

ENVIROMENTAL MONITORING OF LAND SUBSIDENCE IN THE COASTAL AREA OF PADANG CITY USING SENTINEL 1 SAR DATASET

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ABSTRACT: The land surface in the Padang City is thought to be experiencing a continuous relative subsidence due to natural processes and man-made activities. Factors that affect land subsidence include earthquakes, sea level rise, infrastructure development, sediment transport, and excessive use of groundwater sources. The purpose of this research is to map the rate of land subsidence which is processed from the Sentinel 1-A radar, satellite imagery using the Differential Synthetic Aperture Radar (DInSAR) method. The data used are two pairs of Sentinel-1A level 1 Single Looking Complex (SLC) imagery which were acquired in 2018 and 2019. Image processing is carried out by filtering and multilooking techniques on Synthetic Aperture Radar (SAR) images. The following process changes the phase unwrapping to the ground level phase using phase displacement. Land subsidence in 2018–2019 from DInSAR processing reached -10.5 cm / year. The largest land subsidence occurred in North Padang with an average of -7.64 cm/year. Land subsidence in the Padang City, which is located near the estuary, is due to the nature of the alluvial sediment material. The use of Sentinel 1 SAR remote sensing data can provide important information in the context of mitigating land subsidence in the Padang City. Therefore, we need the right policies to handle future land subsidence cases. Land subsidence mapping is one of the factors that determine the vulnerability of coastal areas to disasters.

Keywords: Land Subsidence, SAR, DInSAR



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1. INTRODUCTION

Recent mapping has identified coastal plain areas with sediments accumulating in alluvial basins or coastal plains as the most vulnerable to Land subsidence. Coastal plains have grown rapidly in most regions of the world. The World Bank report in 2012 states that there has been urbanization in all regions of Indonesia, the report notes that there are 11 metropolitan cities and one of them is the Padang City which has experienced population growth and is predicted to continue to increase in the period 2010-2025. [1]

Land subsidence is triggered by several things, one of which is the process of decreasing the amount of groundwater which causes the gradual subsidence of most of the land over months and years. This land subsidence has quite damaging effects on the affected area, including it will result in an increase in environmental disasters such as

the risk of flooding, cracks, and damage to buildings and infrastructure [2,3,4].

Remote sensing technology that continues to develop can bring new alternatives in knowing land subsidence in a large area, one of which is by utilizing SAR data from remote sensing [5,6,7,8], besides that it is also time-saving and low-cost. Land subsidence in coastal areas can be influenced by several main factors, including the number of buildings that increase the surface load of the land, this will have a negative impact, to reduce the negative impacts that may arise, it is necessary to research this phenomenon as part of disaster mitigation efforts. To date, the use of Synthetic Aperture Radar (SAR) to monitor soil deformation associated with subsidence has been demonstrated in a number of studies [9,10,11,12].

Sentinel-1 is the first of a series of seven satellite missions launched as part of the Copernicus programme initiated by the European

Commission (EC) and the European Space Agency (ESA) [13]. Similar to previous ESA SAR satellites, Sentinel-1 has a C-band sensor with two satellites, namely Sentinel-1A and Sentinel-1B which orbit in tandem 180° apart. Each satellite is capable of repeating cycles every 12 days and with the constellation of the two satellites. makes Sentinel-1 have a repeat cycle every 6 days. Sentinel-1 has 4 viewing modes with the main mode on land is the Interferometric Wide Swath (IW) mode with a spatial resolution of about 5mx20 m. A benefit of using Sentinel 1 data is that it is freely accessible to all users.

One of the remote sensing-based methods used to analyze land subsidence is the Differential Interferometri Synthetic Aperture Radar (DInSAR) [14,15,16]. This research is focused on the western part of Padang City, near the coast and the river estuary. This research uses Sentinel-1A satellite imagery in 2018 and 2019.

2. RESEARCH METHODS

2.1 Study Area

The study area of Padang City, which is the capital city of West Sumatra Province, is geographically between 00°05'05"E – 100°34'09"E and 00°44'00"S - 01°08'35"S (Fig 1). The study area is a gently sloping area in the west and hilly in the east. However, this research focuses on the sub-districts along the coast, with a relatively flat topography and the estuaries of 10 rivers. In addition, the coastal area of Padang city is currently dominated by medium to high density residential areas that are prone to flooding, besides that it is the center of economic activity and also a tourism area (Fig 1).

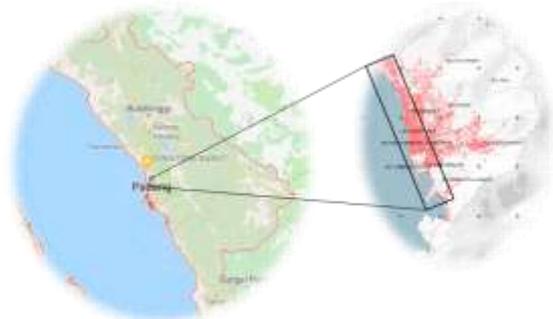


Fig. 1 Study Area

2.2 Data and Procedure

Data used in this study are Sentinel-1A radar data for 2018 and 2019, which are downloaded at <https://scihub.copernicus.eu/>. The two previously downloaded image data were associated with the temporal baseline time in order to obtain a high coherence value (Table 1). These stages are carried

out on the data provider page.

Table 1: SAR Image Data Specifications.

Acquisition	Level	Mode	Polarization	Sensor	Orbits
05/12/2018	1	IW	VV	Sentinel-1	Ascending
24/12/2019					

The DInSAR method is used to see changes in the baseline in SAR data so that the phase difference can later be reduced to displacement, meaning that the information contained in the interferometric phase is calculated as the phase difference between the two SAR images obtained at two different times from the recording position which is almost same. DInSAR is processed using the SNAP (S1TBX) software developed by the European Space Agency (ESA) [17]. The SNAP software is designed for Sentinel data processing and is freely available. When the interferometric phase appears as follows:

$$\Delta\phi = \Delta\phi_{flat} + \Delta\phi_{height} + \Delta\phi_{displacement} + \Delta\phi_{atmosphere} + \Delta\phi_{noise}$$

Where : $\Delta\phi_{flat}$ is the contribution of the flat earth phase,

$\Delta\phi_{height}$ is the topography, $\Delta\phi_{displacement}$ the land deformation displacement is measured along the line of sight (LOS), $\Delta\phi_{atmosphere}$ is the contribution of the atmosphere to the interferometric phase and $\Delta\phi_{noise}$ is the generic noise.

The processing stage begins with data collection, which will then be performed by reference estimation to see the relationship between the master and slave image pairs. After getting the master and slave image pairs, the slave image is matched to the master image at the image coregistration stage. From the completed image, the coregistration phase is performed by forming an interferogram and estimating the coherence of the master and slave image pairs. The consistency value (γ) for the image pair should be greater than 0.2. The next step is to create an interferogram and coherence. The lower the consistency value, the lower the level of adjustment between these images [18]. If the coherence value is more than 0.2, then it can be done to the next stage, namely the TOPSAR Deburst process, where this stage merges separate with black lines between bursts.

The subset process was carried out to focus on the study area after the TOPSAR Deburst process. The next step is to remove topographic phases, where this stage creates an interferogram simulation based on the Digital Elevation Model (DEM) reference and subtracts the topographic phases from the processed interferogram. The DEM used at this stage is the SRTM 3 sec DEM which is downloaded automatically in the SNAP software.

In making the interferogram, a filtering technique is carried out which functions to reduce

phase noise, the filter process uses Goldstein Filtering which is available in the SNAP feature. After being filtered, the next step is Multilooking which functions to reduce the phase noise in the SAR image by forming pixels close to the square. However, the phases that have been formed in processing until Multilooking still contain an ambiguity phase, so it is necessary to remove the ambiguity phase into an absolute phase. This process is called Phase Unwrapping which is done in the SNAPHU software with the Linux operating system. Previously, to enter the process into SNAPHU, the results of the multilooking stage needed to be unwrap export in the SNAP software. After processing in SNAPHU is complete, it can be reworked using SNAP with import setting unwrap.

The next procedure is to convert unwrap data into phase to height to determine the difference in height from the DInSAR process or to convert from slant to height using Phase to Displacement in SNAP software. The next step is geocoding, in SNAP it is called Range Doppler Terrain Correction. The results of this geocoding are used next to create a spatial map of subsidence.

3. RESULTS AND DISCUSSION

The calculation of land subsidence in each area uses the average value, the average value calculated from the total value of land subsidence in a specific area. So that it is considered to represent the region. Overall in the study area there has been a land subsidence, which varies between regions with the highest average land subsidence occurring in the North Padang area, which is -7.64 cm/year with a maximum value of land subsidence of -10.50 cm/year, then followed by land subsidence in the West Padang area with an average of -5.80 cm/year with a maximum value of -10.31 cm/year. The lowest average land subsidence occurred in the Bungus Teluk Kabung area, which was -0.45 cm / year with a max value of -8.77 cm / year (Fig 2).



Fig. 2 Maximum and average land subsidence Padang City in 2018-2019

The Padang City consists of three lithological units, namely tertiary volcanic rocks (Tomv), Plio-

Pliocene volcanic rocks and quaternary alluvial deposits (Qa). The Tomv unit lies on a hill in the southeastern part of the Padang City, which consists of alteration and mineralization of andesite into tuff basalt, breccia and lava. Qtv lithology is located in the northern hills consisting of rhyolite, dacit and andesite tuff. Meanwhile, the youngest unit is Qa which stretches along the western coastline of the Padang City which consists of sand, silt and gravel from swamp deposits [19].

Land subsidence can be caused by several factors, one of which is related to the type and texture of the soil contained therein, resulting in a natural subsidence. Soil is a mineral particle that has no or weak bonds between its particles and is formed due to weathering of rocks. The phenomenon of land subsidence occurs mostly in coastal areas and near estuaries due to the nature of alluvial sediment materials [20].

The sediment comes from weathering and erosion carried by river water and settles on the river estuary. The characteristics of the rock constituent material and subsidence are influenced by the components present in the rock. The alluvial constituent material found in coastal areas and near river estuaries is in the form of sand with a coarse texture and a macro-pore characteristic. This factor will make it easier for alluvial constituent materials to be filled with water and air media so that the bonds between the material and subsidence become weak [20]. The weak bond between soil particles is caused by the influence of carbonates or oxides that are compounded with these particles or it can also be by the presence of organic mineral. This will result in alluvial material being eroded more easily by river water flows.

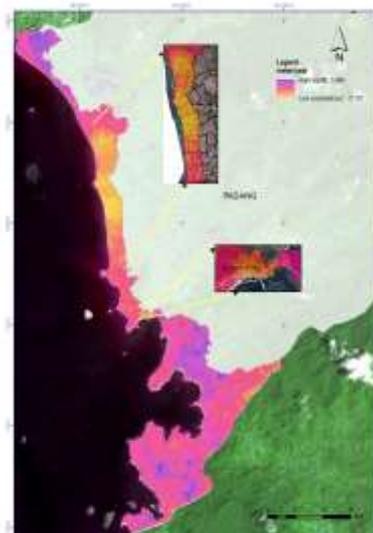


Fig. 3 Spatial Distribution of land subsidence Padang City in 2018-2019

Furthermore, we found that the real land subsidence occurred extensively in urban areas, especially in two areas, namely North Padang, West Padang, and Koto Tengah during the observation period. This subsidence area is mostly concentrated in seventeen sub-districts which are commercial zones in the Padang City, and there is also significant land subsidence in the Industrial area in Teluk Bayur Harbor and the surrounding area (Fig 3). The main factors causing the detected land subsidence include anthropogenic activity, natural compaction of alluvial soil. However, anthropogenic activities, such as land use change to developed land and groundwater use, have a more significant impact on land subsidence rates than natural factors.

Based on this preliminary research, it is necessary to consider appropriate policies to handle land subsidence cases in the Padang City. The use of SAR imagery is able to provide a temporal spatially image to identify the type of hazard as a disaster mitigation effort to reduce the risks it causes [21, 23]. Given the absence of real time GPS observations in the Padang City. Land subsidence mapping using SAR data is one of the important data sources to determine the vulnerability of coastal areas to disasters. The higher the land subsidence, the more vulnerable the area to disasters.

4. CONCLUSION

The lowlands area of Padang city in the western part have experienced a land subsidence in during the study period from 2018 to 2019, Overall in the study area there has been a land subsidence varies between regions with the highest average land subsidence occurring in the North Padang area, which is equal to -7.64 cm/year with a maximum value of land subsidence of -10.50 cm/year, followed by land subsidence in the West Padang area with an average of -5.80 cm/year with a maximum value of -10.31 cm/year. Land subsidence detection and mapping plays an important role in dynamic coastal management and long-term policies.

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