The Comparison of Land Subsidence between East and West Side of Bangkok, Thailand

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ABSTRACT

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The land deformation in line of sight (LOS) direction can be measured using time series InSAR. InSAR can successfully measure land subsidence based on LOS in many big cities, including the eastern and western regions of Bangkok which is separated by Chao Phraya River. There are differences in prosperity between both sides due to human activities, land use, and land cover. This study focuses on the land subsidence difference between the western and eastern regions of Bangkok and the most possible cause affecting the land subsidence rates. The Radarsat-2 single look complex (SLC) was used to set up the time series data for long term monitoring. To generate interferograms, StaMPS for Time Series InSAR processing was applied by using the PSI algorithm in DORIS software. It was found that the subsidence was more to the eastern regions of Bangkok where the vertical displacements were +0.461 millimetres and -0.919 millimetres on the western and the eastern side respectively. The districts of Nong Chok, Lat Krabang, and Khlong Samwa have the most extensive farming area in eastern Bangkok. Besides, there were also three major industrial estates located in eastern Bangkok like Lat Krabang, Anya Thani and Bang Chan Industrial Estate. By the assumption of water demand, there were forty-eight wells and three wells found in the eastern and western part respectively. The number of groundwater wells shows that eastern Bangkok has the demand for water over the west, and the pumping of groundwater is a significant factor that causes land subsidence in the area.

Keywords: *Subsidence, InSAR, Radarsat-2, Bangkok*

INTRODUCTION

Bangkok has continuously experienced land subsidence from the past to the present. From the levelling measurement by the Royal Thai Survey Department, they found that the areas in Bangkok have a problem of land subsidence. Factors affecting land subsidence in Bangkok are groundwater over-pumping in the past for many years. Time Series InSAR technology is a technique that has the potential to detect land subsidence rates (Aobpaet, et al., 2009) Therefore, in this research, we choose the PSI technique, which has the advantage of analyzing data without weather restrictions. Radar waves are capable of travelling through the atmosphere, making it possible to capture the data in almost all-weather conditions, day and night.

LITERATURE REVIEW

There are many methods to monitor land subsidence, such as levelling, GNSS, InSAR, etc. The InSAR technique is suitable for the study area because it is useful in monitoring land subsidence continuously in a large area. Also, it doesn't use many pieces of equipment, and there is some free satellite data (Aobpaet, 2019). For the given reasons, it makes the technique more advantageous compared to other methods in terms of time-consuming and cost-effective (Aobpaet et. al., 2009).

Time Series InSAR (Time Series Interferogram Synthetic Aperture Radar) technique uses the radar backscatter principle from the satellite sensor. By analyzing two or more radar images, all images should have close angles and vertical values with each other but different time recording (Lee et al., 2012). We matched Master and Slave images to generate interferograms for analyzing the phase difference to study the deformation pattern. Time Series InSAR includes two methods are PSI and SBAS. There is a lot of research that has used this technique for monitoring land subsidence. The research (Delgado et. al., 2019) studies urban subsidence in Rome metropolitan, Italy. Which is applied time series 160 Sentinel-1A imagery and PSI method. In Staufen im Breisgau, Germany, the research (Lubitz et. al., 2013) focuses on SBAS technique to process 50 images of TerraSAR-X satellite, data period July 2008 to May 2011 for measuring urban uplift. In this case, we applied only the PSI method.

PSI (Persistent Scatter InSAR) is an algorithm for the solution to the problems of the InSAR technique, which are temporal and geometrical decorrelation. PSI uses one of the radar images to be the master image to generate interferograms with the other images called the slave image. The master should be related to the other images for avoiding atmosphere decorrelation, temporal decorrelation, and low coherence (Zhang et. al., 2015)

STUDY AREA

Bangkok is the capital city of Thailand. It is located in the lower central region (13°45'0'' N 100°31'1.20''E) Area 1,569 square kilometres, concluding 50 boundaries. There is a major river flowing through Bangkok called the Chao Phraya River. There are many large gravels and gaps in underground Bangkok. They provide a large amount of space to store groundwater. Therefore, Bangkok is a significant groundwater supply. The groundwater in Bangkok and vicinity consists of 8 layers (JICA,1995):

1. Bangkok Aquifer (depth about 50 meters.) It's the top aquifer layer. There is a pouring clay covering the top water layer. This quality of the water layer is not suitable for use as it is salty water.
2. Phra Pradaeng Aquifer (depth about 100 meters.) Next to the Bangkok aquifer, the water supply in this layer is very thick. The layer thickness approx. 20-50 meters.
3. Nakhon Laung Aquifer (depth of about 150 meters.) is next to the Phra Pradaeng aquifer. This layer is about 5-70 meters. The quality of the water layer is excellent and plentiful. But in some areas are salty water, the west and the south of Bangkok
4. Nonthaburi Aquifer (depth about 200 meters.) Hydrogeology properties close to the Nakhon Luang aquifer, as this the water layer is placed parallel to the Nakhon Laung aquifer. This layer thickness is approx. 30-70 meters.
5. Sam Khok Aquifer (depth about 300 meters.) next to the Nonthaburi aquifer. Water content is less than the Nonthaburi aquifer but is of similar quality. This layer thickness approx. 40-80 meters.
6. Phaya Thai Aquifer (depth about 350 meters.) Next to the Sam Khok aquifer. Groundwater quality is close to the Sam Khok aquifer, but the freshwater is only found in the north, southwest, and east of Bangkok. This layer thickness is approximately 40-60 meters.
7. Nonthaburi Aquifer (depth about 450 meters.) Next to the Phaya Thai aquifer. This layer thickness is approx. 50-100 meters. The majority of groundwater in this layer is freshwater. But some areas are water-rich, Western or southwest areas of the Thonburi.
8. Pak Nam Aquifer (depth about 550 meters.) It is the deepest water layer, which is the best quality and the largest volume due to the freshwater.

As by the location, it makes a difference in human activities and land use of Bangkok on both sides. It is one of the factors affecting land subsidence. Therefore, the research focuses on the land subsidence comparison between east and west of Bangkok. The scope of this research used the Time Series technique PSI algorithm for processing Radarsat-2 images SLC data, which covers the west and east Bangkok area (Figure 1).

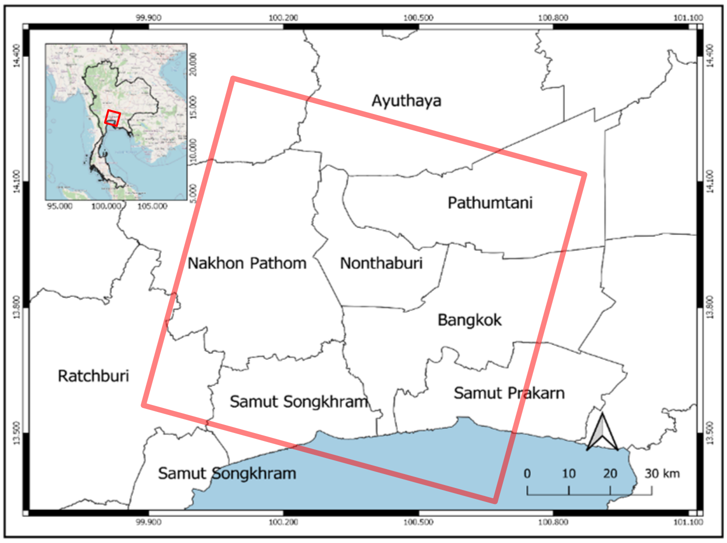

Figure 1. Radarsat-2 image covers Bangkok & vicinities

METHODOLOGY

We used DORIS version 4.0.8 to process data and generate interferograms. We matched the master image with the remaining slave images to analyse phase differences. Then, we used StaMPS version 4.1beta (Hooper et al., 2010) to edit the data and analyse the Persistent Scatterers algorithm of each pixel. To calculate the vertical displacement rate or the rate of land subsidence as shown in Figure 2.

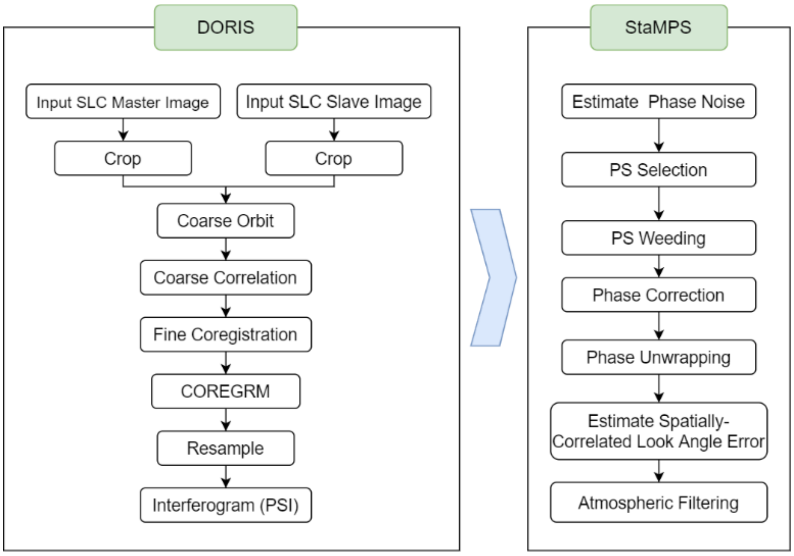

Figure 2. Processing of Time Series InSAR technique PSI algorithm for Radarsat-2 images.

RESULTS AND DISCUSSIONS

Following the time-series InSAR PSI method, we applied nine images of Radarsat-2 (7 months) to generate eight interferograms. We got the result of the subsidence rate in millimetres per year, which covers the west and the east of Bangkok, Thailand as Figure 3. After computing the mean vertical displacement consider each boundary as Figure 4, it is shown that there are subsidence and rebound boundaries in Bangkok.

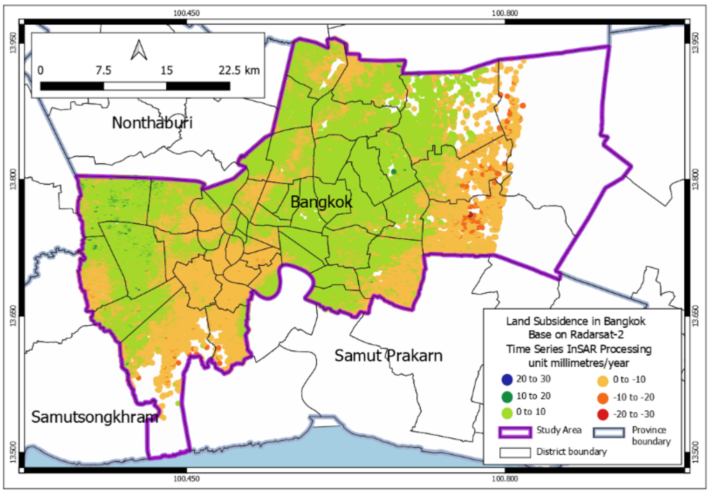

Figure 3. Land subsidence in Bangkok, Thailand. Based on Radarsat-2, Time-Series InSAR Processing.

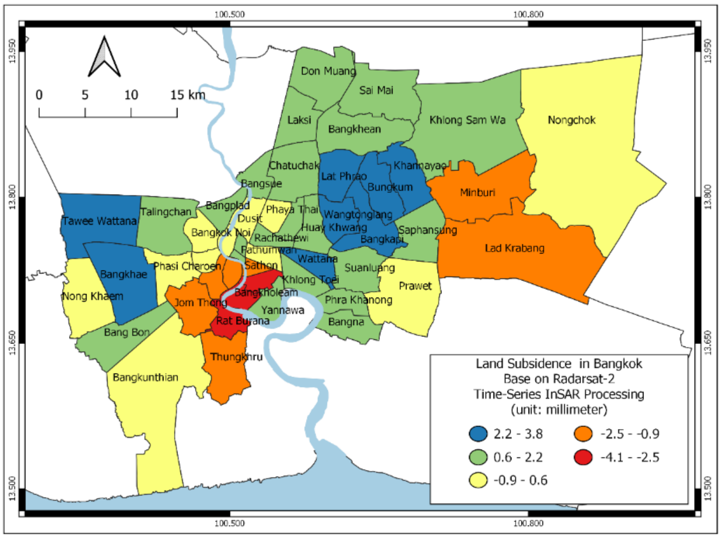

Figure 4. The mean vertical displacement considers each boundary in Bangkok.

Overview both sides of the study area, there is subsidence and rebound area as well. The highest subsidence in the west is Rat Burana, and in the east, there are two areas, which are Bang Kho Leam and Sathon. Finding the relationship between vertical displacement and Longitudinal, we computed the trend of subsidence in that area for showing which side has a more subsidence rate. The trend line of vertical displacement as shown in Figure 5, we found the west of Bangkok has rebound +0.461 millimetres per year, and the east has subsidence -0.919 millimetres per year. The different vertical displacement of both sides is 1.38 millimetres. Therefore, the east side has more subsidence than the west side. R-square between vertical rate and the linear trend line is -2.72e-05. Although R-square is very low which we can't predict subsidence in the future from this trend but in this case, the linear trend line is a good equation that we can see the different vertical displacement between the east and west side of Bangkok.

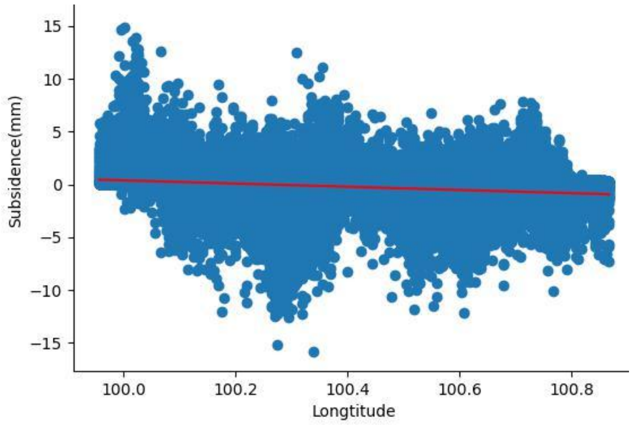

Figure 5. The relationship between vertical displacement and Longitude.

Bangkok city planning management data (Figure 6) found that most of the subsidence areas are located in a residential area, city, and agriculture, both west and east, and the soil has a resurgence in the residential area (Department of City Planning and Urban Development, 2019).

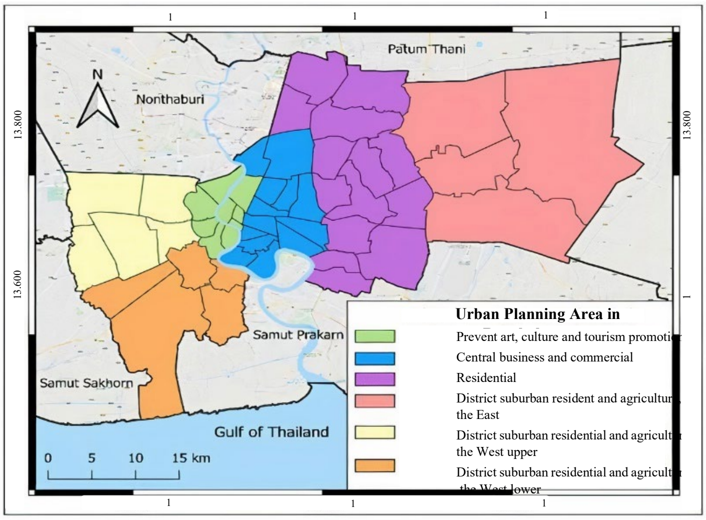

Figure 6. Urban planning area in Bangkok.

From the use of land and human activities, the Bangkok city has a total of 26 of 50 boundaries, and are agricultural areas. Nong Chok district has the most extensive farming area in Bangkok, Lat Krabang and Khlong Samwa, respectively (the three districts located in the eastern city). The most planted plant is rice. Rice is a plant that uses more water than other plants; farmers have to provide a large amount of water for the rice to obtain sufficient water content in the growing period. There are also three major industrial estates located in eastern Bangkok. They are Lat Krabang Industrial Estate (Lat Krabang district), Anya Thani Industrial Estate (Prawet district) and Bang Chan Industrial Estate (Minburi district) Both the agricultural and industrial sectors require a large amount of water. Groundwater is an essential source of raw water to meet human needs. As shown in Figure 7, the groundwater wells of the east are more than the west.

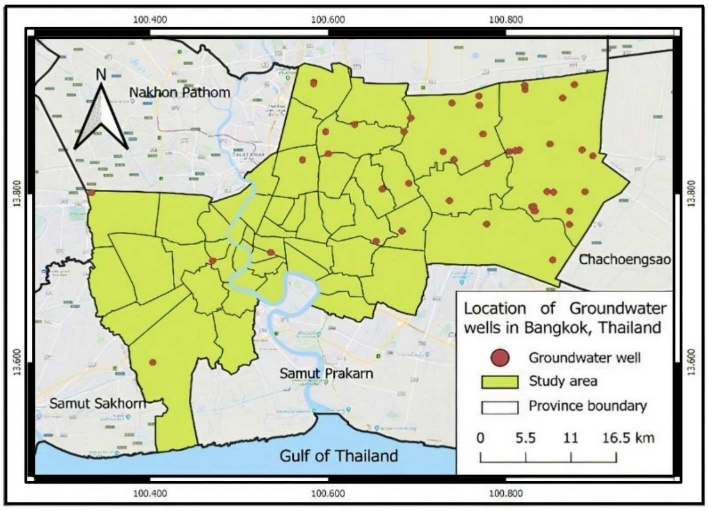

Figure 7. Location of groundwater wells in Bangkok, Thailand.

The total numbers of groundwater in Bangkok (Table 1) of 51 wells concludes the west three wells and the east 48 wells (Department of Groundwater Resources, 2020). The maximum number of groundwater wells is in Nong Chok district, which is 20 wells. From the number of wells, we can clarify that it would be the more groundwater pumping in the eastern side of Bangkok. When the groundwater has been pumping up a lot, it makes groundwater pressure drop, which causes a problem of the land subsidence in the area.

Table 1. The numbers of groundwater in Bangkok, Thailand

Side	District	Number of wells	Total
East	Klong Samwa	10	48
	Min Buri	2	
	Lat Krabang	2	
	Don Mueang	2	
	Bang Khen	5	
	Pra Tum Wan	1	
	Bueng Khum	3	
	Chatuchak	1	
	Nong Chok	20	
	Bang Kapi	2	
West	Tawi Wattana	1	3
	Phasi Charoen	1	
	Bang Khuntien	1	
Total groundwater wells in Bangkok			51

Source: (Department of Groundwater Resources, 2020)

CONCLUSION

In this study, we used a time-series InSAR PSI method to apply 9 Radarsat-2 images for monitoring land subsidence in Bangkok, Thailand. We used Doris version 4.0.8 to generate interferograms and used StaMPS version 4.1beta to analyse the Persistent Scatterers algorithm. The result showed subsidence rates cover the west and the east of Bangkok. The highest subsidence in the west is Rat Burana, and in the east, there are two areas, which are Bang Kho Leam and Sathon. We analysed the relationship between vertical displacement and

Longitudinal. The trend line of vertical displacement showed that the west of Bangkok has rebound +0.461 millimetres per year, and the east has subsidence -0.919 millimetres per year. Therefore, the east side has more subsidence than the west side of 1.38 millimetres. From the use of land and human activities, we found that there are three major industrial estates located in eastern Bangkok. They are Lat Krabang Industrial Estate (Lat Krabang district), Anya Thani Industrial Estate (Prawet district) and Bang Chan Industrial Estate (Minburi district) which require a large amount of water. From the Department of Groundwater Resources, there are the west three wells and the east 48 wells. Accordingly, the groundwater pumping would be more in the east. When the groundwater has been pumping a lot, that makes the groundwater pressure drop. It affects the level of the ground.

Time Series InSAR techniques can determine land subsidence rate which can be used for groundwater monitoring. With the advantage in the wide coverage area and no need for prior data, we can adopt this technique for the regional scale measurement compared to other surveying techniques such as levelling and GNSS. The result can help the government officials or those who involved paying more attention to identifying the most land subsidence areas, as shown by InSAR. After that, we can investigate in depth on the issue that occurs to make land subsidence such as groundwater pumping, illegal construction of buildings, etc.

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