ANALYSING THE IMPACT OF URBANISATION ON LAND SUBSIDENCE IN BANGKOK METROPOLITAN AREA USING DInSAR TECHNIQUE

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ABSTRACT: Land subsidence particularly occurs where the intense urbanization implies increasing water consumption with a significant pumping of the aquifers. In Bangkok metropolitan area, with its rapid urbanization processes, groundwater is the main resource for household and industry. In recent years, land subsidence has been identified an important issue in this region. To investigate the land subsidence, the use of Synthetic Aperture Radar (SAR) technique has been considered an efficient approach. Since April 2014, Sentinel-1 data are freely available via the ESA's Sentinels Scientific Data Hub. In this study, Sentinel-1 SAR images were therefore collected over the 2015 - 2017 period focusing on Bangkok metropolitan including the coastal area. The results are achieved by Differential Synthetic Aperture Radar Interferometry (DInSAR) technique, which generates a land subsidence map, aided by Geographical Information System (GIS). This study shows the recent land subsidence rates and its correlation to urban development map, and also illustrates the applicability of Sentinel-1 data for land subsidence detection monitoring.

1. INTRODUCTION

Land subsidence is an environmental hazard that causes the lowering of the land surface. It is normally caused by aquifer-system compaction, drainage of organic soils, underground mining, hydro compaction, natural compaction, sinkholes, and thawing permafrost [1]. This phenomenon has been occurred in many coastal megacities including Ho Chi Minh City, Jakarta, Manila, West Netherlands and Tokyo [2]. The greatest impacts of land subsidence occur to infrastructures that sited on subsiding area.

In many large metropolitan cities situated on flood plain, the main causes of land subsidence are natural compaction, load of building and infrastructure, and over-pumping from ground water [3]. Over the last decades, land subsidence has been considered as a critical hazard in Bangkok. The phenomenon of ground deformation is particularly occurring where the intense urbanization which implies increasing water consumption with a significant pumping of the aquifers especially from household and industry usage.

The Synthetic Aperture Radar (SAR) has been exploited to investigate the land subsidence because it is useful for land cover and regardless of the weather [4]. Sentinel-1 data are used in this research since it is freely available from the ESA's Sentinels Scientific Data Hub. The Differential Interferometry Synthetic Aperture Radar (DInSAR) was used to achieve the results. This technique is based on the analysis of differential interferogram, which interprets the ground deformation occurring between two SAR images at the same area [5]. The objective of this study is to explore the recent land subsidence rates and its correlation to urbanization processes, and also illustrates the applicability of Sentinel-1 data for land subsidence monitoring by using DInSAR technique.

2. STUDY AREA AND DATA

2.1 STUDY AREA

Bangkok is located in the lower central plain and situated on the Chao Phraya river about 28 km, with average elevation of 1.5 m above sea level. The present population in Bangkok is about 9 million in 2017 [6]. In this area, an average annual rainfall in the basin ranges from 1,000 to 1,400 mm [7]. The geological setting of the lower central plain of Thailand is flat and low-lying in the central of country surrounded by mountain in north, east and west and also connected to the Gulf of Thailand. The southern part is Bangkok clay, consisted of brown stiff and soft clay, silt and sand [8], which can be inclined to subsidence (Figure 1).

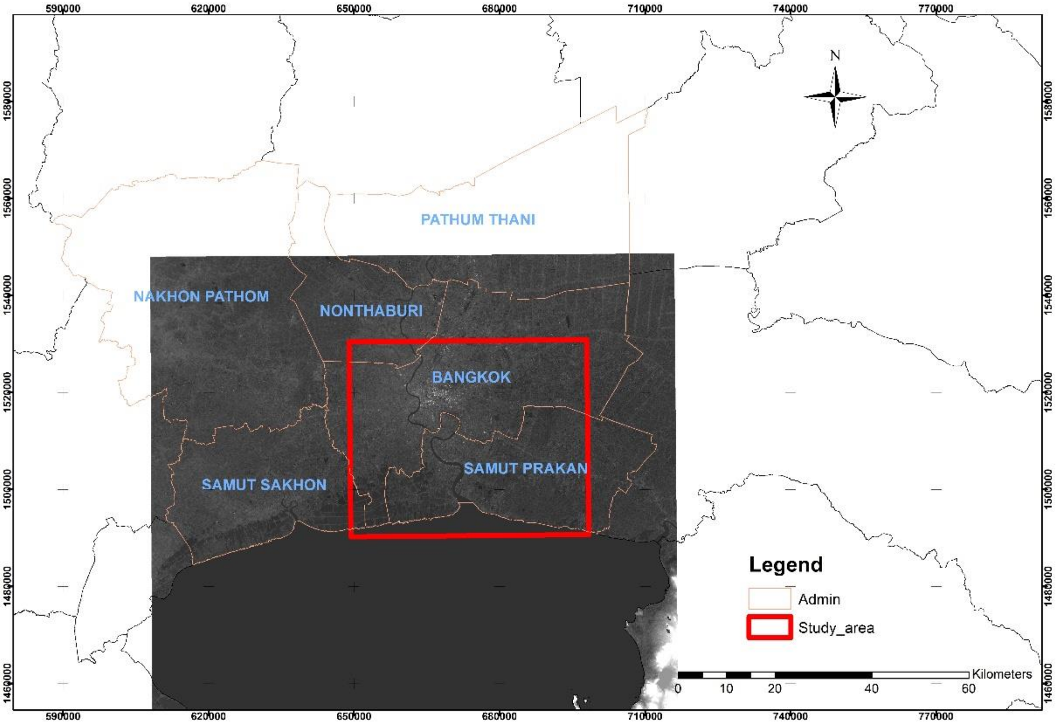


Figure 1. The location of study area (red square), Bangkok Metropolitan

2.2 DATA

Sentinel-1A is a European Space Agency (ESA) radar imaging satellite, launched in April 2014. It has a revisiting time of 12 days and operates in C-band synthetic aperture radar imaging, making it to obtain imagery regardless of the cloud. The C-band SAR instrument supports operation in dual polarization ion (HH+HV, VV+VH), which is useful for land cover classification [9]. In this study, the SAR images, VV+VH dual polarization for Interferometric Wide swath (IW) acquisition mode, acquired between 2015 to 2016 were selected. The detail of image pairs is shown in Table 1. A 30 m Digital Elevation Model (DEM) dataset downloaded from USGS Earth Explorer was also collected to perform DInSAR analysis.

Table 1. Sentinel-1A image pairs information

Image	**Date**	**Mst/Stv**	**Btemp (days)**	**Bperp (m)**
1	25 January 2015	Slave	312	43.80
2	24 July 2015	Slave	132	34.25
3	3 December 2015	Master	0	0
4	8 March 2016	Slave	-96	-18.72

Note: Mst: Master image, Stv: Slave image, Btemp: Day interval, Bperp: Perpendicular baseline

3. METHODS

DInSAR is a technique for measuring ground displacement by calculating the phase difference between two coregistrated SAR images in the same area after the removal of the topographic effect. It can be explained as below:

$$\varphi_{inf} = \varphi_{flat} + \varphi_{topo} + \varphi_{disp} + \varphi_{delay} + \varphi_{noise} \quad (1)$$

where φ_{flat} assumption of an perfectly flat earth terrain; φ_{topo} refers to the topographic distortion; φ_{disp}refers to the displacement along the slant range; φ_{delay} refers to the atmospheric effect; and φ_{noise} refers to noise from radar instrument and temporal deceleration [10]. The displacement map has to estimated in a vertical direction follow equation (2) [11].

$$\Delta z = \Delta sl / \cos\theta \tag{2}$$

where refers to vertical direction ground displacement; refers to slant range ground displacement; and refers to the incidence angle, which ranges between 30-42°in the image dataset.

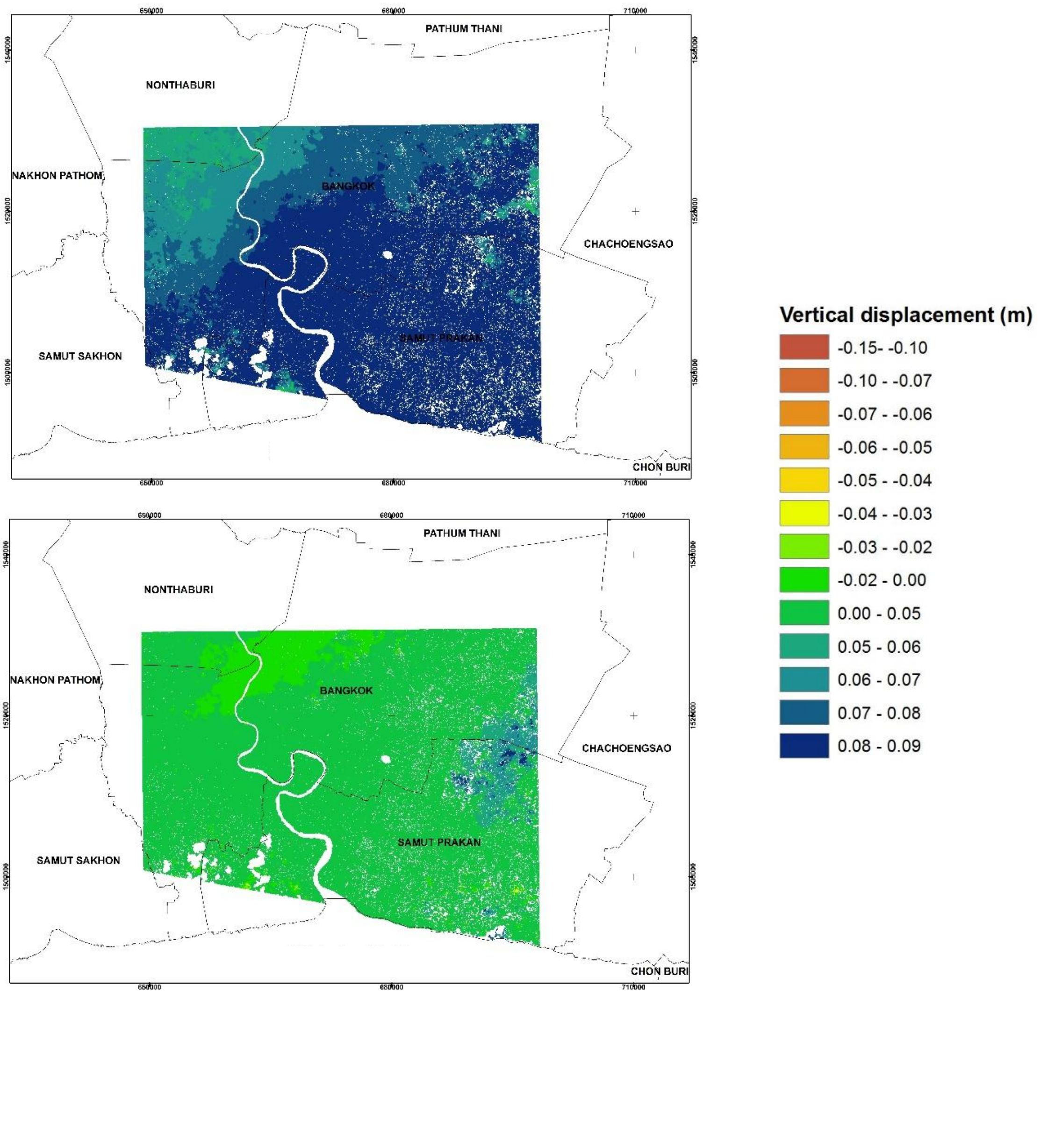
In this study, DInSAR technique is applied based on SAR image pairs using the SARSCAPE module in ENVI software to estimate land subsidence in Bangkok. The DInSAR workflow is briefly described as followings. (1) Image pair matching between master and slave image: the master image was acquired from 3 December 2015 which is suitable used to accumulated land subsidence when comparing to other images (slave images). (2) Image co-registration is the process of master and slave images in the slant range geometry. After the master and slave images can be exactly overlaid, an interferometric can be correctly generated. (3) The 30 m DEM from USGS was applied to imitate the topographic phase to achieve a flattened interferogram. (4) The noise (φ_{noise}) from radar instrument and temporal deceleration was removed by using Goldstein filtering process. (5) The differential phase was unwrapped using a minimum cost flow method, and 0.20 coherence threshold is used to minimise errors. (5) The phase values were converted to displacement by using equation (1) and (2) and projected onto a map projection.

4. RESULTS AND DISCUSSION

We processed the sentinel-1 SAR images in a region of Bangkok with the SARSCAPE module in ENVI software. The results show that ground surface in Bangkok metropolitan has been subsiding within 2 years of observation period, 25 January 2015-8 March 2016 (Figure 2). The significant subsidence is at the eastern side and the Southwestern of Bangkok since they are the factory area implied increasing water consumption. Figure 2 shows the vertical displacement rate in meter. The subsidence value of figure 2(a) and 2(b) are positive while figure 2(c) is negative value because the master image is 3 December 2015. We found that in general the center of Bangkok to be subsiding with a rate of ~ -5 cm/year.

(a)

(b)



(c)

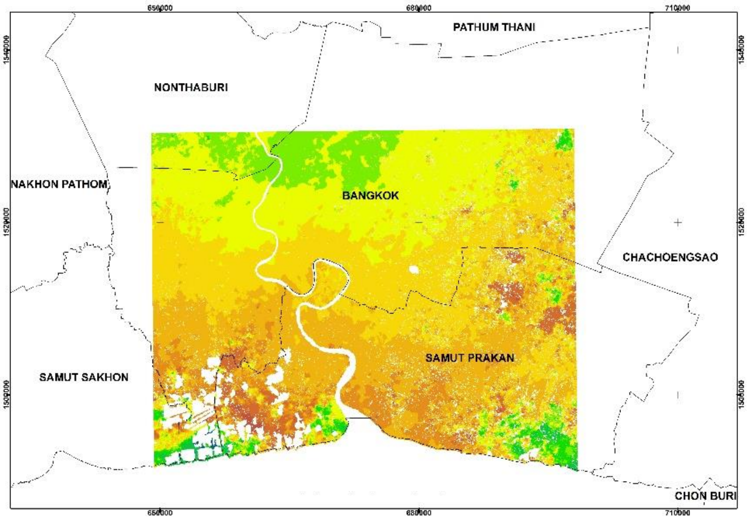


Figure 2. Vertical displacement showing values in meter from DInSAR analysis of Sentinel-1 images with reference to the December 2015. (a) Vertical displacement between 25 January 2015 - 3 December 2015, (b) Vertical displacement between 24 July 2015 - 3 December 2015 and (c) Vertical displacement between 3 December 2015 – 08 March 2016

5. CONCLUSION

We produced the recent ground displacement using DInSAR technique and Sentinel-1 SAR imagery acquired from January 2015 to March 2016. Although it has been reported that the use of ground water has decreased, our result shows that Bangkok has subsided with the rate of -2 to -5 cm/yr. Moreover, this study illustrates the applicability of Sentinel-1 data for land subsidence detection monitoring.

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