Utilization Of PS-InSAR Method Optimizing in Land Subsidence Disaster Mitigation in Bandung City (Indonesia)

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Key words: DInSAR, Geodetic, GPS, Land Subsidence, PS InSAR.

SUMMARY

Spatial technology dependency in monitoring and analyzing every natural disaster events in the currently time is very high. Especially in the Indonesia teritory, which has a wide variety the characteristics of natural disasters and the scale of the natural disaster area. It is requires a lot of combination of spatial technologies to be able quick assessment of natural disaster impact in disaster mitigation concepts. One of the many terrestrial technologies that are part of the natural disaster mitigation process is the radar technology. The ability of radar technology that can penetrate cloud cover and large area coverage to be one of the advantages of quick assessment process.

Application of PS-InSAR technology that has advantages in minimizing the decorrelation effects and get a good accuracy than other radar methods. Make it as research material in this study, especially the analysis of the influence of the data reduction, a combination of data level and the coherence differences apply. In this study, the study area is Bandung city area with a land subsidence as natural disasters research subject. This technique is used to analyze subsidence in Bandung City, West Java-Indonesia by assessing 19 ALOS PALSAR images (Japanese L band spaceborne) during the periods of July 2007-February 2011. After PS-InSAR processing, the land subsidence results will be validate with land subsidence observations using a GPS method. The results of land subsidence velocity in Bandung city have a various value results between 0,6 ± 0,4 cm/year and 2,1 ± 1,2 cm/year. The result of validation has resulted such as 1,4 ± 1,4 cm/year (PS InSAR-DInSAR) and 1,6 ± 0,7 cm/year (PS-InSAR-GPS). Analysis of the effect of PS-InSAR processing results of the combined use of data ALOS PALSAR level 1.0 and 1.1 as well as differences in the determination of the value of coherence was also performed.

The objective of this research is to get a light processing in PS-InSAR method as part of quick assessment in disaster management concept. Also this research shows a capability of data optimalization in PS-InSAR technique as basic concept of PS-InSAR optimizing.

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1. INTRODUCTION

A case study is Bandung city which is located in western Java Island-Indonesia at longitude $107^0 10'48"$-$108^0 13'12"$ and latitude of $6^0 10'48"$-$7^0 44'24"$ as shown in Fig 4.

The compaction in alluvial sediments containing clay causes land subsidence in Bandung. Compaction is a natural process that it happens by uncontrolled usage and overexploitation of ground water, especially in Bandung's industrial area. This over-exploitation of ground water is leading to a rapid decline of water levels, drying out clay layers that finally results in land subsidence [2]. The PS-InSAR technique is used to derive long-term consecutive deformation changes at the surface and eliminate decorrelation effects in final result. We implemented the phase information of consecutive multiple complex data as PS-InSAR data to retrieve the volume change caused by long-term consecutive land surface deformation especially subsidence or uplift.

PS-InSAR technique was published in first time in Permanent Scatterers in SAR interferometry journal [6] at International Geoscience and Remote Sensing Symposium-Hamburg Germany, 28 June-2 July 1999. The advantage of this method compared to other method such as DInSAR method, it can eliminate decorelation effects and improve result accuracy. But the disadvantage of PS-InSAR method were needed a large number radar images and a high hardware specification. In this research, we try to optimize images data with iteratively reducing a number images data. Beside to know the optimal time processing, the PS-InSAR was validated by the other methods like DInSAR and GPS. From this validation, we knows the best of number images data in PS-InSAR processing in order to get an accurate land subsidence value.

2. PS-INSAR METHOD

PS-InSAR technique is applied in a long duration measurement ALOS PALSAR data and is used to investigate the land subsidence rate in Bandung city.

Nineteen ALOS PALSAR images are used to observe study area from the period September 10^{th}, 2007 through February 11^{th}, 2010, as shown in Tab 1. In order to get and visualize the subsidence rate in study area, we will combine the other data like geographic and geodetic data. To get one master image from stack ALOS PALSAR images, we use precise estimation method and the most recent image will become slave images, as shown in Fig 1. Based on this rule, we can get a lot of combination between master and slave image that it is depend on a number of images. From 19 ALOS PALSAR images, we must analyze the critical baseline and normal baseline between images pairs (master image and slave

images set). We put minimum coherence value (0.9) and PS density point (200), in order to get good coherence between master slave images combination. Otherwise, the geometry of radar geometry for land deformation [10] as shown in Fig 2.
Based on Fig 2 [10], we can compute vertical deformation from equation 1, 2 and 3 below:

$$dc_{i,j} = -dz_{i,j} \cdot \cos\theta' + dx_{i,j} \cdot \sin\theta' \quad ....(1)$$

$$z' = -\frac{r_m \sin\alpha}{B_p}\left(\frac{\lambda\phi}{4\pi} - B_h + dc_{i,j}\right) \quad ....(2)$$

where is wavelength. i, j (=1, 2, …) shows sub-pixel position. Then B_h and B_p are horizontal and perpendicular baseline distance then α is off-nadir angle. Φ' is incidence angle on a deformed pixel. $dx_{i,j}$ and $dz_{i,j}$ are the displacement of a sub-pixel or a small area at range and elevation directions. $dc_{i,j}$ is the total displacement of a sub-pixel. r_m is slant range distance. We assume the incidence angle on a deformed sub-pixel is same with the incidence angle Φ' at whole area within Φ a pixel. Hence the phase difference ϕ shows the topographical information (z') and total surface deformation ($dc_{i,j}$) in sub pixel as shown in Eqs (2). If we consider only the land deformation at vertical direction (uplift or subsidence) and assume the horizontal deformation could be neglected or $dx_{i,j}$ in Eqs (1) to be zero. The vertical deformation could be derived by employing the Eqs. (1) and (2) as:

$$dz_{i,j} = \frac{1}{\cos\theta'}\left\{\frac{z' B_p}{r_m \sin\alpha} + \frac{\lambda\phi}{4\pi} - B_h\right\} \quad ....(3)$$

In this PS-InSAR processing, we use two kind of hardware specifications with a great differences in process capability, as shown in Tab 2. We compare time processing in two kind of hardware in same method (PS-InSAR) to know pattern of optimal time processing.

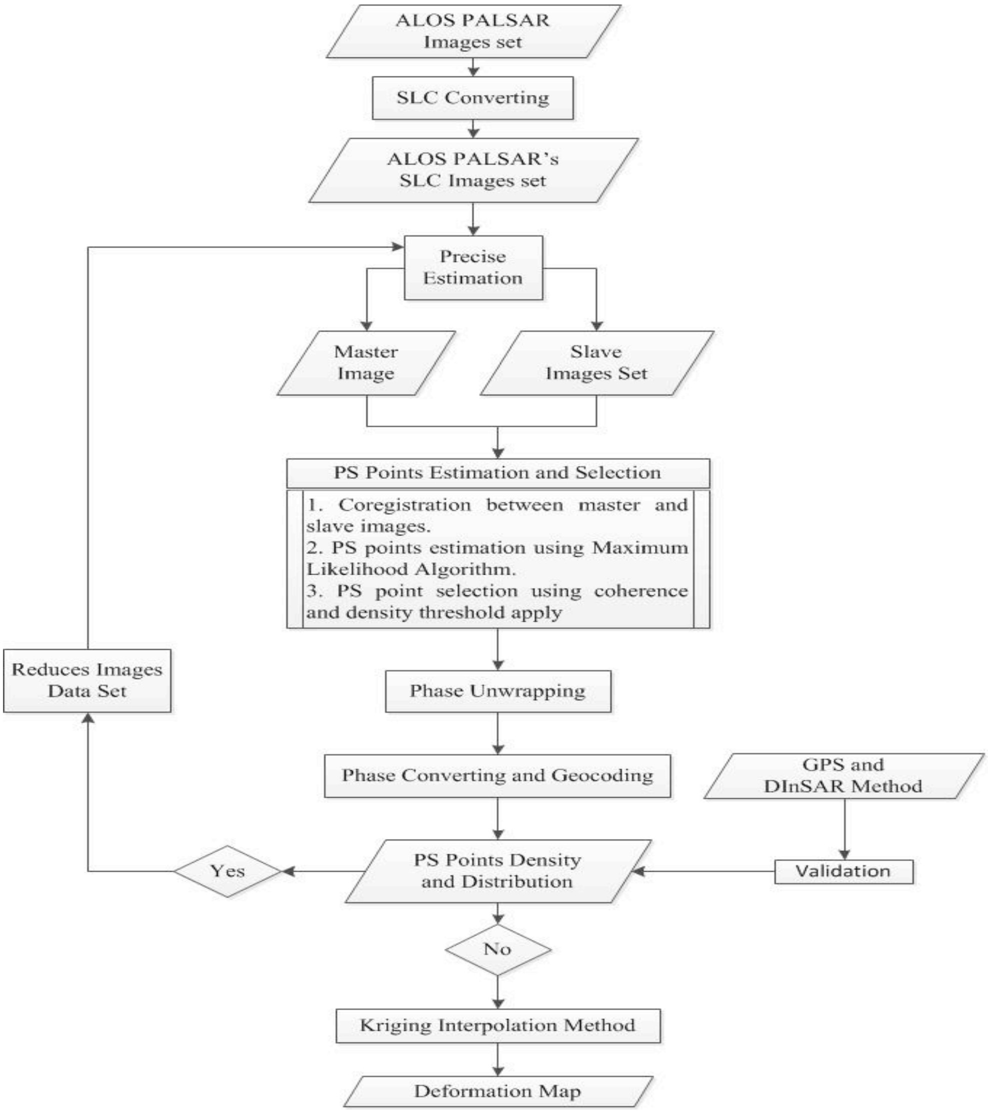


Figure 1. PS-InSAR methodology in the present study

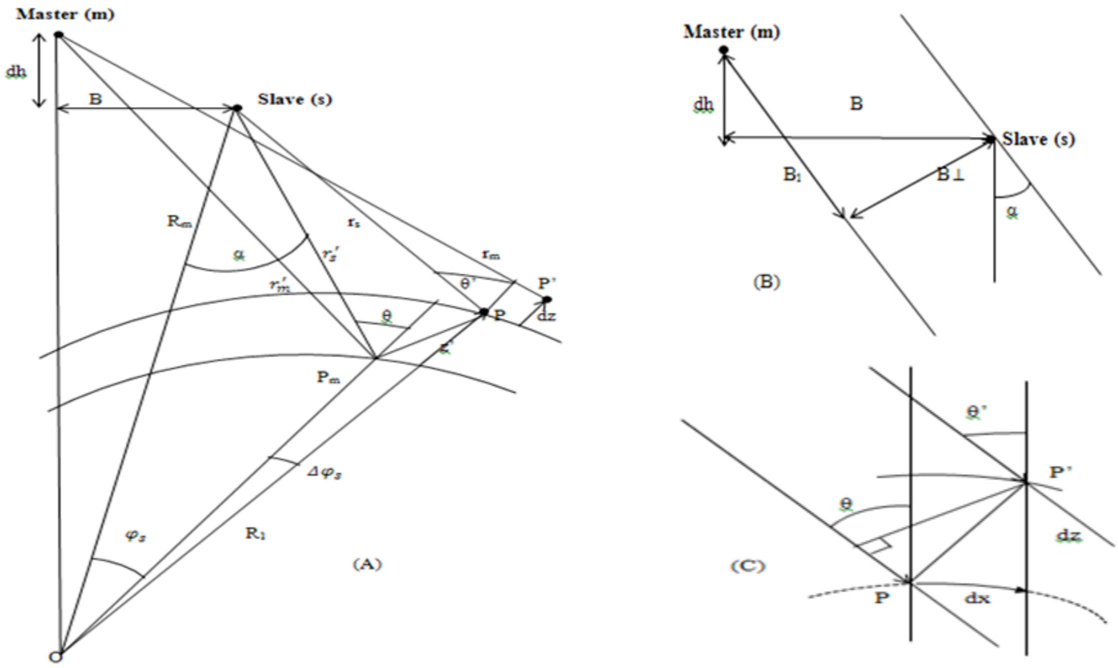


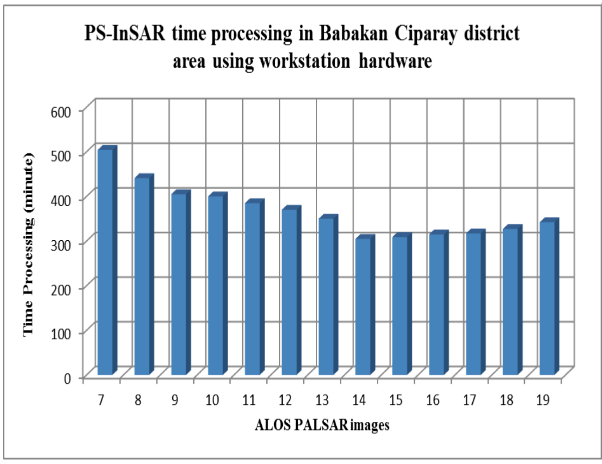
Figure 2. Radar geometry for earth surface deformation (Sumantyo *et al*., 2009)

Table 1. ALOS PALSAR images used in the present study

No.	ALOS Images	Format	Level	Acquisition
1.	ALPSRP086653760	FBS	1.0	10-09-2007
2.	ALPSRP106783760	FBS	1.0	26-01-2008
3.	ALPSRP133623760	FBS	1.0	28-07-2008
4.	ALPSRP153753760	FBS	1.0	13-12-2008
5.	ALPSRP160463760	FBS	1.0	28-01-2009
6.	ALPSRP187303760	FBS	1.0	31-07-2009
7.	ALPSRP207433760	FBS	1.0	16-12-2009
8.	ALPSRP254403760	FBS	1.0	03-11-2010
9.	ALPSRP078707040	FBD	1.1	17-07-2007
10.	ALPSRP085417040	FBD	1.1	01-09-2007
11.	ALPSRP125677040	FBD	1.1	03-06-2008
12.	ALPSRP132387040	FBD	1.1	19-07-2008
13.	ALPSRP186067040	FBD	1.1	22-07-2009
14.	ALPSRP199487040	FBD	1.1	22-10-2009
15.	ALPSRP246457040	FBD	1.1	09-09-2010
16.	ALPSRP248937040	FBD	1.1	26-09-2010
17.	ALPSRP255647040	FBD	1.1	11-11-2010
18.	ALPSRP259877040	FBD	1.1	10-12-2010
19.	ALPSRP269067040	FBD	1.1	11-02-2011

3. RESULTS AND VALIDATION

Based on PS-InSAR processing in two kind hardwares, we can see a pattern of time processing between notebook and workstation as shown in Fig 3. In workstation, we do PS-InSAR processing in Bandung city area that is more larger and heavier than PS-InSAR processing in notebook. It shows the hardware specification requirement in PS-InSAR method held an important factor in order to get an optimal process.



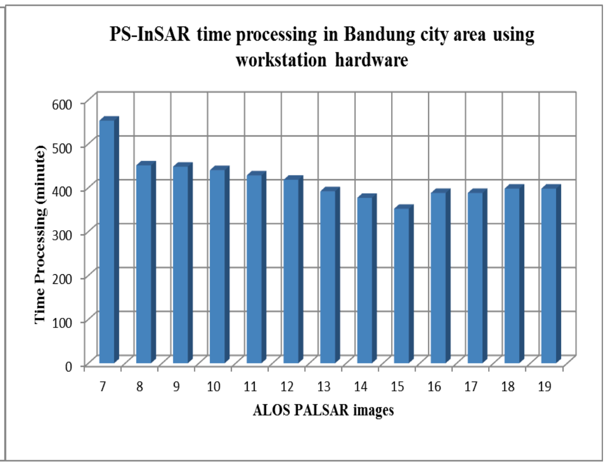


Figure 3. Time processing results from consecutive decreasing number radar images in notebook and workstation hardware.

After PS-InSAR processing, we get a large PS point density and distribution that is contains a land subsidence value, as shown in Fig 3. In next step, we process this PS points with Kriging interpolation method to get a good spatial modelling of land deformation, as shown in Fig 4. The final result, we get a deformation map that is show a deformation pattern of Bandung city.

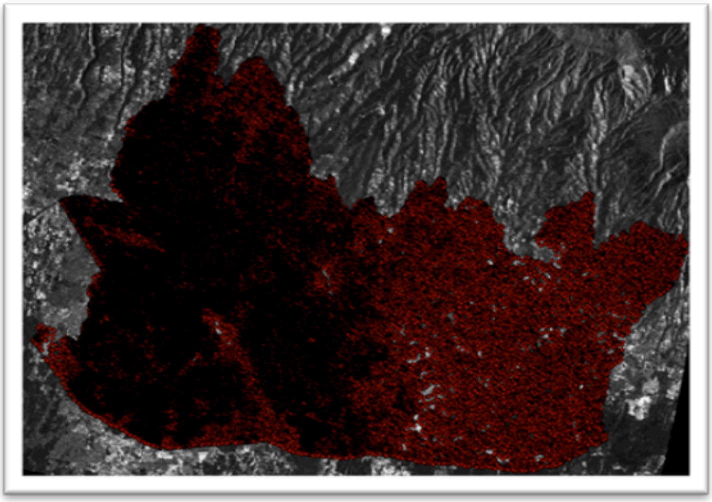


Figure 3. PS points density distribution of PS-InSAR processing in Bandung city area.

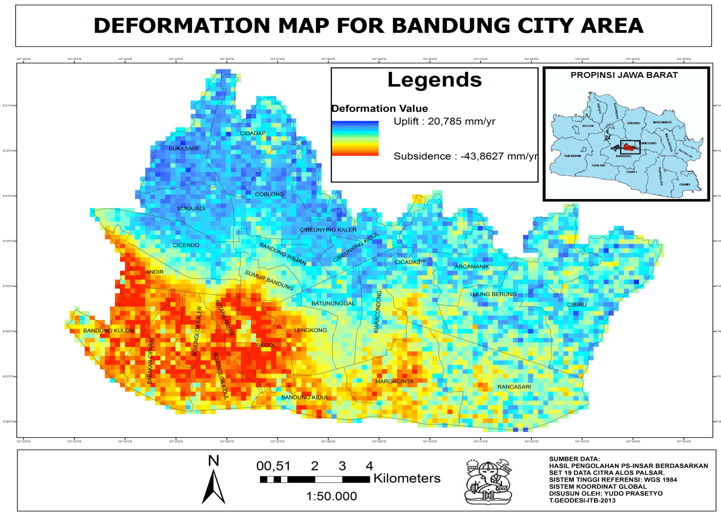
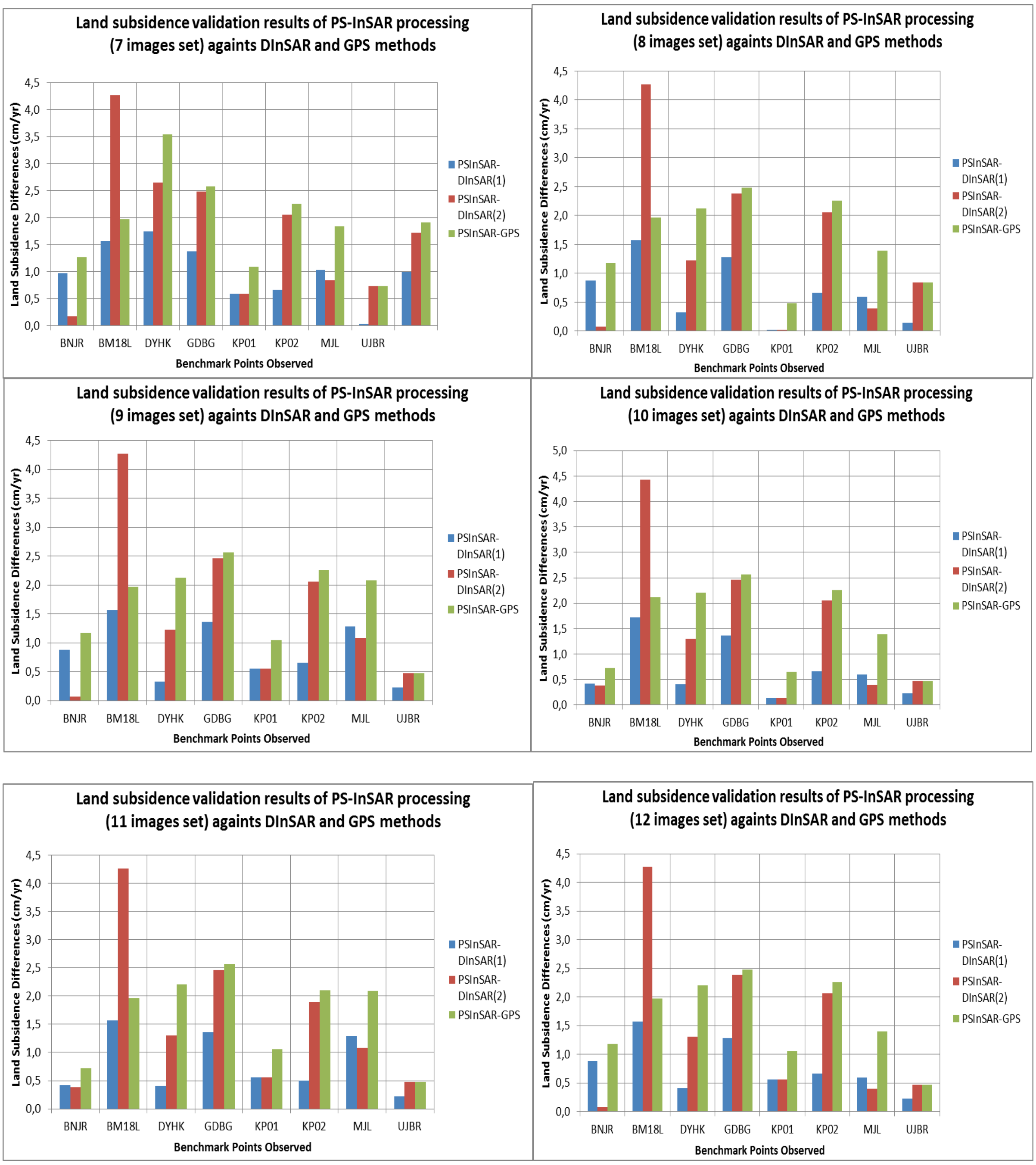
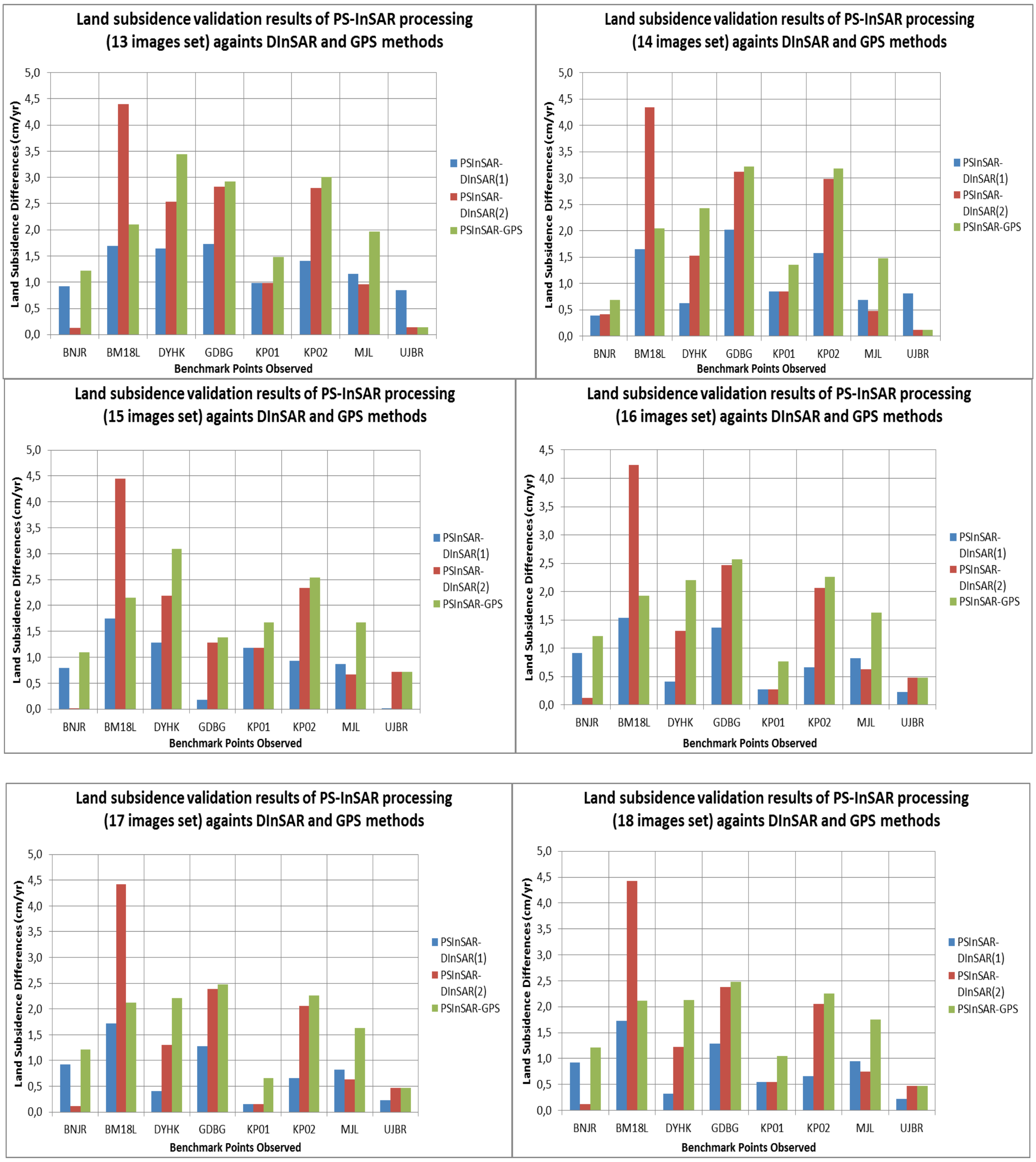


Figure 4. Deformation map from PS-InSAR processing in Bandung city area.

In order to confirm the PS-InSAR processing results that will be used for land subsidence calculation, we compared the vertical deformation or subsidence obtained by DInSAR [12] [13] and GPS observation [13]. Eight points of GPS observation are prepared to investigate the subsidence in the study area and used to validate the PS-InSAR results, as shown in Fig 6. Based on validation results, we know the optimal number of ALOS PALSAR images in PS-InSAR processing compare to DInSAR and GPS methods, as shown in Fig 5. Final results of PS-InSAR processing are land subsidence values in every districts of Bandung city, as shown in Fig 6.


Land subsidence validation results of PS-InSAR processing
(7 images set) againts DInSAR and GPS methods
Land subsidence validation results of PS-InSAR processing
(8 images set) againts DInSAR and GPS methods
Land subsidence validation results of PS-InSAR processing
(9 images set) againts DInSAR and GPS methods
Land subsidence validation results of PS-InSAR processing
(10 images set) againts DInSAR and GPS methods
Land subsidence validation results of PS-InSAR processing
(11 images set) againts DInSAR and GPS methods
Land subsidence validation results of PS-InSAR processing
(12 images set) againts DInSAR and GPS methods
Land Subsidence Differences (cm/yr)
Benchmark Points Observed
BNJR
BM18L
DYHK
GDBG
KP01
KP02
MJL
UJBR
PSInSAR-DInSAR(1)
PSInSAR-DInSAR(2)
PSInSAR-GPS


Land subsidence validation results of PS-InSAR processing (13 images set) againts DInSAR and GPS methods
Land subsidence validation results of PS-InSAR processing (14 images set) againts DInSAR and GPS methods
Land subsidence validation results of PS-InSAR processing (15 images set) againts DInSAR and GPS methods
Land subsidence validation results of PS-InSAR processing (16 images set) againts DInSAR and GPS methods
Land subsidence validation results of PS-InSAR processing (17 images set) againts DInSAR and GPS methods
Land subsidence validation results of PS-InSAR processing (18 images set) againts DInSAR and GPS methods
Land Subsidence Differences (cm/yr)
Benchmark Points Observed
BNJR
BM18L
DYHK
GDBG
KP01
KP02
MJL
UJBR
PSInSAR-DInSAR(1)
PSInSAR-DInSAR(2)
PSInSAR-GPS

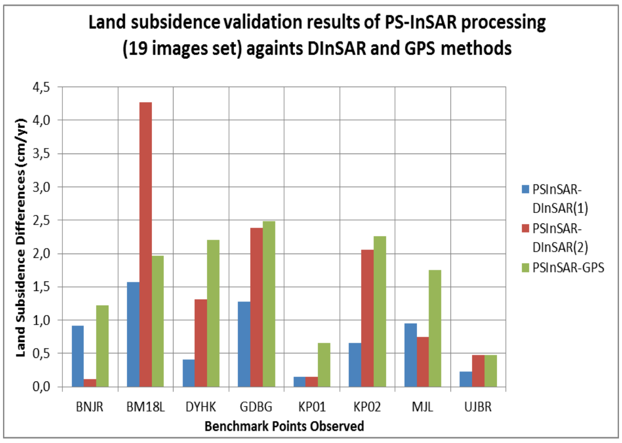


Figure 5. Distribution of GPS Points Observed.

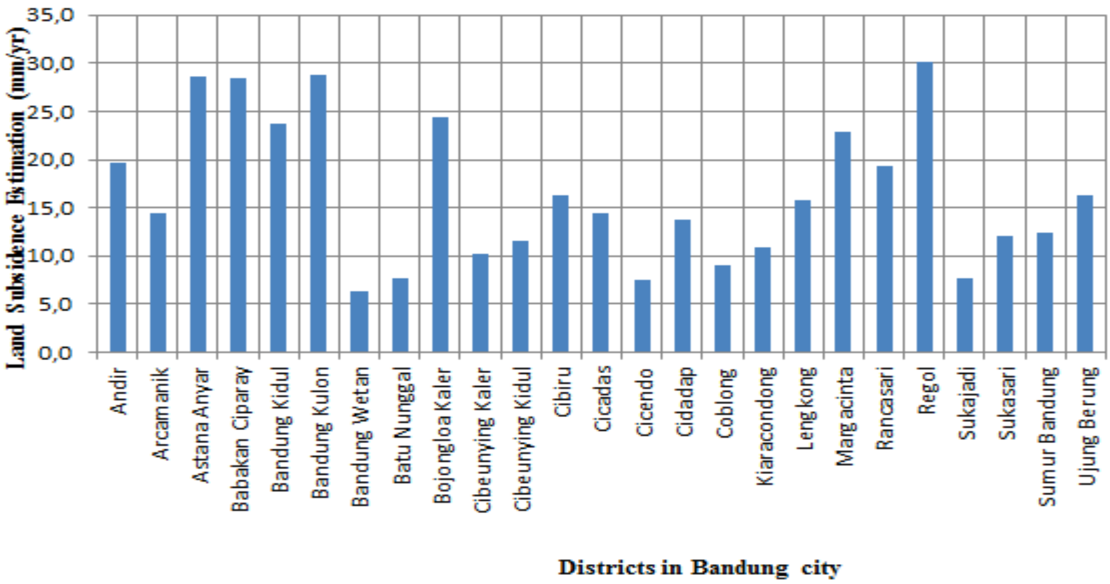


Figure 6. Land subsidence value estimation in Bandung city from 12 ALOS PALSAR images with PS-InSAR technique

4. CONCLUSION

Based on PS-InSAR results, validation and analysis of the research, we can summarize several conclusions as follows:

1. In order to get better result in land subsidence value computation using PS-InSAR method, we will need a good hardware system with multi-processor core, 4 GB minimum internal memory and cooling system. Otherwise, a fewer radar images were used in PS-InSAR processing, it could increase time processing. To compensate time processing increase, the highly hardware specification was needed to reduce span time

processing. The balancing between hardware specification with a minimum software requirements will optimize the PS-InSAR processing.
2. In this research, PS-InSAR method can process a minimum radar images set with good results in validation step. This method can process 7 ALOS PALSAR images set from 19 ALOS PALSAR raw images to get land subsidence value. It proves that PS-InSAR method can be done with a data images set that are not always large number regardless of the need for accuracy and reliability.
3. The results of PS-InSAR validation to the previous DInSAR (DInSAR[1]) produce the smallest difference in standar deviation value (1.3±0.4cm/yr) from 13 ALOS PALSAR images. Otherwise, the results of PS-InSAR validation to DInSAR (DInSAR[2]-Prof. Josaphat Tetuko Sri Sumantyo, Ph.D) produce the smallest difference in standar deviation value (1.6±1.3cm/yr) from 11 ALOS PALSAR images. Finally, the results of PS-InSAR validation to GPS method (GPS-Prof. DR. Ir. Hasanuddin Zainal Abidin, M.Sc) produce the smallest difference in standard deviation value (1.6±0.7 cm/yr) from 8 and 12 ALOS PALSAR images.
4. Based on PS-InSAR processing, Bandung city has a variety land subsidence value in every districts as shown in Fig 6. The maximum values of land subsidence are variety around 28,7±4,3 mm/yr through 58±9,5 mm/yr in Astana Anyar, Babakan Ciparay, Bandung Kulon and Regol districts.

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He was researcher of Remote Sensing Research Division, Geodesy Engineering, Engineering Faculty, Diponegoro University, Indonesia. He received his Ir. Degree from Gadjah Mada University in 1985, M Eng and Ph.D from Institute of Technology Bandung, Indonesia in 2005 and 2014, respectively. He is member of ISI and MAPIN. His research interests include: polarimetric remote sensing applications, use of microwave for land subsidence deformation monitoring and optical remote sensing applications for urban area development monitoring.

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He was a Researcher with the Indonesian Govermental Agency for Assessments and Application of Technology, Jakarta and the Education and Training Commando (Kodiklat), Indonesia National Army (TNI-AD), Bandung and Baturaja from 1990 to 1999. He was with the Center for Environmental Remote Sensing, Chiba University, Japan as Research Assistant in 2000, and a Lecturer (Post Doctoral Fellowship Researcher) with the Center for Frontier Electronics and Photonics-Venture Business Laboratory (VBL) of the same university from 2002 to 2005. He has been a director with the Remote Sensing Research Center, Pandhito Panji Foundation, Indonesia (www.pandhitopanji-f.org) since 2000. He is currently an Associate Professor (permanent staff) with the Josaphat Microwave Remote Sensing

Laboratory, Center of Environmental Remote Sensing, Chiba University, Japan from 1 April 2005. His main interest include microwave remote sensing (synthetic aperture radar-SAR), SAR onboard small satellite and unmanned aerial vehicle (UAV), weather radar, scattering wave analysis and its applications, analysis of printed (microstrip), carbon micro coil very small antennas for mobile satellite communications and microwave remote sensing, including microsatellite. He is also member of IEICE, JSPRS, and RSSJ. He is Adjunct Professor and Visiting Professor of University of Indonesia, Institute of Technology Bandung, University Udayana and others. He is the recipient of many awards and research grants related to his study and research.

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He was a remote sensing Professor, Faculty of Earth Science and Technology, Institute of Technology Bandung, Indonesia. He received his Ir. Degree from Institute of Technology Bandung in 1975, M.Sc.Eng from University Tolousse III, France in 1982 and Ph.D from Institute of Technology Bandung, Indonesia in 2002, respectively. His research interests include: application and development of radar remote sensing especially in Interferometric Synthetic Aperture Radar, Digital Elevation Model and Land Subsidence monitoring.

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Land and Ocean Observing System (LaOOS) and Environmental Database Development (EnDD) are two main topics of my research which are based on terrestrial, airborne and satellite systems. Those topics focus on application and development of optical and radar remote sensing systems. Those topic focus on application and development of optical and radar remote sensing data in identifying and modelling land use or land cover, disaster, population and other environmental analysis purposes. In the context of national problems, food security (monitoring paddy phase growth and its productivities) and energy security (finding new oil and gas resources as well other renewable energy resources) are also conducted by using remote sensing technology.

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