LAND SUBSIDENCE MONITORING IN JAKARTA DERIVED BY INSAR (2008-2010)

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1. INTRODUCTION

Jakarta Metropolitan, as the capital city of the Republic of Indonesia, is situated on the northern coastal alluvial plane of Jawa which shares boundaries with West Jawa Province in the south and in the east, and with Banten Province in the west. The area of the capital city is about 652 km2 and consist of 5 regions (Center Jakarta = 122.75 km2, North Jakarta = 150.52 km2, East Jakarta = 183.73 km2, South Jakarta = 144.92 km2 and West Jakarta = 130.76 km2). The population of Jakarta was about 800,000 people when Indonesia proclaimed its independence in 1945 and increase to 8.2 million in 1990 as

shown in Figure 1 and Figure 2 *(BAPPEDALDA,2003)*. An annual increase of 2.4% was calculated during the 1980-1990 period. In 2005 the population of Jakarta is estimated to be 12 million. Unlike other regions, over 75% of the population of Jakarta is in an urban

setting. Most people who are working in Jakarta during the day are commuters and live in the three neighboring cities, Bogor and Bekasi (West Jawa Province) and Tangerang (Banten Province). That is why during the day the population of Jakarta may increase up to 10 to 11 million people. Land use in Jakarta is primarily for settlement areas, industrial estates, commercial and trade areas, and government’s and non-governmental offices.

Land subsidence monitoring using InSAR is already commonly used besides the GPS observation. InSAR provide better understanding in spatial variation, which become the weakness of GPS method. Some researchers have been conducted to perform land subsidence monitoring, such as (Hirose 2001), (Chang 2004), (Guoqing 2008), (Koehn 2009), (Abidin 2003), etc.

In case of Jakarta, InSAR method is very appropriate to be applied. Most of land cover is good material for radar backscatter that lead into good SAR observation. Land subsidence derivation from InSAR method in Jakarta will be explained briefly below.

2. DATA

ALOS PALSAR data is the only SAR data available on the research. ALOS PALSAR is a successor of JERS satellite which was operated effectively on July 2006. The most important feature of ALOS PALSAR is the use of L-Band for its radar imaging. The L-Band opens a higher possibility of good data acquisition on a heavy covered canopy like Indonesia. L-Band which has wavelength about 23.6 cm can penetrate the canopy layer very well, so it can improve the correlation between two images.

Another important feature of ALOS PALSAR data is the high orbit accuracy, and smaller de-correlation effect caused by longer temporal baseline compared to other radar satellite which using shorter wavelength. The high of deformation rate is also another constrain of the subsidence monitoring using InSAR method. GPS data show 26 cm of deformation happened in only one year during 2007-2008 (Abidin, 2009). Degree of coherence would affected significantly, or even lost (remain zero) if the deformation gradient exceed one half of the wavelength used (Hanssen,2001).

There are three SAR data involved during the process, which are listed on the table below,

Table 1 : Data Used On The Research

No	Date	Orbit Direction	Sensor Type
1	3 February 2008	Ascending	Fine Beam Sensor
2	5 February 2009	Ascending	Fine Beam Sensor
3	8 February 2010	Ascending	Fine Beam Sensor

All data was taken using Fine Beam Sensor (FBS) mode, and have the same orbit direction as well, ascending. To prevent the data processing from low coherence value, the data were choosen to have same flight track and orbit path. Having the acquisition position as close as possible between the data, which means shorter baseline, is quite important to improve coherence value. The same flight track and orbit are also make all data have more common parameter, such as same look angle, more flapping area, and nearly same line of sight parameter. These parameters are important to result good subsidence map.

The data were received in level 1.0 format. The radiometric correction, auto focusing, and SLC image creation was done using MSP module of Gamma Software. Pictures below show the multi look image created form SLC image format,

Figure 1 : Multi Look Angle of Image Date 3 February 2008

As can be seen from the picture above, most of the area covered Northern part of Jakarta. The southern part of Jakarta was not included on the SAR data because the GPS data indicate small subsidence in this area (Abidin, 2005).

Only 2-pass differential method was used on the research. And 3-arc second of SRTM global DEM data was used on the research. The study used SRTM version 4, which can be downloaded from www.cgiar.srtm.org. The good feature of the SRTM version 4 is that the data is already has less gap, and combined with other global DEM data to improve its quality. Nonetheless, the area which mostly covered by water (e.g. swamp, fish pool, lake, etc.) are remain no data.

3. DEM LIMITATION

SRTM is the best available and open global DEM. Its resolution is 3-arc second or around 90 meter for Jakarta area. Since the SRTM data acquisition was done using C-Band SAR observation, the data is influenced significantly by water coverage on the land. The areas that have much water land cover such as swamp, fish pool, lake, and shore are often badly influenced. On the case of Jakarta area that covered by SAR data, nearly half of the data is sea.

Another problem occurs related with DEM is its accuracy regarding the shoreline. Inaccuracy of the shoreline remains both geocoding and differential problems. Figure below show the comparison of the shoreline from SRTM and high resolution of shoreline from NASA.

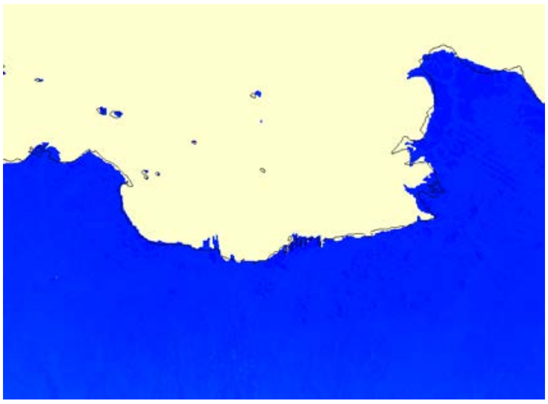


Figure 2: SRTM DEM Overlaped with GSHHS Shoreline

Because the topography in Jakarta region is typically featureless, it leads inaccuracy of the geocoding. The coordinate transformation from the map coordinate system into radar coordinate system would remain high deviation. These limitations may lead to failure of revealing deformation in no-data area. In fact, many area of high subsidence is located on the no-data area.

4. METHOD

On this research, we use only dual-pass differential method to produce the deformation image in Jakarta. Dual-pass DInSAR needs only two SAR images consist of master and slave to produce deformation image. The master and slave combination used on the research are listed on table below,

Table 2 : SAR Image Pair

No	Master Date	Slave Date
1	3 February 2008	5 February 2009
2	5 February 2009	8 February 2010

All SAR data processing, start from Level 1.0 ALOS PALSAR image to deformation image is produced using Gamma SAR Processing. For better visualization and analysis, another software were used. Data processing flowchart can be seen on the diagram below,

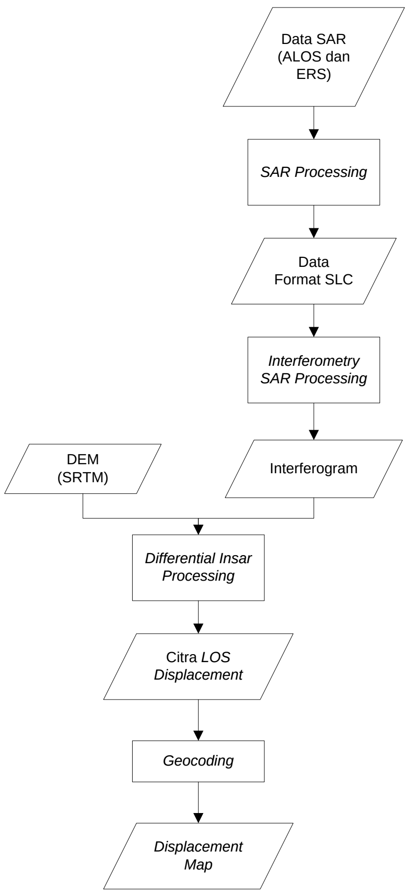
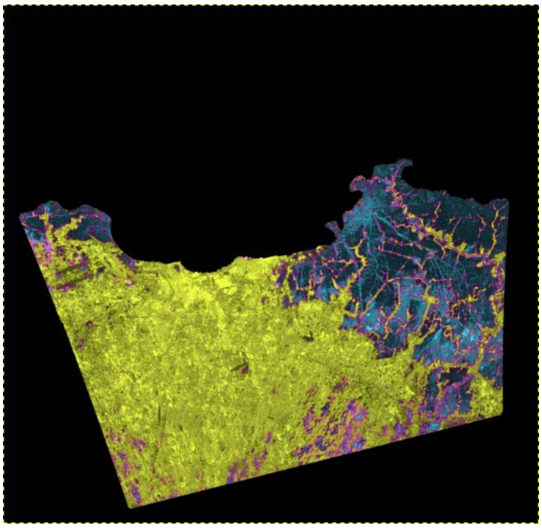


Figure 3 : DInSAR Processing Flowchart

5. RESULT

Principally, there was not significant problem during the data processing. The quality of data processing can be seen from the coherence image from each pair. Figures below depict the coherence value for each pair, yellow show higher coherence value (close to 1), while blue color shows lower coherence value (close to 0). The black color indicate no correlation at all between master and slave image, this usually found in water area, such as sea, swamp, fish pool, etc.



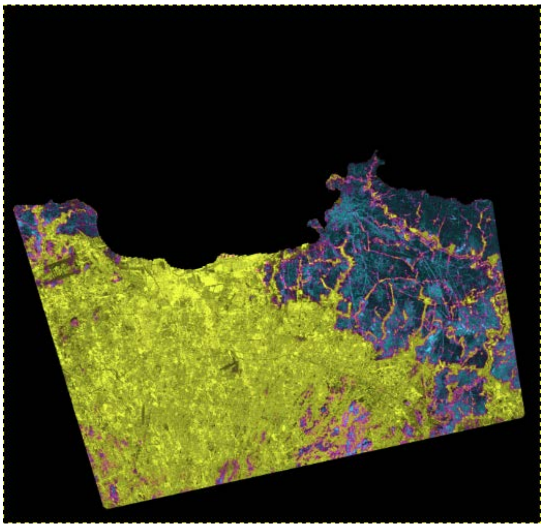
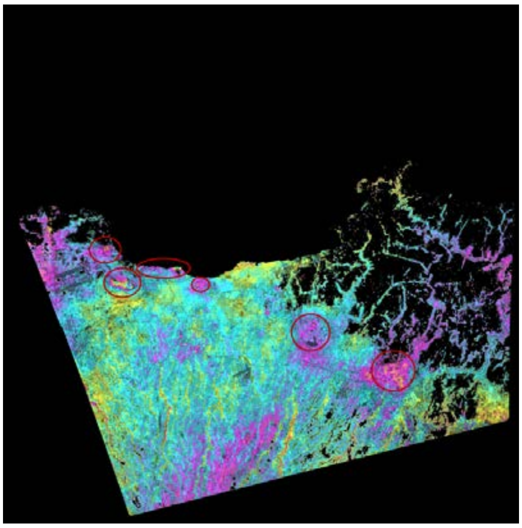


Figure 4 : Coherence image, left : 2008-2009, right : 2009-2010

From the figure above, it is clearly seen that the low coherence value exist the most in the eastern part of the image. That area is located outside Jakarta metropolitan, which a swampy area and there are many fish pool in that region. Administratively, most of the low coherence area is in Kabupaten Bekasi.

The InSAR data processing result shows some regions in Jakarta area are suffering subsidence. Figure below depict the subsidence happen in Jakarta area, produced by Gamma Software,



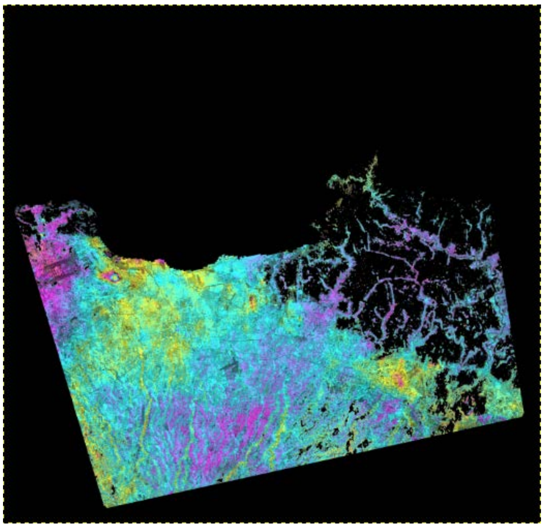


Figure 5 : Deformation Image, left : 2008-2009 right 2009-2010

The red circled area is indicated subsidence. As can be seen, there are at least 6 areas that are indicated subsidence from InSAR observation. Figures below show the deformation map and its magnitude around Jakarta. The highest deformation occurs in the northwest part of the image, which is area of Cengkareng and Daan Mogot. The scale indicate that the deformation on that area reach 19 cm for year 2008 to 2009, and 22 cm for year 2009-2010. The deformation in Muara Baru, and other area adjacent to shoreline cannot be revealed well because the problem of DEM geocoding during the process.

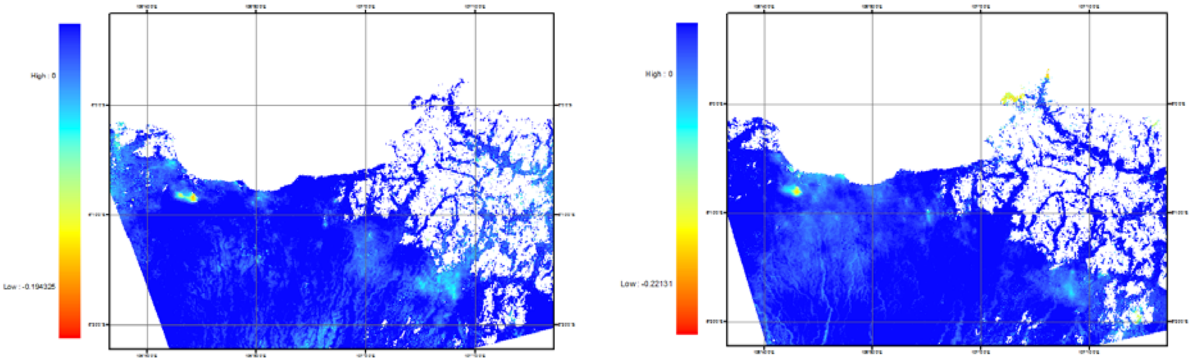


Figure 6 : Deformation Map, left 2008-2009, right : 2009-2010

It should be noted that the deformation value showed on the figure above is referenced to the way satellite look, or in line of sight reference. There are not enough data to decompose it into horizontal and vertical component.

As had been explained earlier, the use of SRTM DEM remains relatively high value of topographic error. The tropospheric error is reduced using model that depend on height. But, considering the DEM is the main problem during the processing, tropospheric error cannot be reduced well. The availability of high resolution DEM, both horizontal and vertical, is needed to perform good analysis of subsidence in Jakarta using InSAR method.

6. SUBSIDENCE IN JAKARTA AND GROUND WATER EXTRACTION

Supplying the water to the user is considering a pressing problem in Jakarta. The volume of groundwater extraction carried out by some people and companies has increased. The groundwater is of considerable economic and social importance because almost 60%-70% of the Jakarta population and the majority of both industries and activities rely on this resource (Adi,1994).

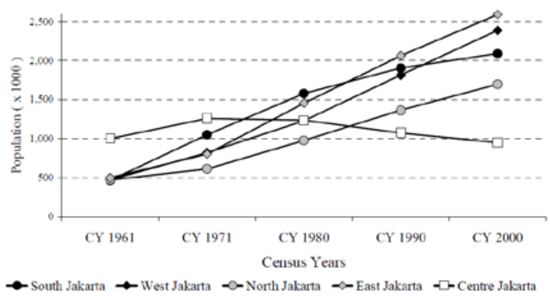


Figure 7 : Jakarta Population Growth

The limited distribution of fresh water in Jakarta affects the people and the industries extract groundwater for their basic needs. This causes imbalances between discharge and recharge of groundwater that resulting in the lowering of the water table in the aquifers. In fact, reducing of the groundwater level (water table) makes getting water from wells more and more difficult, especially for ordinary people who used to get water from their own wells. Coincidentally, a number of groundwater monitoring wells are established in a number of places in Jakarta. Even though, the monitoring is basically intended to assess the availability and the quality of the groundwater.

The explanation above clearly states the positive correlation between ground water extraction and subsidence in Jakarta. Further analysis about this will be done in the future.

7. PLAN IN THE FUTURE

The data processing has not included the GPS data comparison. We will do that in the near future. Another big plan in the future is doing the time series analysis, using both ALOS data and ERS1/2 data since year 1992.

8. REFERENCES

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