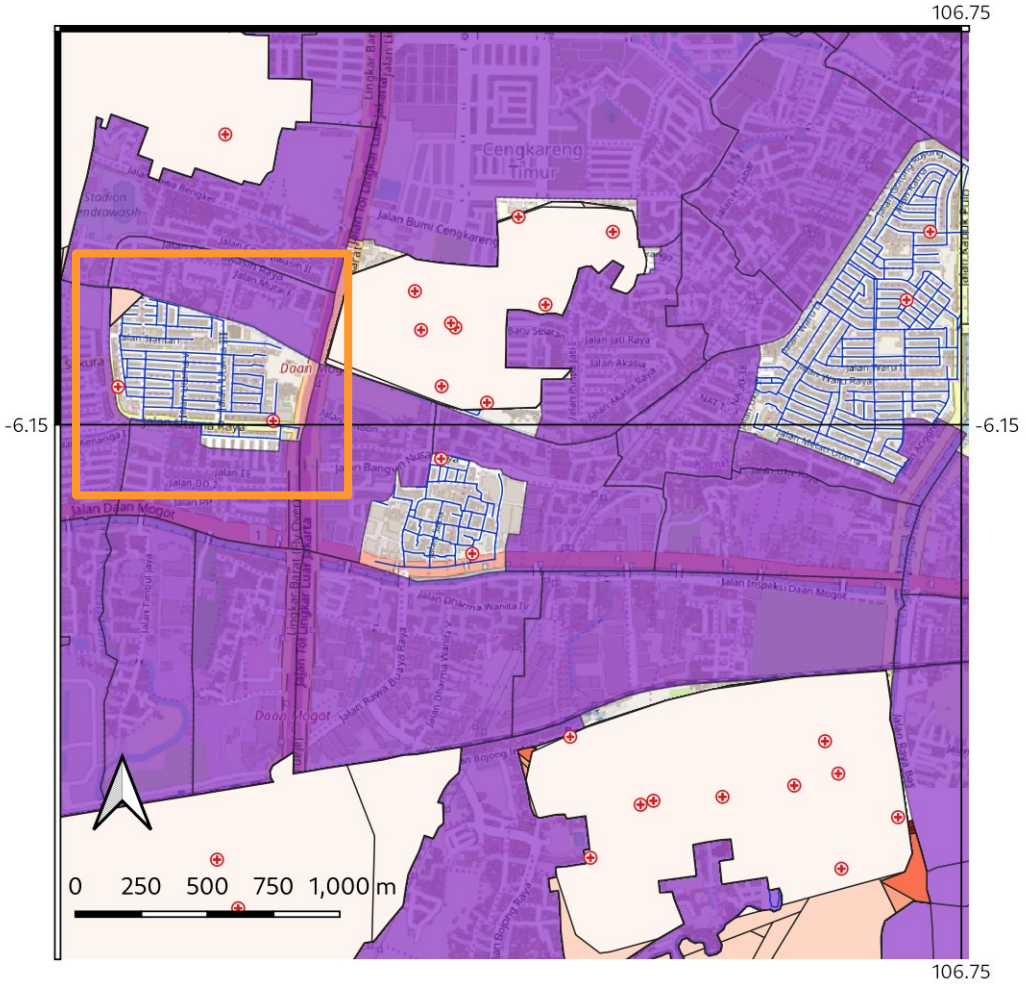
Hospital accessibility
-
Floodprone scenario

- hospital

isochrones_in_min

- 5
- 10
- 15
- 20
- 25
- 30
- floodprone

OSM Standard



Note:

Connected subgraph size too small → not built by ORS and therefore not included in the routing graph → decrease minimum graph size

→ Limited supply to and from those areas

Isolated healthsites

healthsite

isochrone_in_min

5

10

15

20

25

30

floodprone

edges/roads

OSM Standard