

# Environmental Impacts of Land Subsidence in Urban Areas of Indonesia

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## Outline of Presentation

1. Introduction
2. Observed Land Subsidence
3. Impacts of Land Subsidence
4. Environmental Impacts of Land Subsidence
5. Closing Remarks

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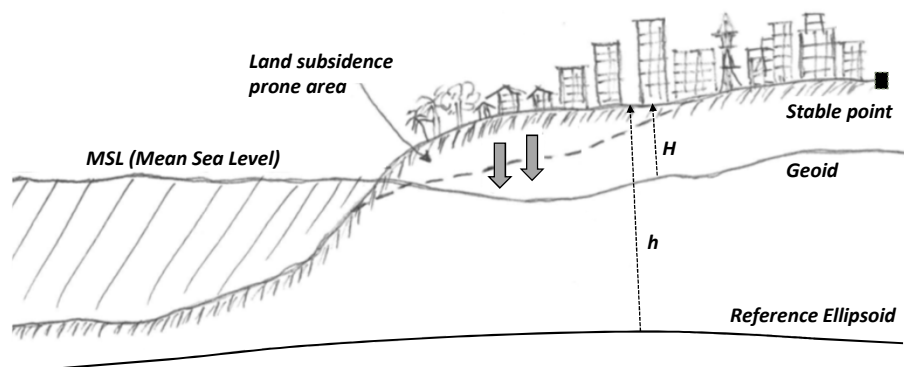
## Land Subsidence

- **Land subsidence** is the downward displacement of the land surface relative to certain reference surface, such as mean sea level (MSL) or reference ellipsoid.
- It may **occurs** in active volcanic and tectonic areas, mining areas, oil and gas exploration areas, and large urban areas.
- Can be **caused** by natural and/or human activities.



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## Land Subsidence



$LS(i,j)$  = land subsidence  
between the two epochs  
 $i$  and  $j$  :

$$LS(i,j) = H(j) - H(i), \text{ or } LS(i,j) = h(j) - h(i)$$

$$LS(i,j) = dH(j) - dH(i), \text{ or } LS(i,j) = dh(j) - dh(i)$$

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## Land Subsidence in Indonesian Cities



Observed land subsidence :

- Jakarta
- Bandung
- Semarang

Expected land subsidence :

- Surabaya
- Denpasar *observed decrease in groundwater level*
- Cilegon *observed decrease in groundwater level*
- Medan

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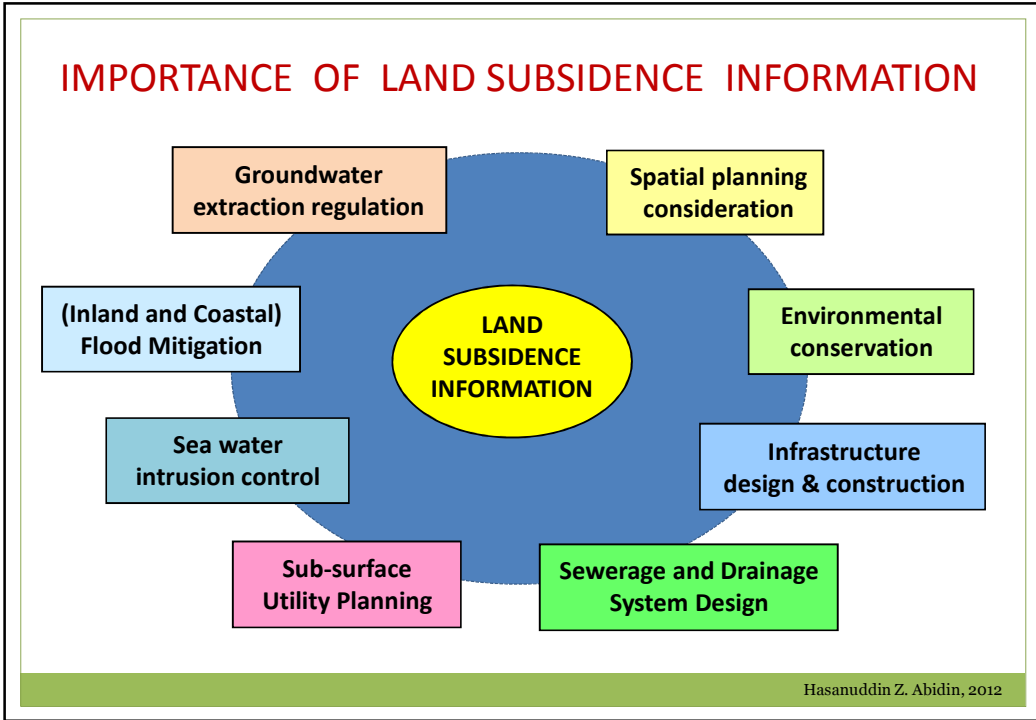
## Causes of Land Subsidence

Causative factors of land subsidence in urban areas of Indonesian :

- |                      |  |
|----------------------|--|
| <b>ANTHROPOGENIC</b> | 1. excessive groundwater extraction,   |
|                      | 2. load of buildings and constructions (i.e. settlement of high compressibility soil), |
| <b>NATURAL</b>       | 3. natural consolidation of alluvium soil, and   |
|                      | 4. tectonic activity.  |

Land subsidence is usually caused by combination of factors

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# Observed Land Subsidence

## Geodetic Methods for Land Subsidence Monitoring

City	Leveling	GPS	InSAR	Gravity	Geometric - Historic
<b>JAKARTA</b>	Since 1982	Since 1997	Since 2005	Since 2008	Since 2010
<b>BANDUNG</b>	Limited	Since 2000	Since 2007	Since 2008	Since 2010
<b>SEMARANG</b>	Since 1999	Since 2008	Since 2007	Since 2002	Since 2011

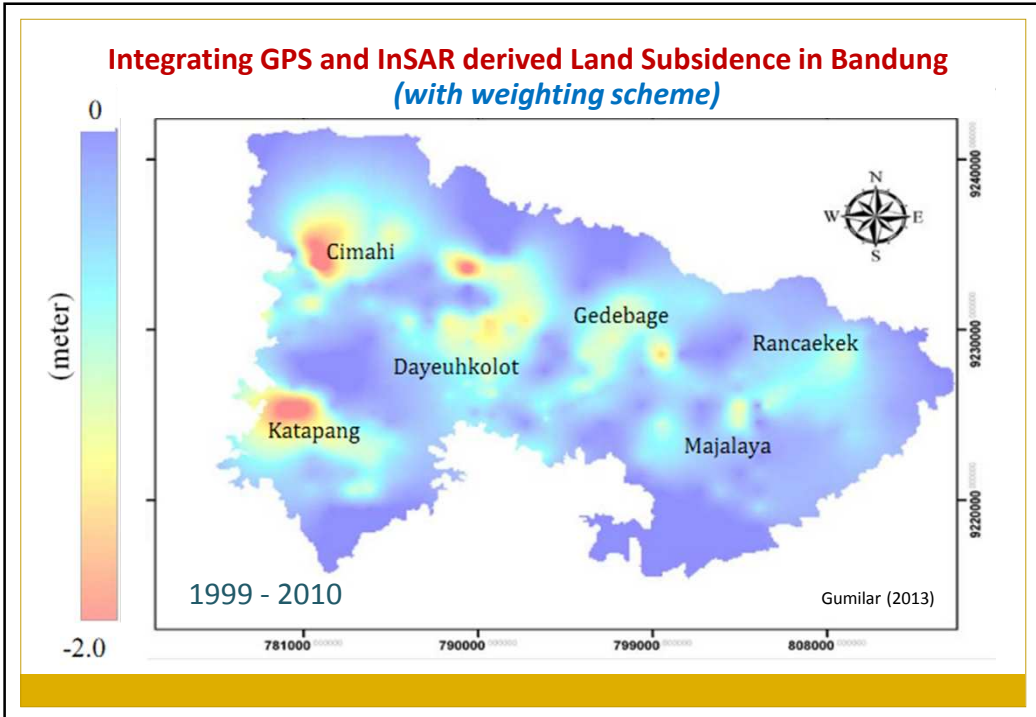
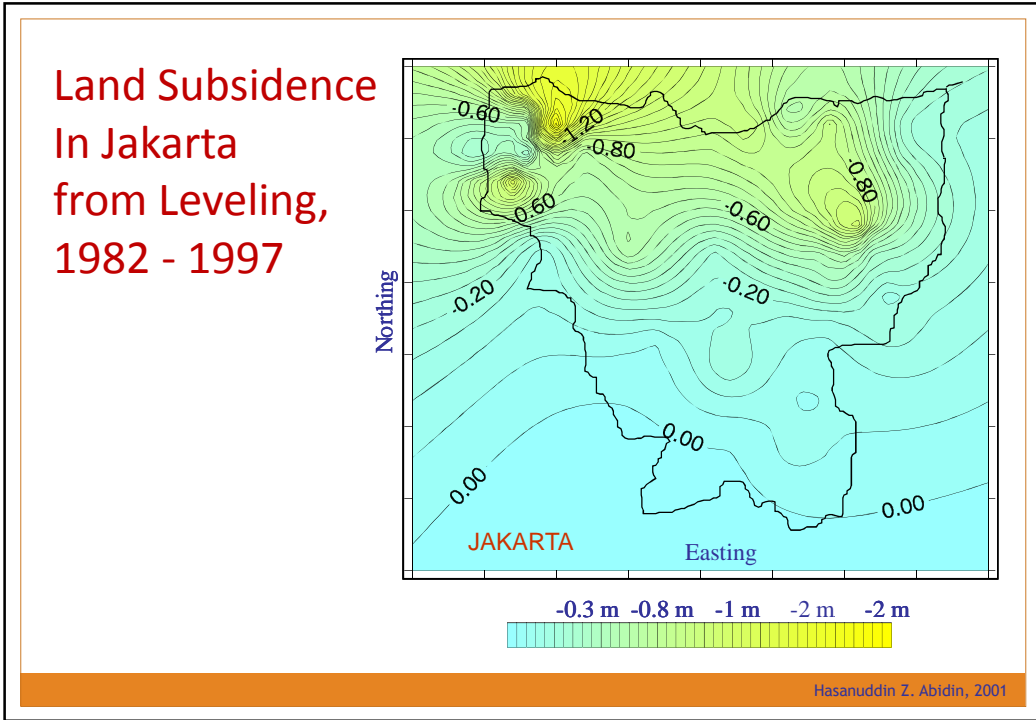
**Geodesy Research Group of ITB mainly involved with GPS Surveys, InSAR and Geometric - Historic**

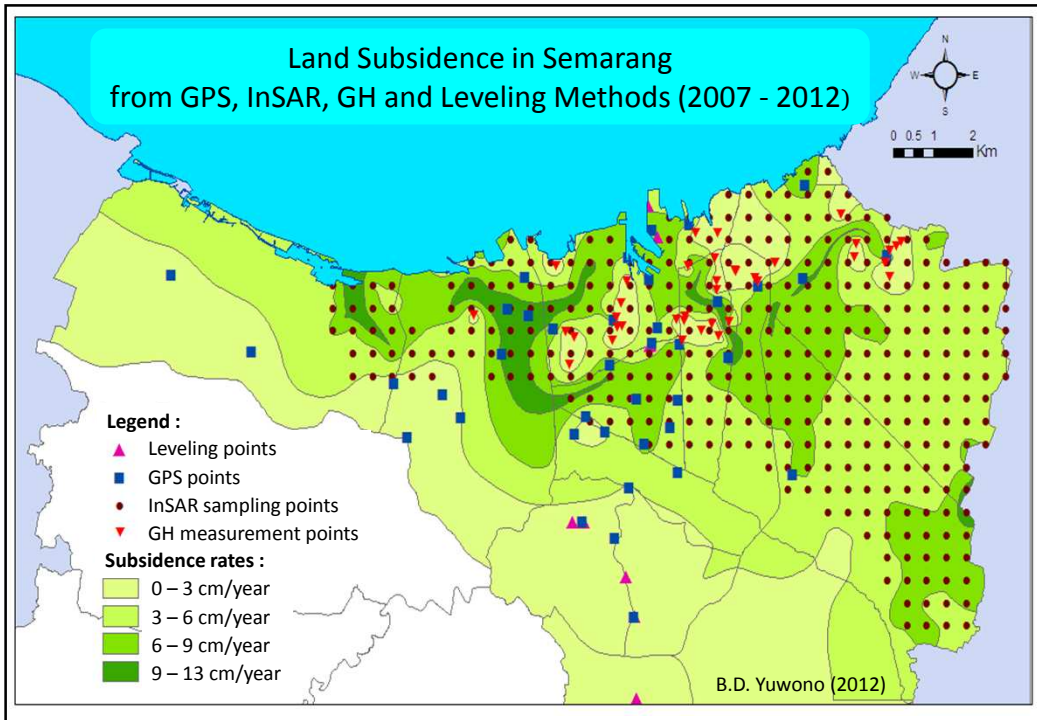
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## Summary of observed land subsidence rates in Jakarta, Bandung, and Semarang

No.	Method	Subsidence Rates (cm/year)		Observation Period	References
		Min - Max	Typical		
<b>JAKARTA</b>					
1	Leveling Surveys	1 - 9	3 - 7	1982 - 1991	Abidin et al. (2001, 2008a, 2010a, 2011, 2012a, 2012b, 2013a), Ng et al. (2012)
		1 - 25	3 - 10	1991 - 1997	
2	GPS Surveys	1 - 28	4 - 10	1997 - 2011	
3	InSAR	1 - 12	3 - 10	2006 - 2010	
<b>BANDUNG</b>					
1	GPS Surveys	1 - 23	4 - 11	2000 - 2010	Abidin et al. (2008b, 2009, 2012a, 2013b), Chaussard et al. (2013), Chatterjee et al. (2013)
2	InSAR	1 - 19	5 - 12	1999 - 2010	
<b>SEMARANG</b>					
1	Leveling Surveys	1 - 17	2 - 10	1999 - 2003	Abidin et al. (2010b, 2012b), Kuehn et al. (2009), Murdohardono et al. (2007, 2009), Supriyadi (2008)
2	GPS Surveys	1 - 19	3 - 10	2008 - 2011	
3	PS InSAR	1 - 10	3 - 8	2002 - 2006	
4	Microgravity	1 - 15	2 - 10	2002 - 2005	

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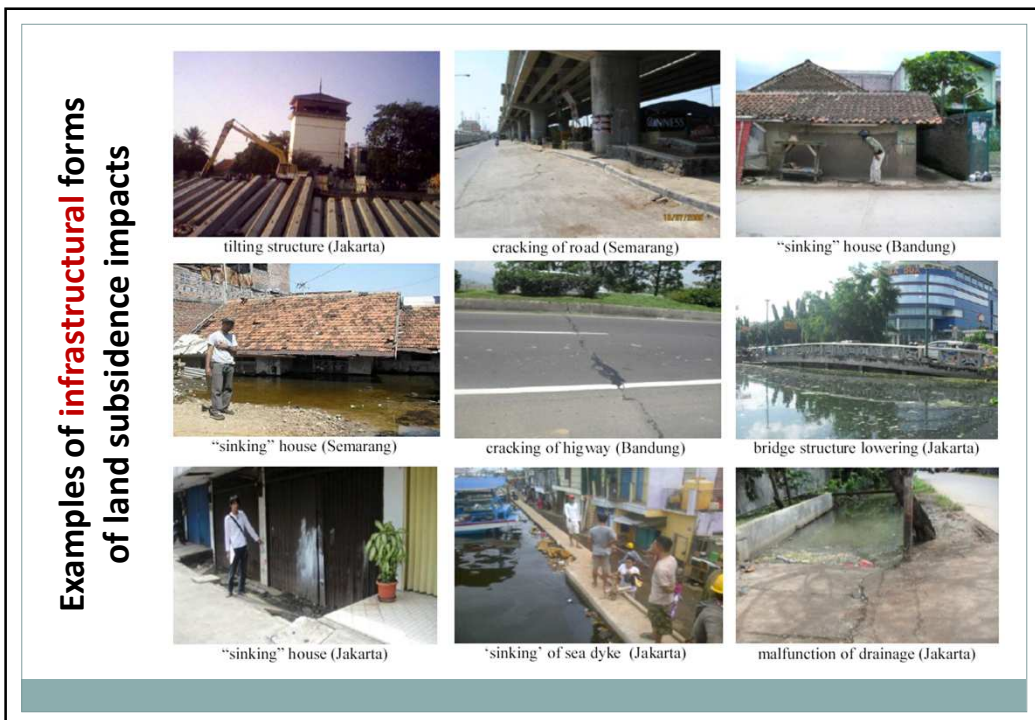
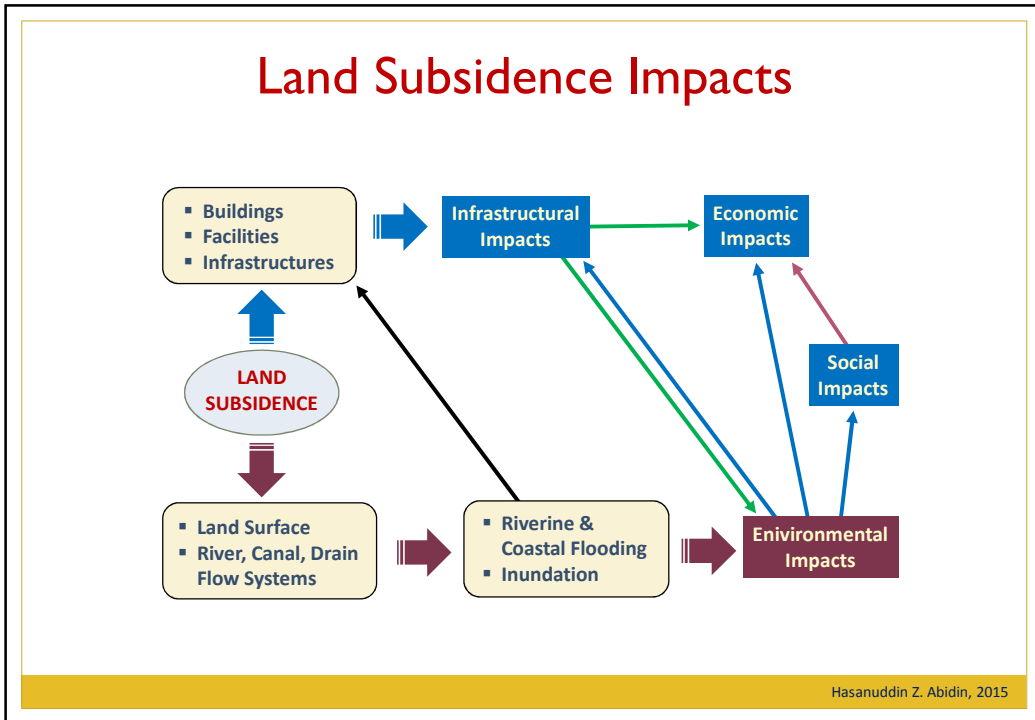


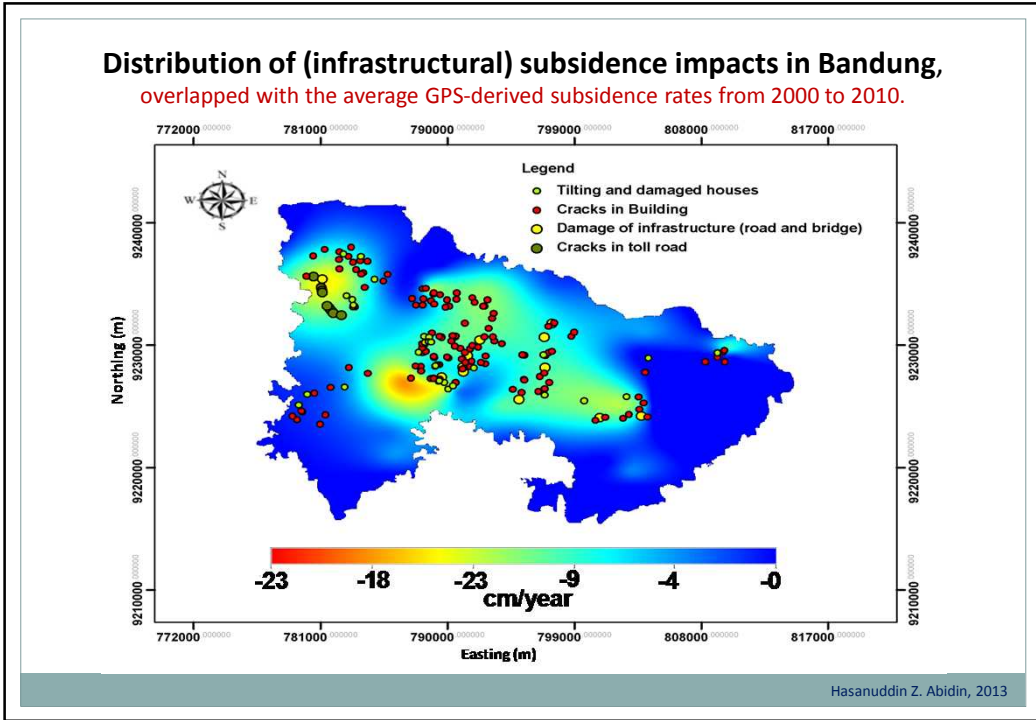
# Land Subsidence Impacts

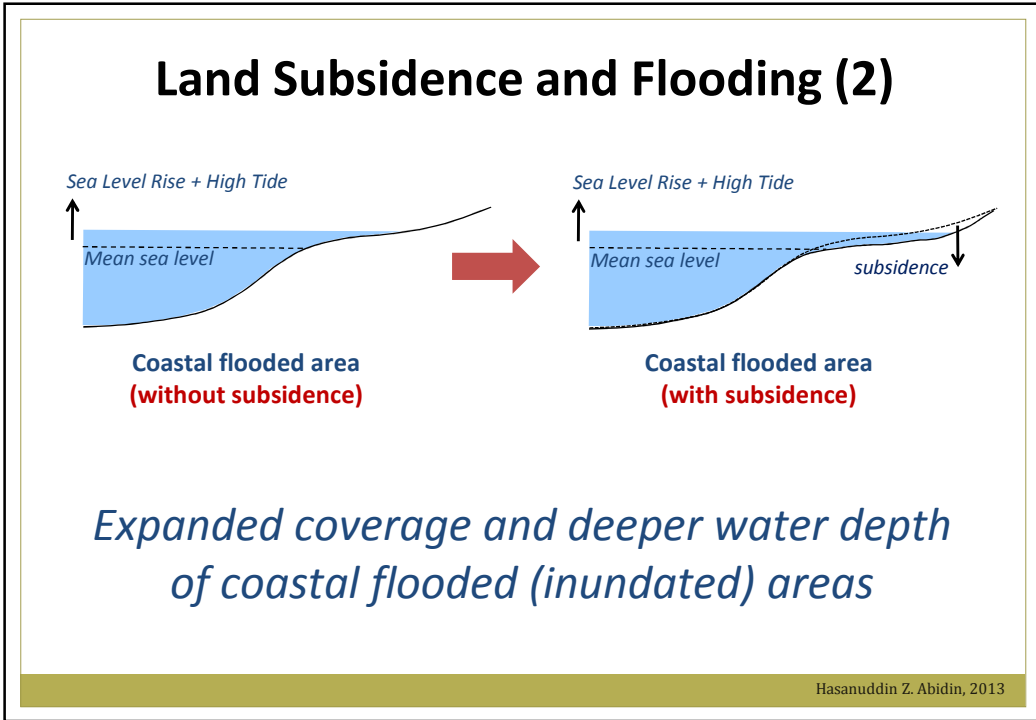
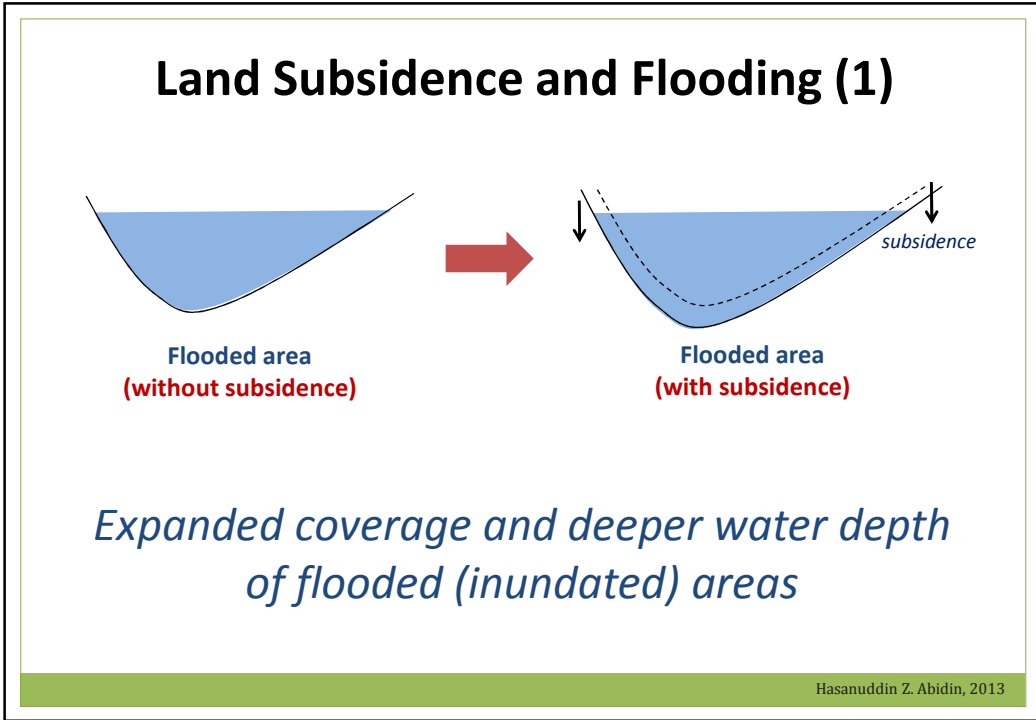
<b>IMPACTS OF LAND SUBSIDENCE IN URBAN AREAS (CITIES)</b>		
<b>Cracking of buildings and infrastructure</b>	<b>The wider expansion of inland &amp; coastal flooding areas</b>	<b>Malfunction of drainage system</b>
<b>Increasing the maintenance costs for the affected buildings and infrastructure</b>		<b>Changes in river canal and drain flow systems</b>
<b>Lowering the quality of living environment and life (e.g. health and sanitation condition) in the affected areas</b>		
<small>Hasanuddin Z. Abidin, 2012</small>		

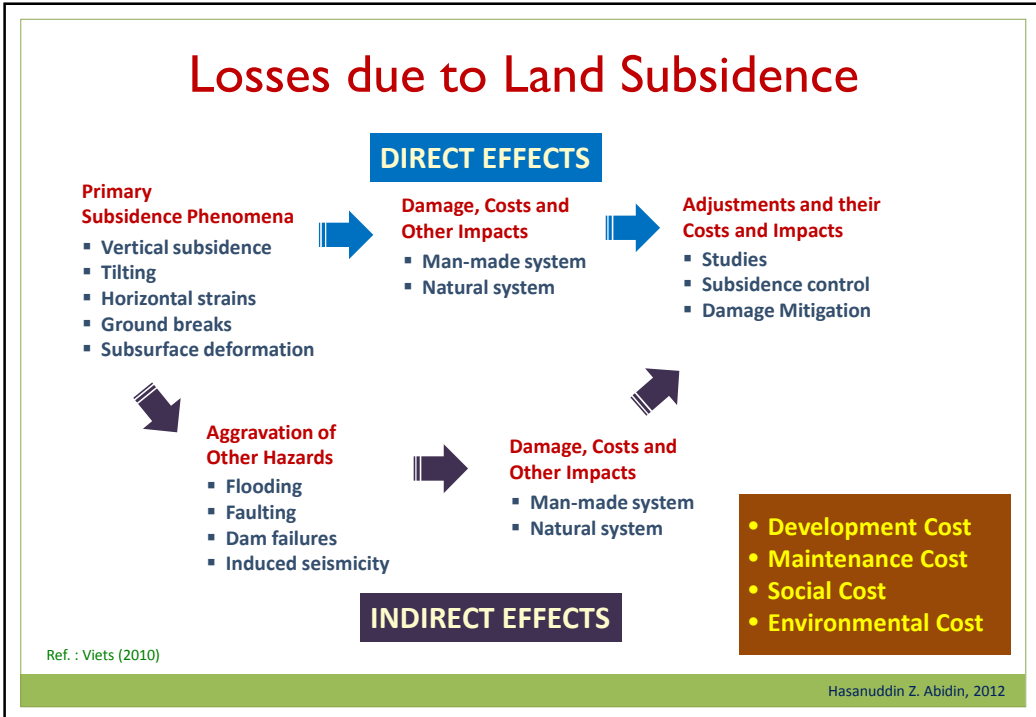
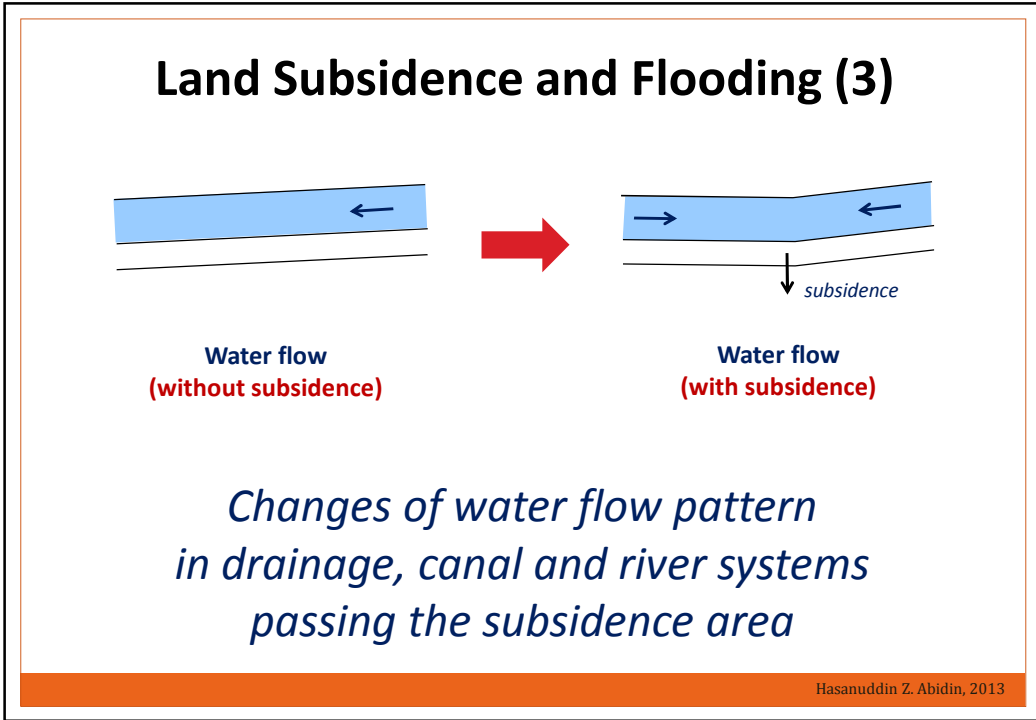
<b>CHARACTERISTICS OF LAND SUBSIDENCE IMPACTS</b>			
No.	Category	Representation of impact	Level of impact
1.	Infrastructural	cracking of permanent constructions and roads	direct
		tilting of houses and buildings	direct
		'sinking' of houses and buildings	direct
		breaking of underground pipelines and utilities	direct
		malfunction of sewerage and drainage system	indirect
2.	Environmental	deterioration in function of building and infrastructures	indirect
		changes in river canal and drain flow systems	indirect
		frequent coastal flooding	indirect
		wider expansion of flooding areas	indirect
		inundated areas and infrastructures	indirect
3.	Economic	increased inland sea water intrusion	indirect
		deterioration in quality of environmental condition	indirect
		increase in maintenance cost of infrastructure	indirect
		decrease in land and property values	indirect
4.	Social	abandoned buildings and facilities	indirect
		disruption to economic activities	indirect
		deterioration in quality of living environment and life (e.g. health and sanitation condition)	indirect
		disruption to daily activities of people	indirect
<small>Hasanuddin Z. Abidin, 2015</small>			



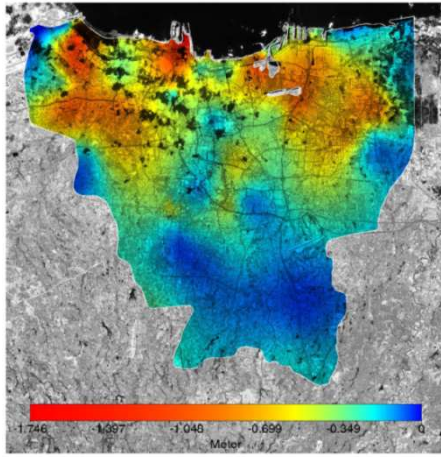








### Spatial Correlation between GPS-derived Land Subsidence (2000-2011) and Flooding area in Jakarta (2014)



*GPS-derived subsidence (2000-2011)*



source: geospasial.bnppb.go.id

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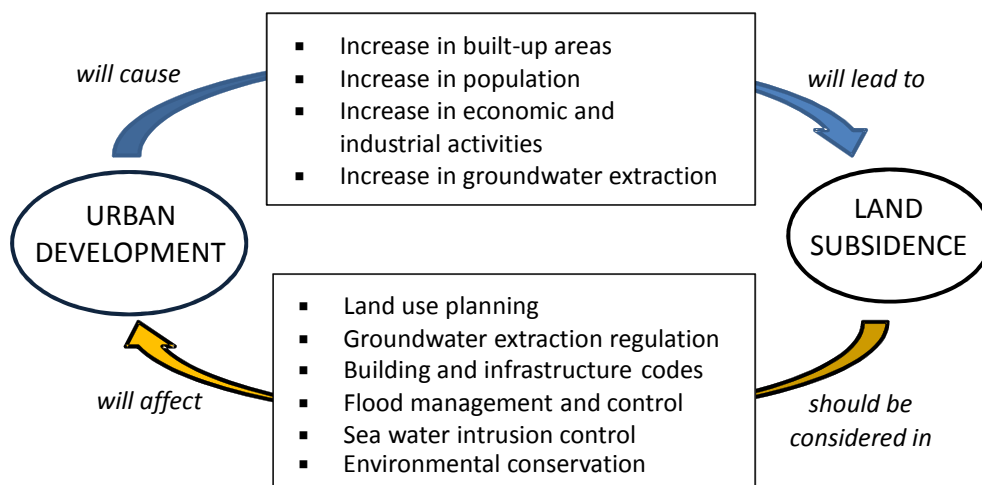
## Closing Remarks

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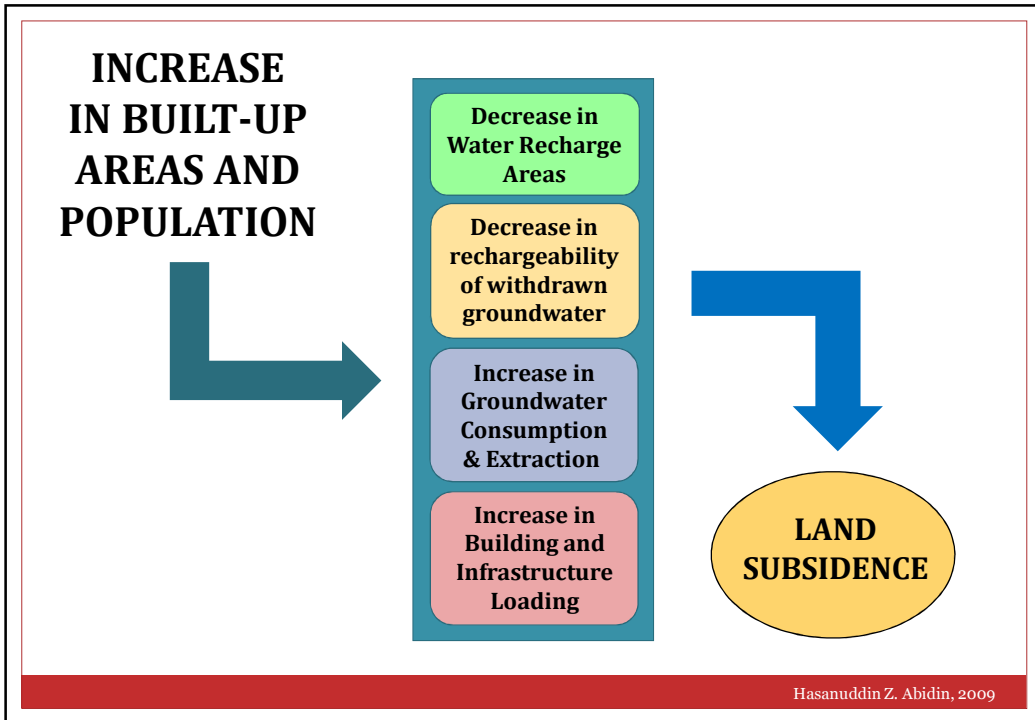
1. Land subsidence impacts in urban areas are quite numerous: **infrastructural, environmental, economic and social impacts.**
2. Environmental impacts of subsidence is usually **under-estimated**, since it is indirect effect and its appearance usually is **unseen** and has a relatively **longer time response** than infrastructural impacts.
3. Land subsidence in urban areas contribute to inundation and flooding phenomena, and should be included in assessment and modeling of **flooding and inundation in urban areas.**
4. Land subsidence in urban areas of Indonesia has a close relation with **urban development.**

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## Urban Development and Land Subsidence



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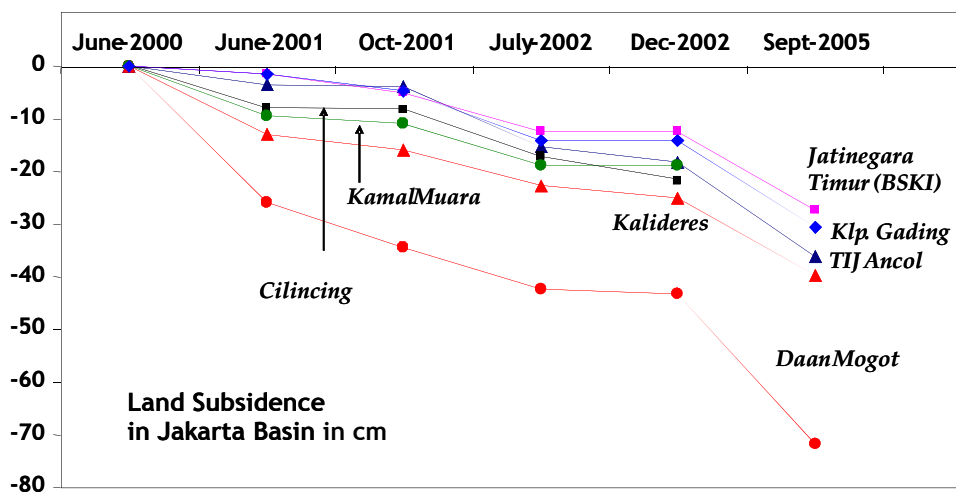
**Thank You**

## Observed Subsidence Rates in Jakarta (the rates vary both spatially and temporally)

No.	Method	Subsidence Rates (cm/year)		Observation Period
		Min - Max	Typical	
1	Leveling Surveys	1 - 9	3 - 7	1982 - 1991
		1 - 25	3 - 10	1991 - 1997
2	GPS Surveys	1 - 28	4 - 10	1997 - 2011
3	InSAR	1 - 12	3 - 10	2006 - 2010

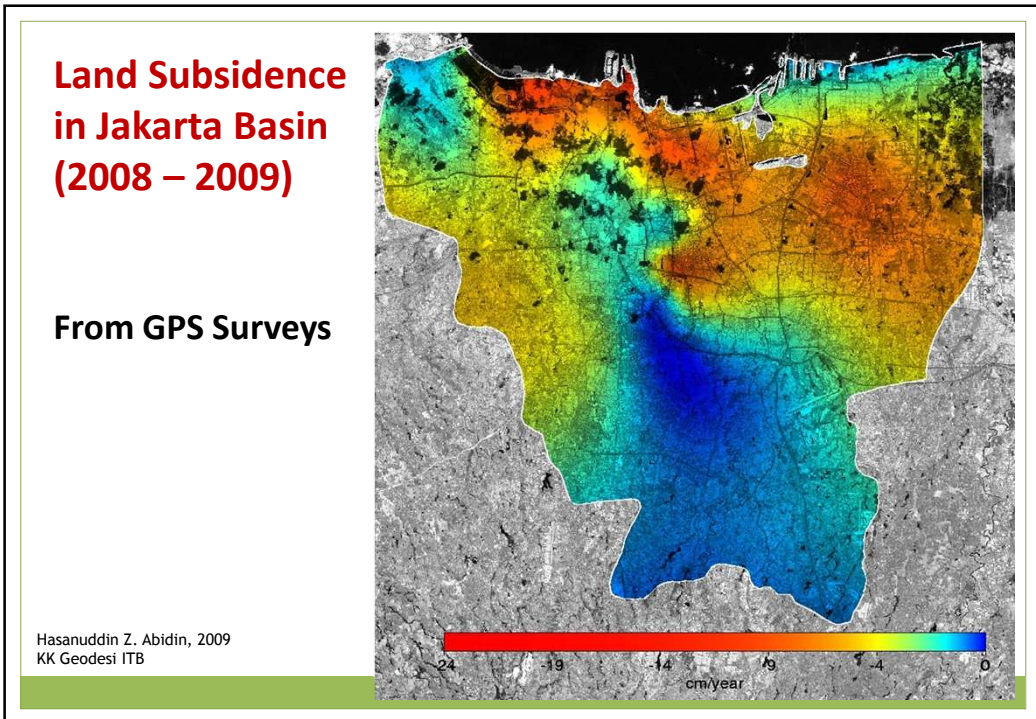
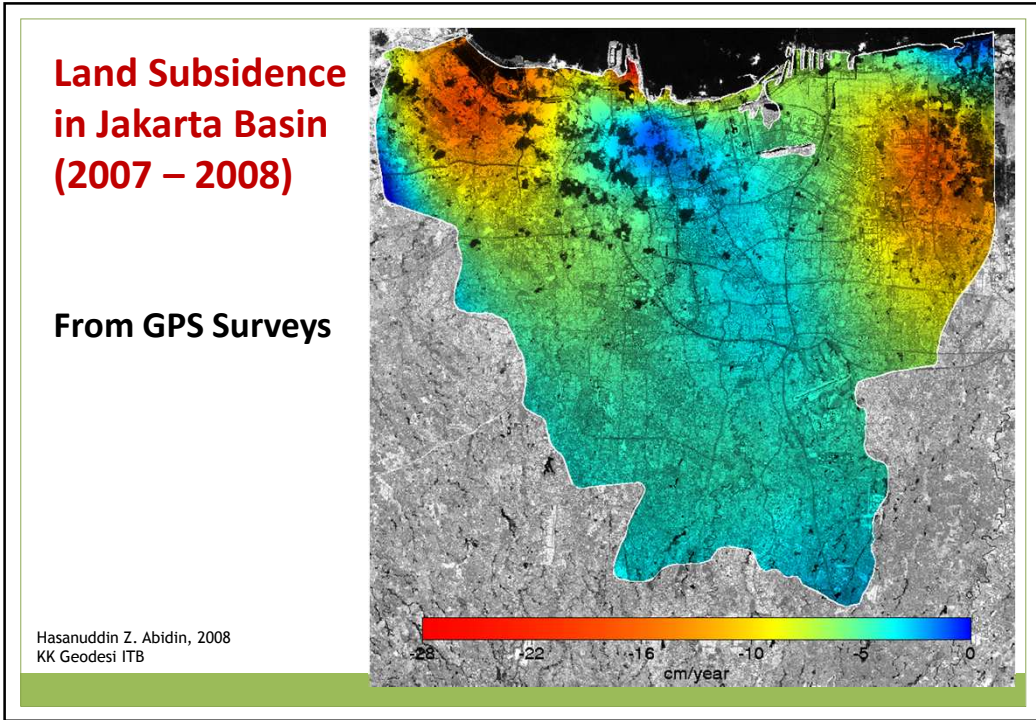
Hasanuddin Z. Abidin, 2014

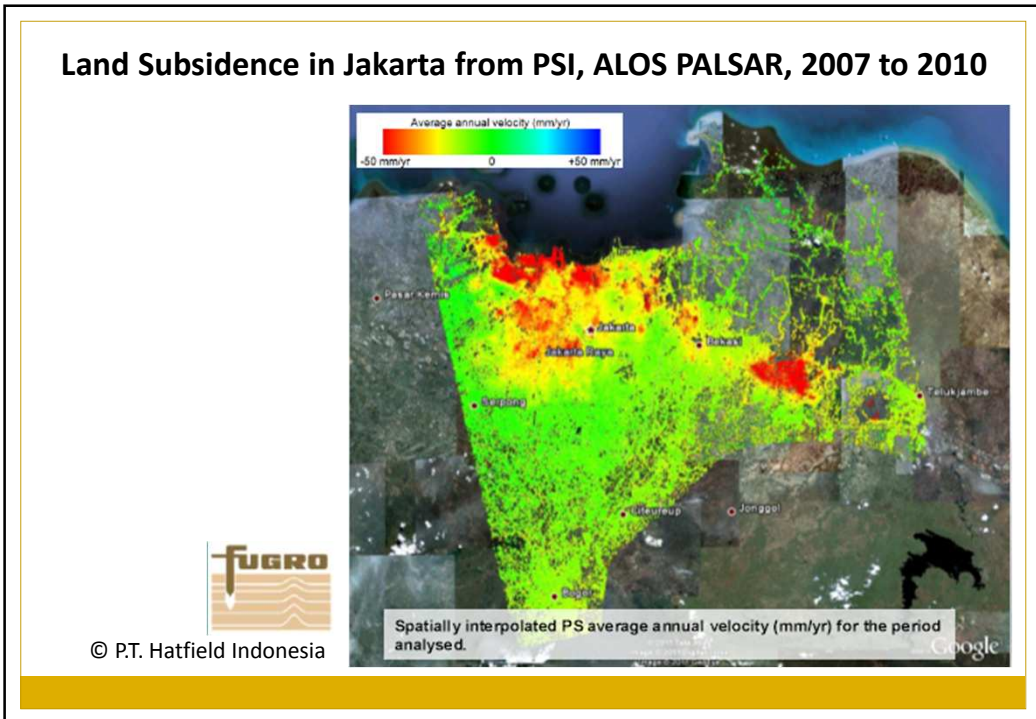
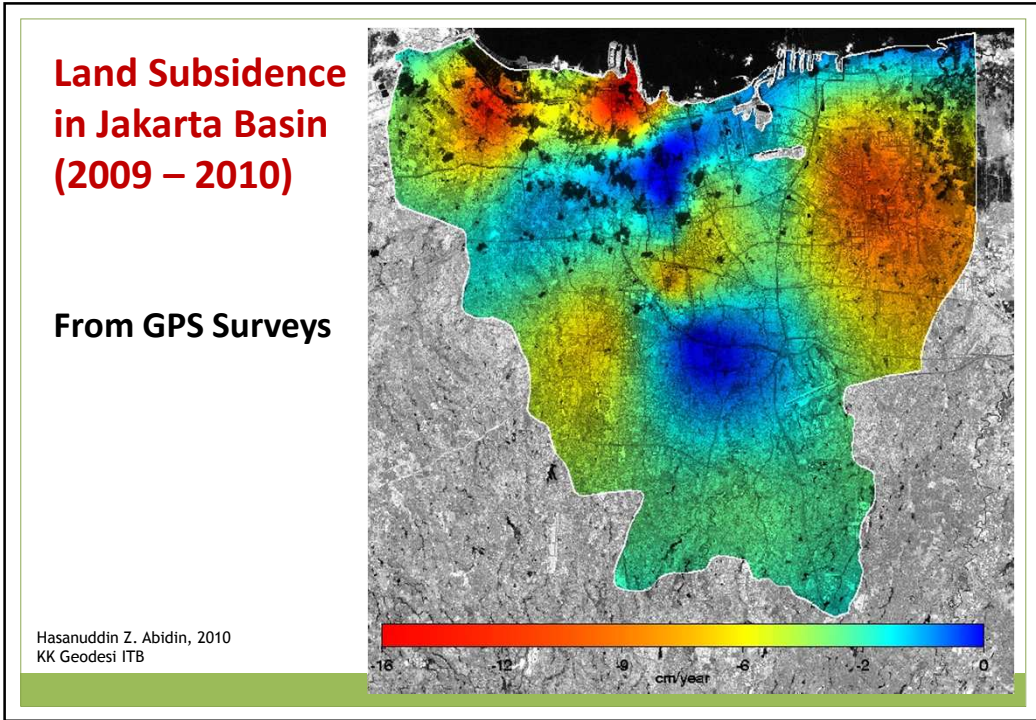
## GPS-derived Land Subsidence in Jakarta (2000 – 2005) in cm



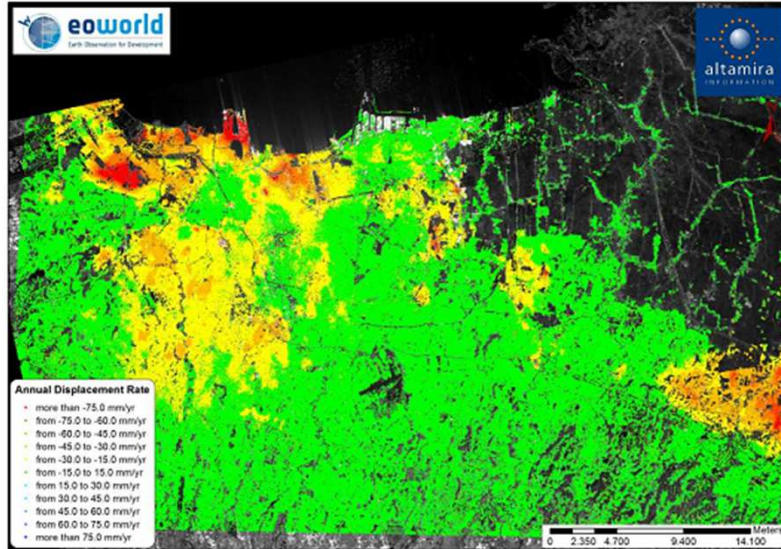
Hasanuddin Z. Abidin, 2006







### Land Subsidence in Jakarta ALOS PALSAR, 2007 to 2011



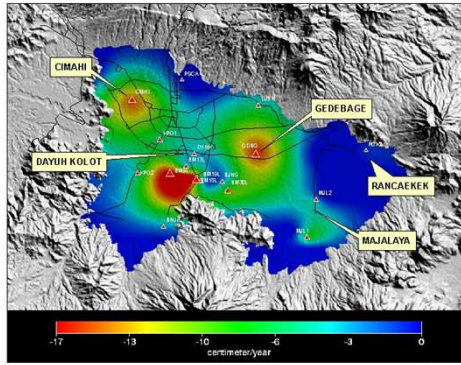
Koudogbo et al. (2011)

### Observed Subsidence Rates in Bandung (the rates vary both spatially and temporally)

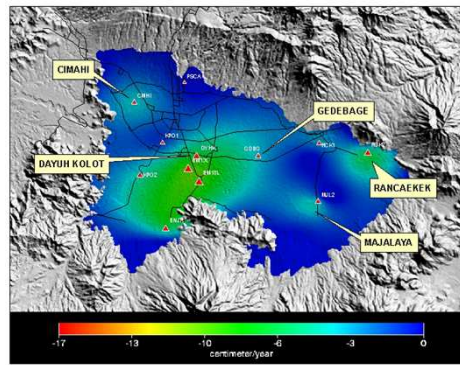
No.	Method	Subsidence Rates (cm/year)		Observation Period
		Min - Max	Typical	
1	GPS Surveys	1 - 23	4 - 11	2000 - 2010
2	InSAR	1 - 19	5 - 12	1999 - 2010

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### GPS-DERIVED LAND SUBSIDENCE IN BANDUNG (2002 - 2005)



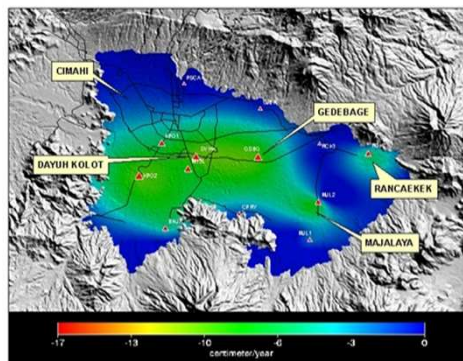
July 2002 – June 2003



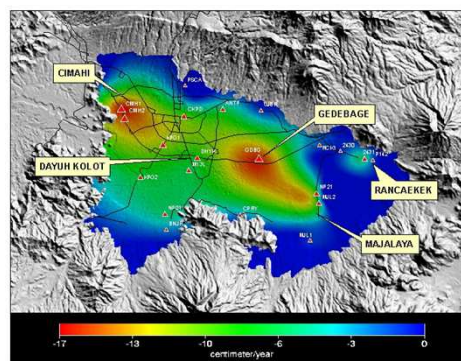
June 2003 – June 2005

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### GPS-DERIVED LAND SUBSIDENCE IN BANDUNG (2005 - 2009)



June 2005 – Augt 2008



Augt 2008 – July 2009

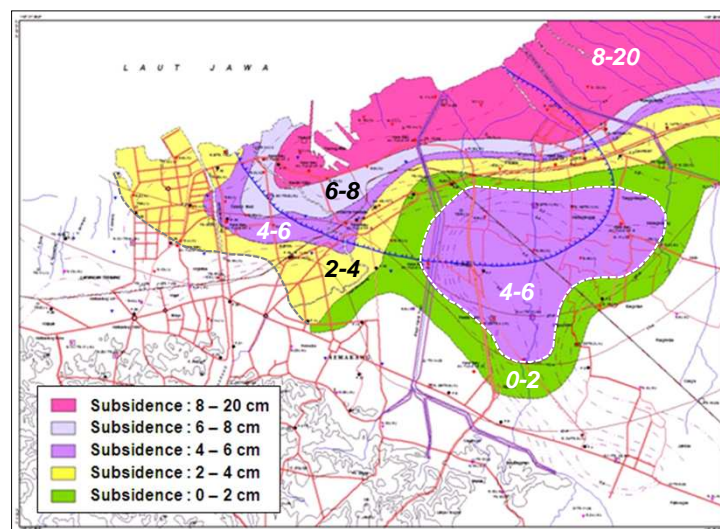
Hasanuddin Z. Abidin, 2011

## Observed Subsidence Rates in Semarang (the rates vary both spatially and temporally)

No.	Method	Subsidence Rates (cm/year)		Observation Period
		Min - Max	Typical	
1	Leveling Surveys	1 - 17	2 - 10	1999 - 2003
2	GPS Surveys	1 - 19	3 - 10	2008 - 2011
3	PS InSAR	1 - 10	3 - 8	2002 - 2006
4	Microgravity	1 - 15	2 - 10	2002 - 2005

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## Levelling derived Subsidence in Semarang in the period of 2000 to 2001

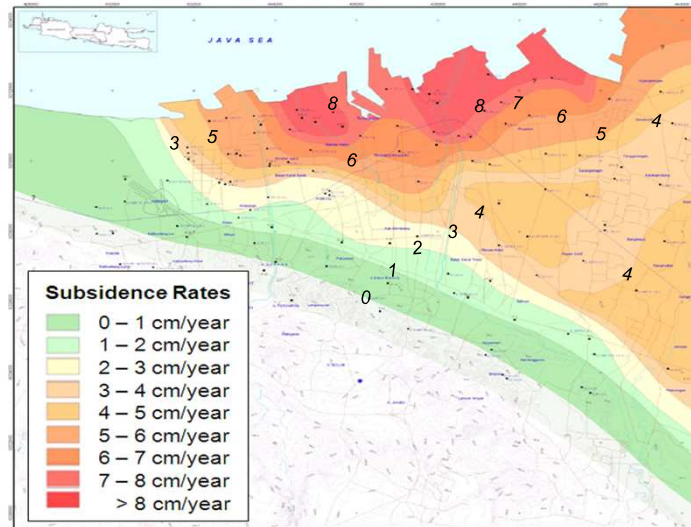


Courtesy of Geological  
Agency Bandung, after  
[Murdahardono et al., 2007]

## PS InSAR derived Subsidence Rates in Semarang

The contour lines in this Figure are based on the PS InSAR based velocity data derived from 28 ERS-2 and ENVISAT-ASAR radar scenes recorded between 27 November 2002 and 23 August 2006.

Courtesy of Geological Agency Bandung, after [Murdahardono et al., 2009]



## Microgravity derived Subsidence in Semarang

from Sept. 2002 to Nov. 2005

after [Supriyadi, 2008].

