

# Spatial Analysis of Land Subsidence and Flood Pattern Based on DInSAR Method in Sentinel Sar Imagery and Weighting Method in Geo-Hazard Parameters Combination in North Jakarta Region

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**Abstract:** The reclamation program carried out in most cities in North Jakarta is directly adjacent to the Jakarta Bay. Beside this program, the density of population and development center in North Jakarta office has increased the need for underground water excessively. As a result of these things, land subsidence in North Jakarta area is relatively high and so intense. The research methodology was developed based on the method of remote sensing and geographic information systems, expected to describe the spatial correlation between the land subsidence and flood phenomenon in North Jakarta. The DInSAR (Differential Interferometric Synthetic Aperture Radar) method with satellite image data Radar (SAR Sentinel 1A) for the years 2015 to 2016 acquisitions was used in this research. It is intended to obtain a pattern of land subsidence in North Jakarta and then combined with flood patterns. For the preparation of flood threat zoning pattern, this research has been modeling in spatial technique based on a weighted parameter of rainfall, elevation, flood zones and land use. In the final result, we have obtained a flood hazard zonation models then do the overlap against DInSAR processing results. As a result of the research, Geo-hazard modelling has a variety results as: 81% of flood threat zones consist of rural area, 12% consists of un-built areas and 7% consists of water areas. Furthermore, the correlation of land subsidence to flood risk zone is divided into three levels of suitability with 74% in high class, 22% in medium class and 4% in low class. For the result of spatial correlation area between land subsidence and flood risk zone are 77% detected in rural area, 17% detected in un-built area and 6% detected in a water area. Whereas the research product is the geo-hazard maps in North Jakarta as the basis of the spatial correlation analysis between the land subsidence and flooding phenomena.double point.

**Keywords:** DInSAR, Flood, Geo-Hazard, Land Subsidence, North Jakarta

## 1. Introduction

The reclamation program carried out in most cities in North Jakarta is directly adjacent to the Jakarta Bay. Beside this program, the density of population and development center in North Jakarta office has increased the need for underground water excessively.



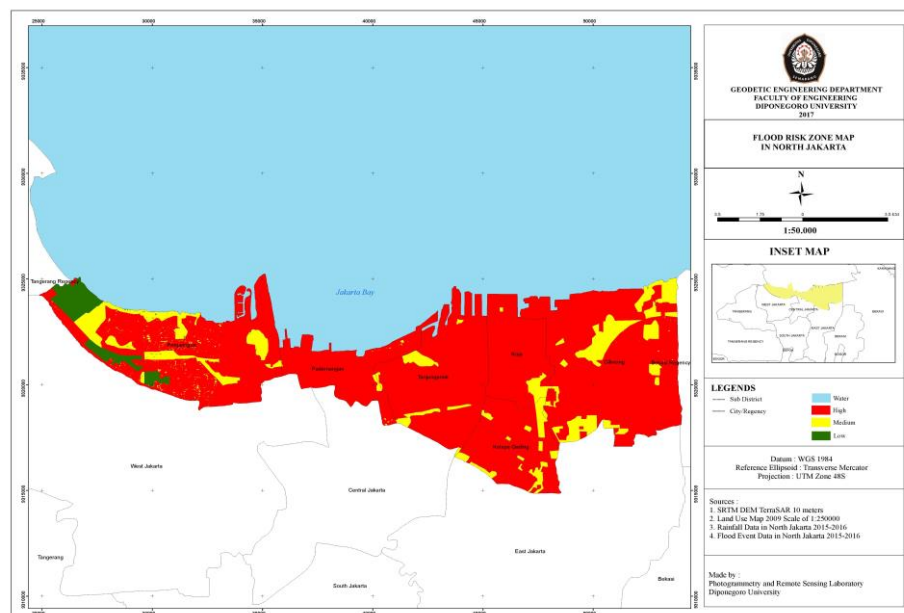
Office infrastructure development which is dominated by high buildings has made enormous pressure on land consolidation. As a result of these things, land subsidence in North Jakarta area is relatively high and so intense. In addition to this situation, the emergence of flood disasters that periodically and tends to expand in all around of the area of North Jakarta to be one of the main issues to be solved in this study. The research methodology was developed based on the method of remote sensing and geographic information systems, expected to describe the spatial correlation between the land subsidence and flood phenomenon in North Jakarta. The previous research that examined the land subsidence in Jakarta used the method of measurement Levelling, GPS and InSAR [1]. The research was conducted in 1982 until the 1991 years which was obtained the land subsidence results in Jakarta reaches 3-10 cm per year.

The DInSAR (Differential Interferometric Synthetic Aperture Radar) method with satellite image data Radar (SAR Sentinel 1A) for the years 2015 to 2016 acquisitions was used in this research. It is intended to obtain a pattern of land subsidence in North Jakarta and then combined with flood patterns. For the preparation of flood threat zoning pattern, this research has been modeling in spatial technique based on a weighted parameter of rainfall, elevation, flood zones and land use (Geo-hazard modelling) [2–4]. In the final result, we have obtained a flood hazard zonation model then do the overlay against DInSAR processing results.

## 2. Data and Methods

### 2.1. Research Area

The study area of this study is North Jakarta City at latitude  $6^{\circ} 8' 18.29''$  S and longitude  $106^{\circ} 51' 50.24''$  E with a width research area around 146.7 km<sup>2</sup> and covers 6 districts. The research area can be seen in the Figure 1.



**Figure 1.** The Flood Risk Zone Map

### 2.2. Research Data

The data needs related to the research using a combination of satellite image data including Sentinel and SRTM images combined with attribute data related to the flood phenomenon in Jakarta can be seen in the Table 1.

**Table 1.** Research Data

No	Data	Acquisition Time
1.	Sentinel Imagery-1A IW level 1 SLC	2015 – 2016
2.	DEM SRTM TerraSAR	2011
3.	Land Use Map of DKI Jakarta Area	2009
4.	Rainfall Intensity Data	2015 – 2016
5.	Flood Intensity Record	2015 – 2016
6.	GPS Survey Data in Jakarta Area	1997-1999

### 2.3. DInSAR Method

DInSAR is an acquisition technique of two paired SAR images in combination of complex image data at the same spatial position or slightly different position in the same area by multiplication of multiple conjugations resulting in digital elevation model (DEM) or shifting of the earth surface [5].

The DInSAR method utilizes coherent in phase measurements to obtain distance differences and distance changes from two or more SAR images that have complex values from the same surface. The result of the phase difference produces a new type of image called an interferogram. The interferogram will show whether the area under study is experiencing a decrease in the face of the soil or soil rise. The flowchart of DInSAR data processing can be seen in Figure 2.

### 2.4. Geohazard Modelling Method

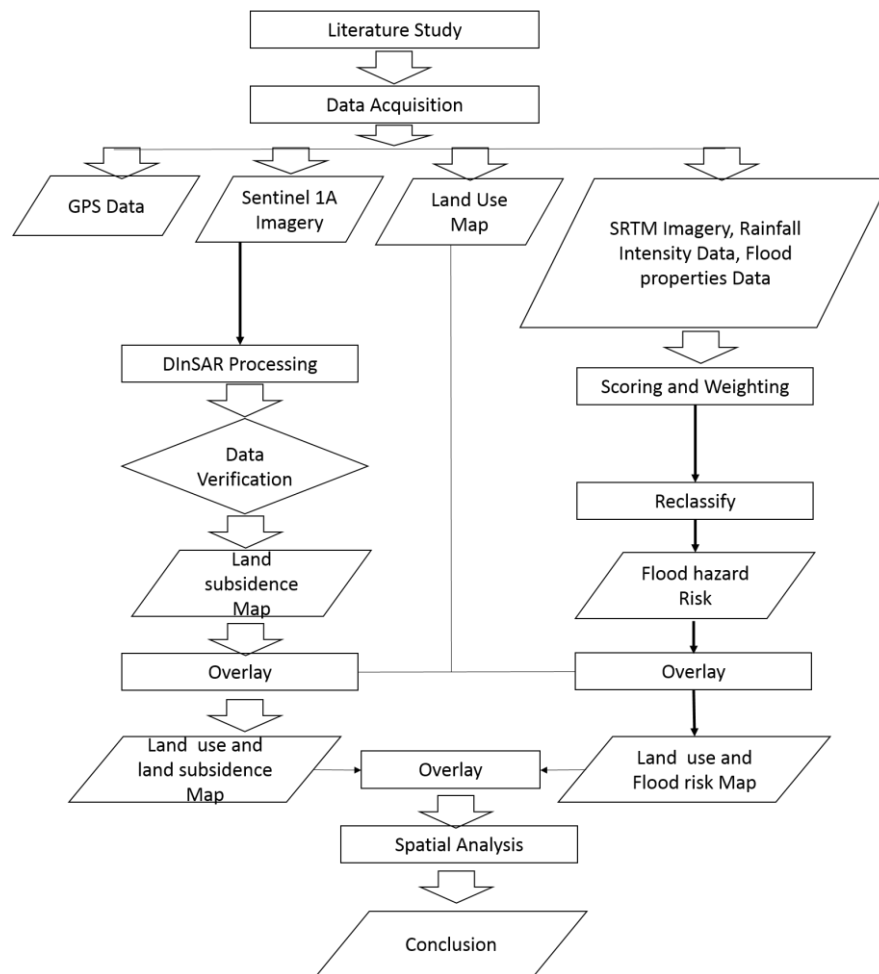
**Table 2.** Geohazard Parameter and Score

Parameter	Criteria	Score	Weight	Final Weight
Rainfall Intensity (mm/year)	>3000	5	0,25	1,25
	2500-3000	4	0,25	1,00
	2000-2500	3	0,25	0,75
	1500-2000	2	0,25	0,50
	<1500	1	0,25	0,25
Topography Height (m)	< 10	5	0,25	1,25
	10-50	4	0,25	1,00
	50-100	3	0,25	0,75
	100-200	2	0,25	0,50
	>200	1	0,25	0,25
Flooding Deep Zone (m)	< 0,76	1	0,25	0,25
	0,76-1,5	2	0,25	0,50
	> 1,5	3	0,25	0,75
Land Use	Rural Area	5	0,25	1,25
	Building	5	0,25	1,25
	Paddy Field	4	0,25	1
	Paddy Wet Field	4	0,25	1
	Hujan			
	Farm	3	0,25	0,75
	Field	2	0,25	0,50
	Rock and Hill Area			
	Forest	1	0,25	0,25
	Grass	1	0,25	0,25
	Savannah	1	0,25	0,25
	Land Water Area	1	0,25	0,25
		0	0,25	0

For this Geo-hazard modeling was used 4 parameters (Rainfall Intensity, Topography Height, Flooding Deep Zone and Land Use) based on previous research [6] and can be explained in detail related to the assessment and weighting in the Table 2.

## 2.5. Research Methodology

The research stages can be explained based on the sequence of data processing in Figure 2.



**Figure 2.** Research Methodology Flowchart

Stages of this research are generally divided into four parts that include the stages of data collection and literature studies, stages of data processing, stages of data validation and stages of data analysis. At the stage of data collection is done by collecting the required data (refer to Table 1) which includes four main parameters namely rainfall intensity data, topography data, flooding deep zone and land use data. Furthermore, at the stage of data processing apply three methods of data processing include DInSAR method, DEM data extraction method, weighting method and interpolation methods of rainfall intensity. The processing result is then validated using GPS data to DInSAR processing data. For data on flood inundation and land subsidence are also verified using field survey. The result of data processing that has been validated and verified then overlaid with land cover data to get spatial pattern of flood inundation and land subsidence. The next stage of data analysis to be drawn general conclusions in related to the correlation between flood inundation and land subsidence in the study area.

### 3. Result and Discussion

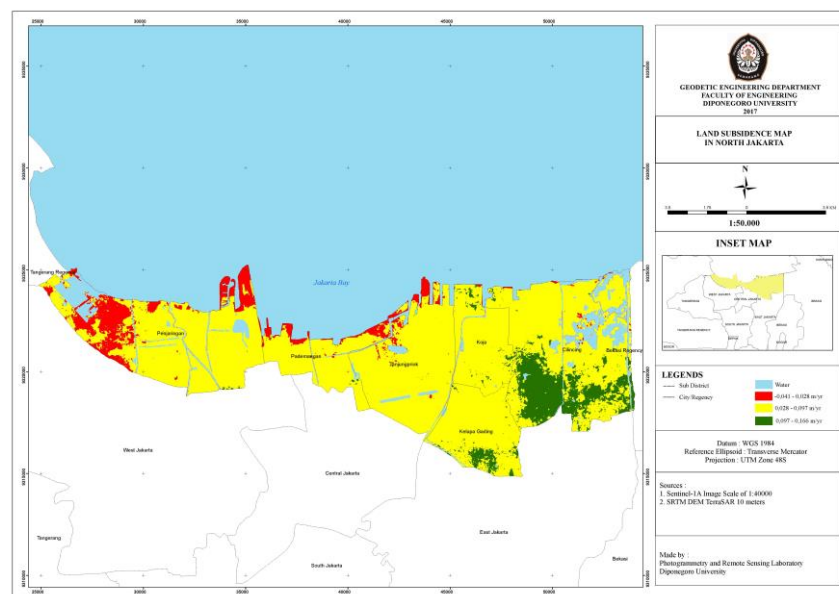
There are several results and analysis based on the stages of data processing which can be explained as follows:

#### 3.1. Land Subsidence Analysis Based On DInSAR Method Processing

Based on the result of processing, the result of the highest land subsidence occurred in Penjaringan sub district in North Jakarta, with the most highest land subsidence around -0.0437 meter/year where the details of the results can be seen in the Table 3 and Figure 3.

**Table 3.** Land Subsidence Velocity in Sub District on North Jakarta Based on DInSAR Method

Sub District	Average (m/yr)	Minimum (m/yr)	Maximum (m/yr)
Kelapa Gading	0,0821	0,0247	0,1294
Koja	0,0823	0,0331	0,1270
Tanjungpriok	0,0573	-0,0245	0,1082
Cilincing	0,0829	-0,0018	0,1566
Penjaringan	0,0469	-0,0437	0,1118
Pademangan	0,0522	-0,0042	0,1186



**Figure 3.** Land Subsidence Map Based on DInSAR Method

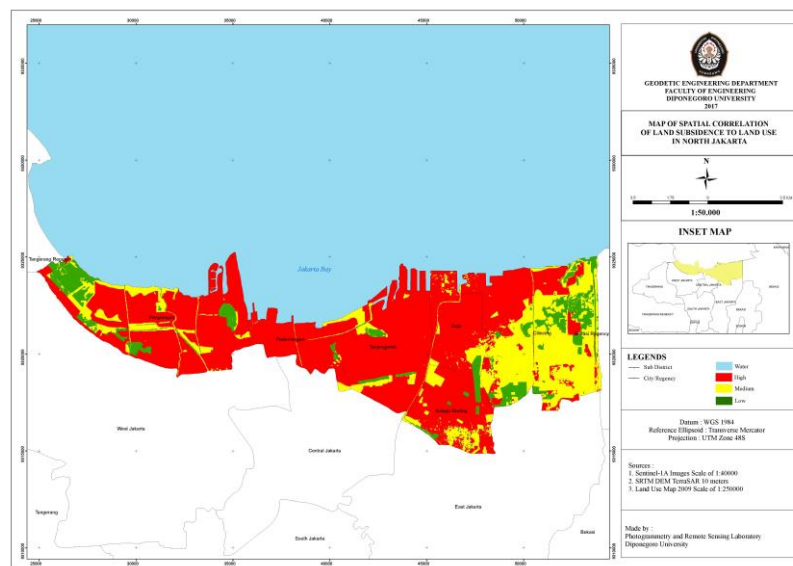
#### 3.2. Flooding Hazard Risk Analysis Based On Geo-Hazard Modelling

Based on Geo-hazard modelling [2,3,7], the result of flooding hazard risk can be resulted from 4 parameters (rainfall intensity, topography height, land use and flood deep zone) can be seen in Figure 1. From that map it can be seen that is the red color representation is a high flood threat zone reaching 82% or 115,706,032.444 m<sup>2</sup>, the yellow is a zone of medium flood threat that reaches 15% or 21,229,545.740 m<sup>2</sup> and the color green is a low flood threat zone that reaches 3% or an area of 4,350,438.643 m<sup>2</sup>.

From the results obtained, that almost all areas of North Jakarta City has high potential for flood threats. This is because almost the whole area of North Jakarta is used as a settlement, while the largest score on land use parameter is settlement with score value of 5. Thus, modeling flood disaster threat generated by weighting method tend to have high flood threat class. This is also evidenced by the percentage of high flood threats that reached 82%.

### 3.3. Spatial Analysis Between Land Subsidence and Land Use Combination Data

The results of the correlation map between Land Subsidence and Land Use of North Jakarta can be seen in Figure 4.



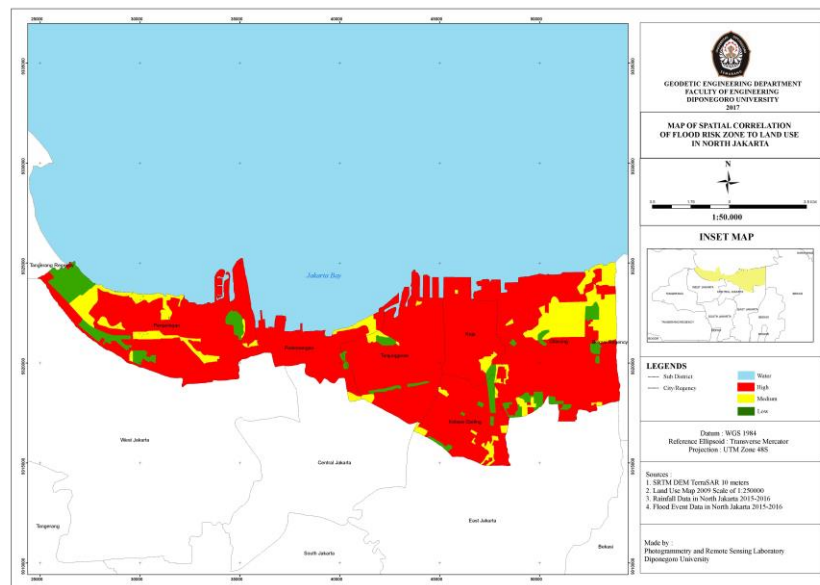
**Figure 4.** Land Subsidence and Land Use Correlation Map

Based on the results of data processing obtained that the percentage of spatial correlation of the highest land subsidence with residential, industrial, office building and rural area is the highest suitability class (red color indicator), reaching 61% or 86,762,837.094 m<sup>2</sup> spread evenly in all districts in North Jakarta City. Meanwhile, for percentage of spatial correlation area of land subsidence with farm, garden, forest and unbuilt area, the second highest land subsidence is medium grade suitability, which is 25% or 34,703,273.64 m<sup>2</sup>. Meanwhile, for the percentage of the last is the low grade suitability between land subsidence with open water area, reaching 14% or 19,819,906.090 m<sup>2</sup>.

### 3.4. Spatial Analysis Between Flooding Hazard Risk and Land Use Combination Data

The purpose of making this map is to analyze the spatial impacts arising from the phenomenon of flood hazard threat against land use in North Jakarta [4]. The results can be seen in Figure 5. The red color is a representation of the high suitability of spatial phenomena in the form of built areas, such as settlements, industrial estates, transport areas, government areas, and so on. Then, the yellow color is a representation of the moderate suitability of the spatial flood phenomenon in the form of non-built areas, such as: agricultural land and livestock, empty land, mangroves, and so on. Furthermore, the green color is a representation of the low suitability in the form of open water areas, such as: rivers, reservoirs, and so forth.



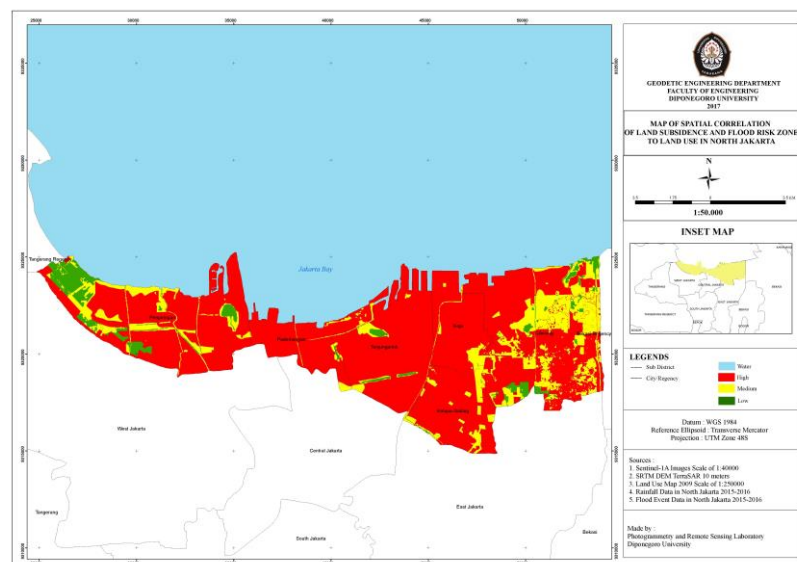


**Figure 5.** Flood Hazard Threat Zone and Land Use Correlation Map

In Figure 5, it can be seen that the percentage of spatial correlation area of the highest flood hazard threat is the high suitability class, reaching 81% or 114,244,882.530 m<sup>2</sup>, medium grade suitability class, reaching 12% or 17,365,058.16 m<sup>2</sup> and the lowest class, reaching 7% or 9.636.076,131 m<sup>2</sup>.

### 3.5. Spatial Analysis Between Land Subsidence and Flooding Hazard Risk Combination Data

The purpose of making this map is to analyze the spatial impacts arising from the phenomenon of land subsidence against flooding hazard threat [8]. The results of this spatial analysis can be seen in Figure 6.



**Figure 6.** Flood Hazard Threat Zone and Land Subsidence Correlation Map

The red color is a representation of the high spatial suitability of the phenomenon of land subsidence and flooding hazard threat of spatial form of rural areas, such as settlements, industrial estates, transport areas, government areas, and so on. Then, the yellow color is a representation of the

moderate conformity of the phenomenon of land subsidence and flooding to spatial form of non-built areas, such as: agricultural land and livestock, empty land, mangroves, and so on. Furthermore, the green color is a representation of the low suitability of open water areas, such as: rivers, reservoirs, and so forth. In Figure 6, it can be seen that the highest percentage of spatial correlation of the highest decrease in soil surface is the high grade suitability, reaching 77% or 108,182,957.001 m<sup>2</sup>, medium grade suitability, reaching 17% or 24,392,097.28 m<sup>2</sup> and low grade suitability, reaching 6% or 8,710,962.545 m<sup>2</sup>.

#### 4. Conclusion

The conclusion in this research based on data results and analysis, it can be explain as follows:

1. The phenomenon of land subsidence can be examined based on the DInSAR processing that is occurred in four sub-districts in North Jakarta. In Specifically the results of the land subsidence measurements can be described as follow: Tanjungpriok at -2.45 cm/year, Cilincing at -0.18 cm/year, Penjaringan at 4.37 cm/year and Pademangan District at -0.42 cm/year. This phenomenon of land subsidence, because most of North Jakarta area is built or rural area. It can be seen from North Jakarta Land Use Map which consists of 71.6% of rural area. The more dense *settlements*, the more densely populated in North Jakarta, so that the occurrence of continuous water taking and causing the land subsidence. In addition, the number of skyscraper building in the form of apartments and industrial sectors will be one big problem in a compaction soil in North Jakarta. It is always accelerate a speed of land subsidence in North Jakarta.
2. The result of the spatial correlation of land subsidence to flooding is a largely correlated. This is because almost all zones of high threat flood disaster detected as land subsidence area. The percentage of high risk flood disaster zone in North Jakarta is 82% with an area of 115,706,032.444 m<sup>2</sup> and land subsidence is found in four of the six sub-districts of North Jakarta. In addition, areas that have a corresponding between land subsidence and flood is around 77% with an area of 108,182,952.001 m<sup>2</sup>.
3. The impact area of the land subsidence and the flood zone is 77% in higher correlation class with an area width around 108,182,952.001 m<sup>2</sup>, 17% in normal correlation with an area width around 24,392,097.28 m<sup>2</sup> and 6% in lower correlation with an area width around 8,710,962.545 m<sup>2</sup>. That is, because most of the North Jakarta area consists of 71.6% rural area which is compose a solid majority of the residential area, industrial areas, transportation area, district administration area, district office area and social facilities.

#### 5. Acknowledgments

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