Performance of the Geometric-Historic Method for Estimating Land Subsidence in Urban Areas of Indonesia

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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.

Hasanuddin Z. Abidin, 2012

Land Subsidence in Indonesian Cities

Observed land subsidence :

- **Jakarta**
- **Bandung**
- **Semarang**

Expected land subsidence :

- **Surabaya**
- **Denpasar**
- **Cilegon**
- **Medan**

observed decrease in groundwater level

Hasanuddin Z. Abidin, 2011

Land Subsidence

TYPES OF SUBSIDENCE IN LARGE INDONESIAN CITIES :

- **subsidence due to groundwater extraction,**
- **subsidence induced by the load of constructions (i.e. settlement of high compressibility soil),**
- **subsidence caused by natural consolidation of alluvium soil, and**
- **tectonic subsidence.**

Hasanuddin Z. Abidin, 2006

IMPACTS OF LAND SUBSIDENCE IN URBAN AREAS (CITIES)

Cracking of buildings and infrastructure	**The wider expansion of inland & coastal flooding areas**	**Malfunction of drainage system**
Increasing the maintenance costs for the affected buildings and infrastructure		**Changes in river canal and drain flow systems**
Lowering the quality of living environment and life (e.g. health and sanitation condition) in the affected areas		

Hasanuddin Z. Abidin, 2012

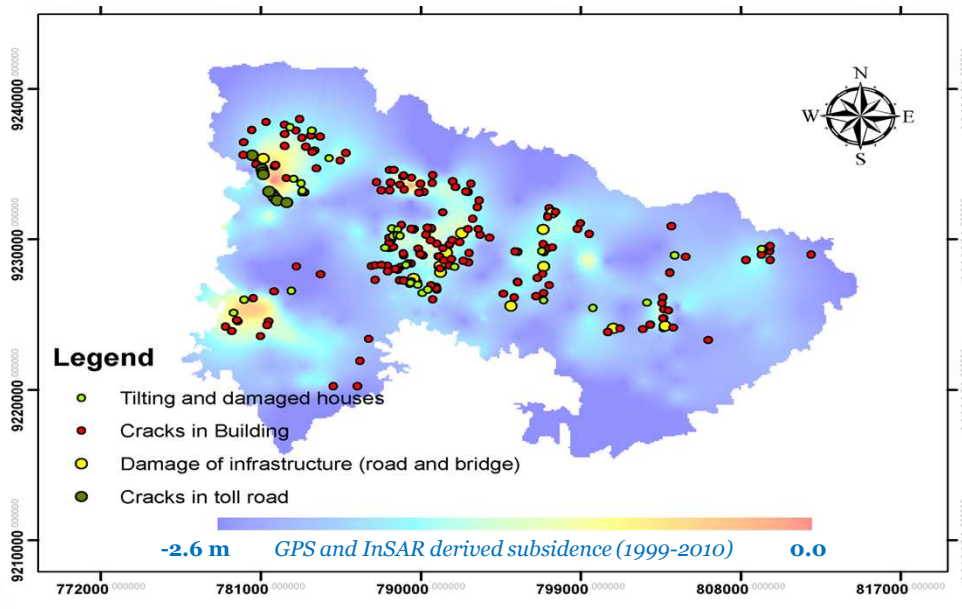
Example of Land Subsidence Impacts in Jakarta, Bandung and Semarang

Hasanuddin Z. Abidin, 2008

Coastal Flooding in Semarang (mid April 2009)

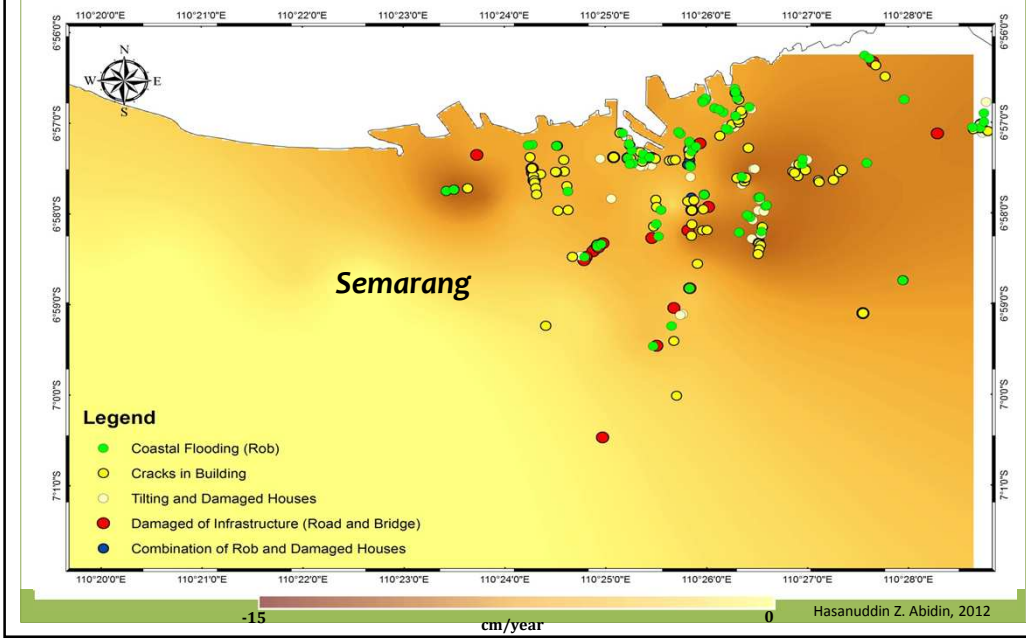
courtesy of Kompas photo, 2 July 2009

Distribution of LS Impacts in Bandung

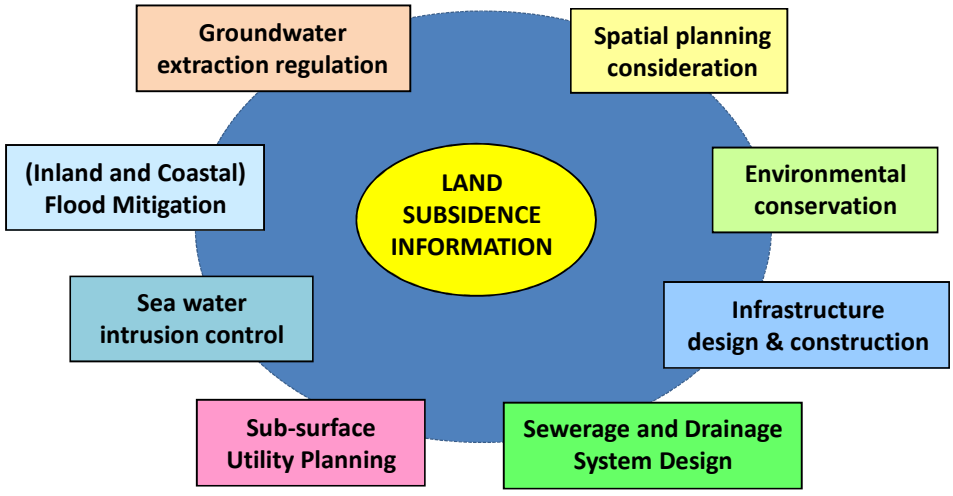


Gumilar et al. (2012)

Distribution of LS Impacts in Semarang

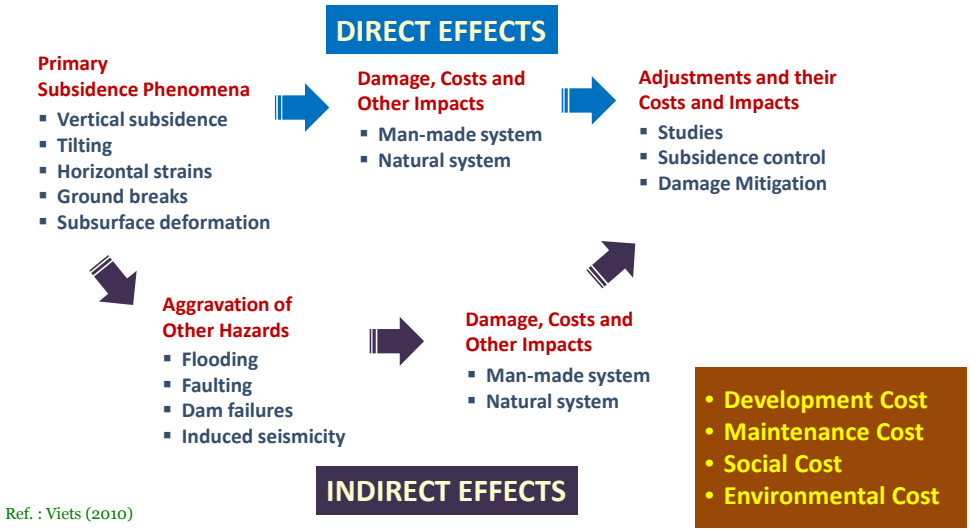


IMPORTANCE OF LAND SUBSIDENCE INFORMATION



Hasanuddin Z. Abidin, 2012

Losses due to Land Subsidence



Ref. : Viets (2010)

Hasanuddin Z. Abidin, 2012

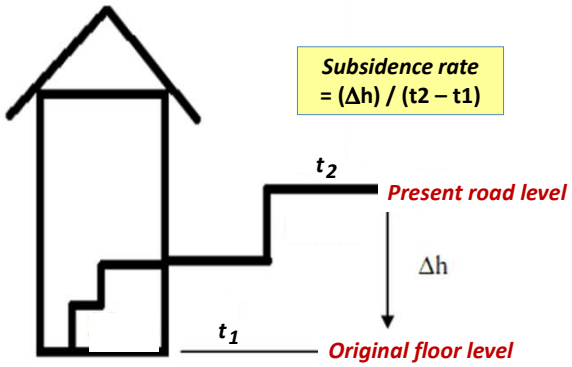
Measurement and Observation of Land Subsidence in Urban Areas

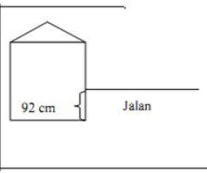
- ✓ Leveling Survey
- ✓ GPS Survey
- ✓ InSAR
- ✓ Microgravity
- ✓ Geometric-Historic

Hasanuddin Z. Abidin, 2012

Geometric – Historic Method

- *Based on field measurement, historical (documented) data and interview.*
- *Linear rate assumption.*
- *Average rate.*

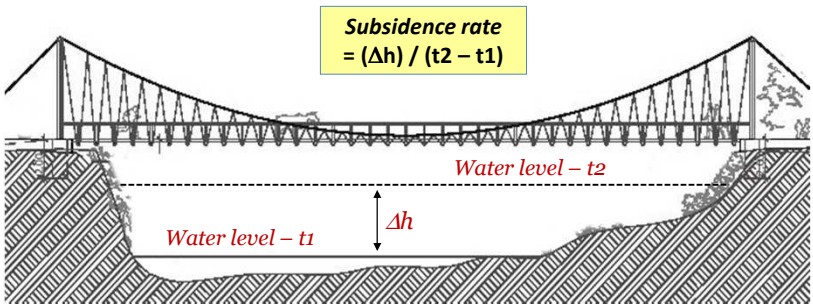




Wilayah Cimahi Selatan
Δh = 92 cm
Δt = 12 tahun (2000-2012)
Rata-rata = 7,67 cm/tahun

Example in Bandung

Geometric – Historic Method



- *Based on field measurement, historical (documented) data and interview.*
- *Linear rate assumption.*
- *Average rate.*

Strength and Limitation of Geodetic Method for LS Study In Urban Areas

	Leveling surveys	GPS surveys	InSAR	Microgravity	Geometric-Historic
LS information	point-wise	point-wise	continuous	point-wise	point-wise
Spatial coverage	local	local to regional	local to regional	local	local
Temporal coverage	user dependent	user dependent	images availability dependent	user dependent	user dependent
Ground benchmark	required	required	not required	required	not required
Data acquisition (survey)	day time and weather dependent	day and night, weather independent	dependent on satellite passes in the region	day and night, weather dependent	day time and weather dependent
Typical limitation	laborious and time consuming	signal obstruction by buildings, infrastructures and trees	poor image coherence due to land use and land cover dynamics	requires stringent observation strategy and quite costly	based on historical and interview data which not always accurate
Typical accuracy level of LS	mm (relative)	mm-cm (relative)	mm-cm (relative)	mm-cm (relative)	cm-dm (relative)

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Geodetic Methods for Land Subsidence Monitoring

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

GRD of ITB mainly involved with GPS Surveys, InSAR and Geometric - Historic

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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

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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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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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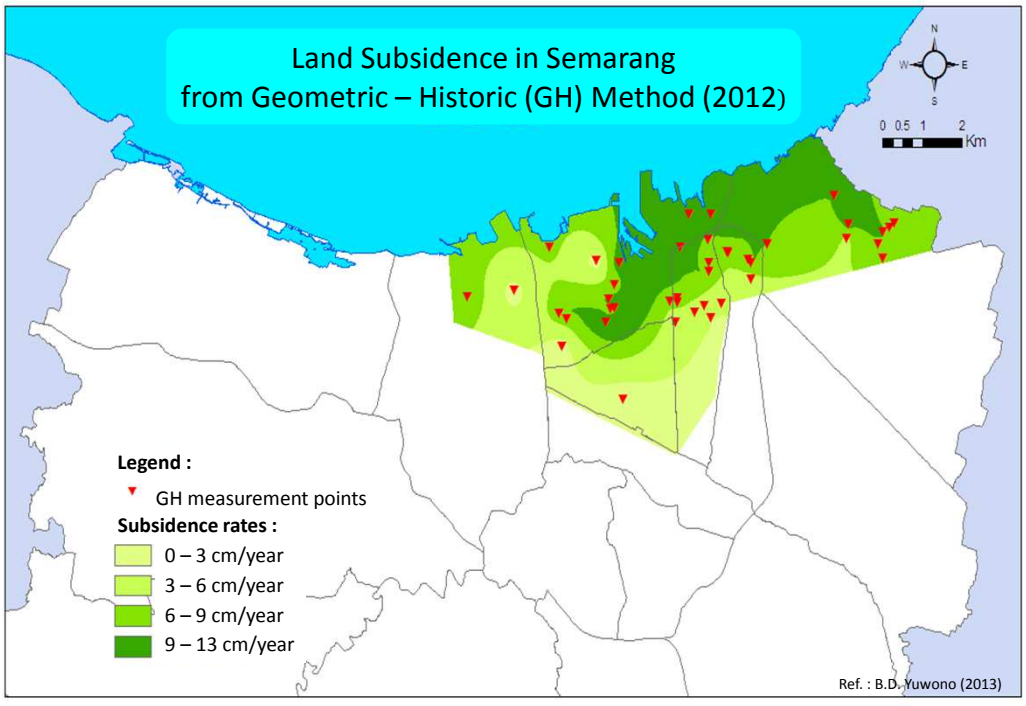
Examples of Land Subsidence estimated using Geometric-Historic Method

GEOMETRIC-HISTORIC METHOD FOR ESTIMATING LAND SUBSIDENCE RATES AT SEVERAL LOCATION IN SEMARANG IN 2012

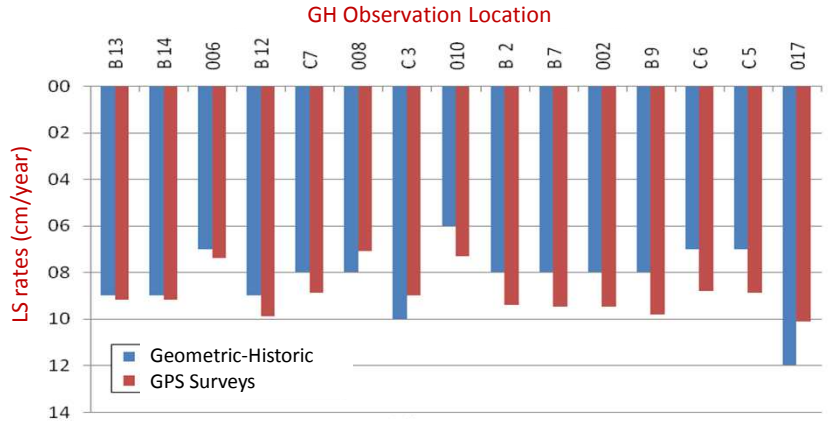
Ref. : B.D. Yuwono (2013)

Land Subsidence in Semarang from Geometric – Historic (GH) Method (2012)



Ref. : B.D. Yuwono (2013)

Comparison between Geometric-Historic measured subsidence in SEMARANG with subsidence from the closest GPS point



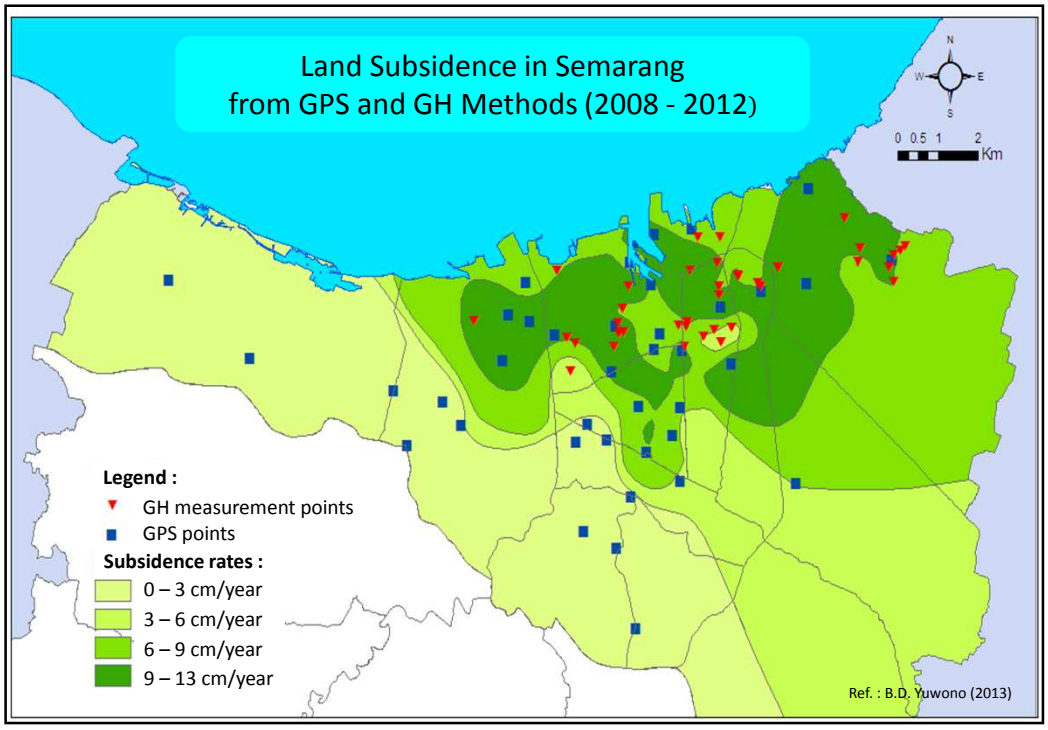
Ref. : B.D. Yuwono (2013)

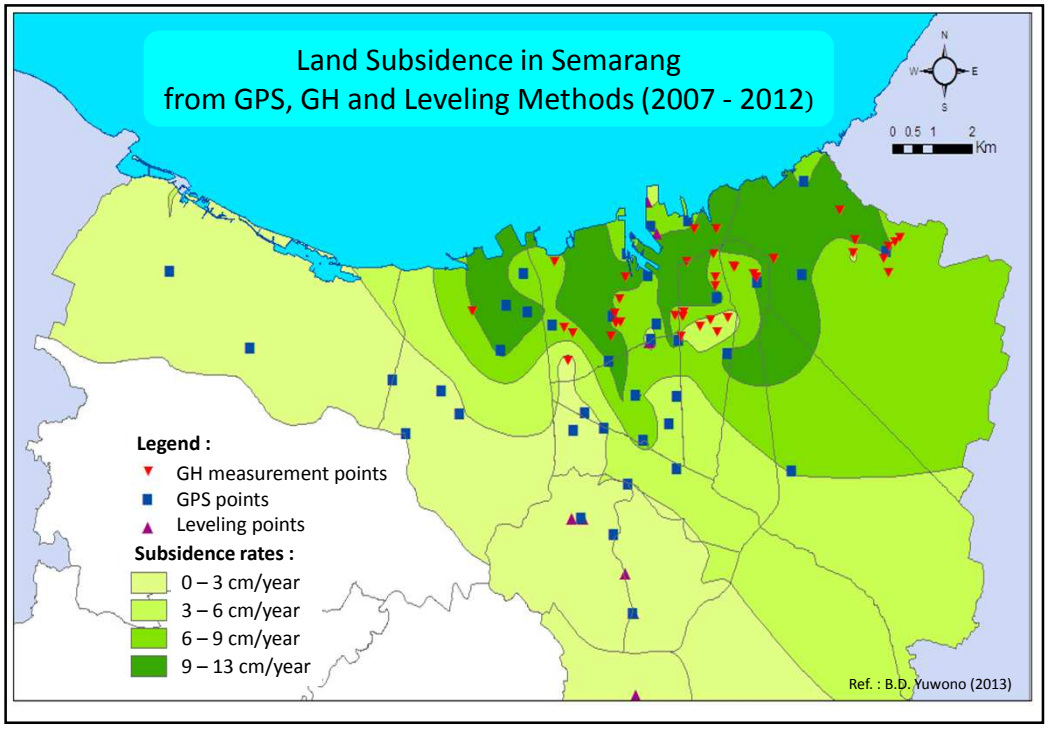
Comparison between Geometric-Historic measured subsidence in BANDUNG

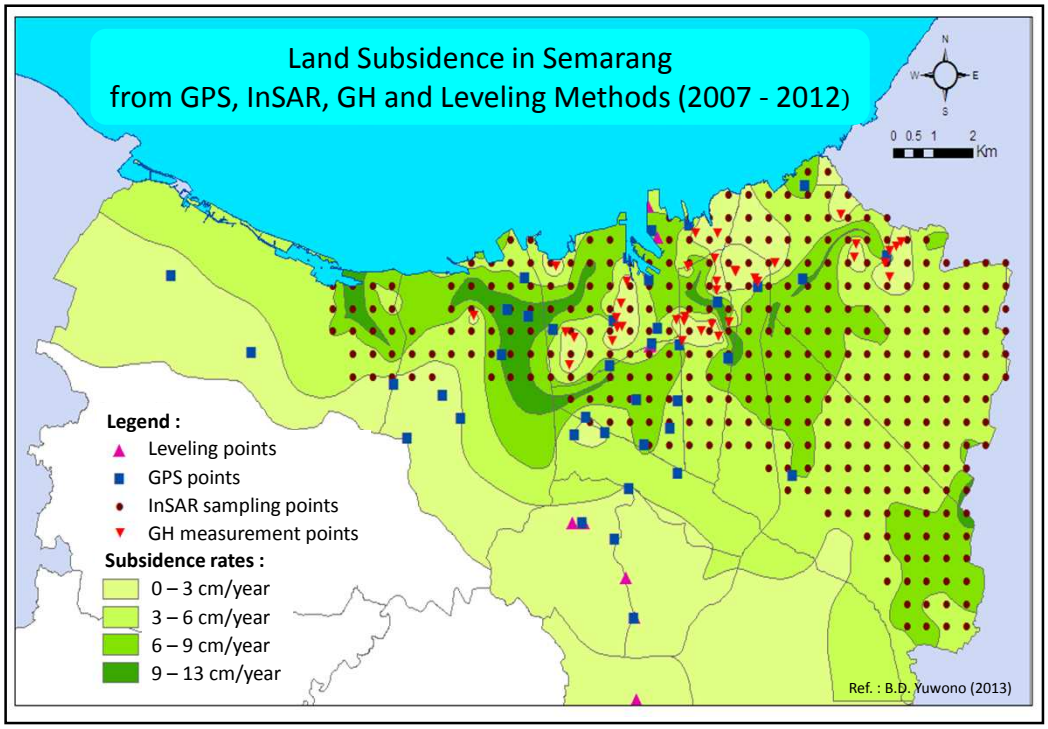
No	Subsidence Rates (cm/year)			Distance (m) from GPS to GH/InSAR location
	GH	InSAR	GPS Surveys	
1	4.6	6.5		246
2	4.7	6.2		246
3	5.0	6.6		214
4	4.7	7.0	5.9	156
5	3.1	7.0		194
6	2.3	7.3		152
7	4.1	7.5		179
8	10.9	12.7	14.2	251
9	7.7	14.4		532
10	9.2	14.8	16.9	576
11	8.3	15.5		543
12	8.3	6.7		568
13	7.1	15.5	15.3	544
14	5.3	8.5	1.9	146
15	4.3	8.1	4.3	58
16	5.3	6.9		80
17	3.5	1.9	4.4	114
18	9.2	5.6	5.1	98
19	8	6	3.9	562
20	9	7.2		173
21	7.3	8.9		654
22	3.7	8.9		643
23	8.8	8.9	9.2	678
24	6.7	8.9		690
25	4.3	9.2		632
26	11.7	11.8		709
27	5	8.4	9.3	15
28	5.9	6.2	9.2	125

Ref: Gumilar (2013)

Integration of subsidence derived by Geometric-Historic method with results from other methods




Land Subsidence in Semarang
from GPS, GH and Leveling Methods (2007 - 2012)
N
W
E
S
0 0.5 1 2
Km
Legend :
GH measurement points
GPS points
Leveling points
Subsidence rates :
0 – 3 cm/year
3 – 6 cm/year
6 – 9 cm/year
9 – 13 cm/year
Ref. : B.D. Yuwono (2013)


Land Subsidence in Semarang
from GPS, InSAR, GH and Leveling Methods (2007 - 2012)
N
W
E
S
0 0.5 1 2
Km
Legend :
Leveling points
GPS points
InSAR sampling points
GH measurement points
Subsidence rates :
0 – 3 cm/year
3 – 6 cm/year
6 – 9 cm/year
9 – 13 cm/year
Ref. : B.D. Yuwono (2013)

Closing Remarks

Strengths of Geometric-Historic Method

- It can estimate the subsidence rates from only a single measurement epoch.
- It can be used at location which are not accessible by other geodetic measurement techniques.
- The measurement cost is also relatively much cheaper than other geodetic technique.

Weaknesses of Geometric-Historic Method

- It has strong subjectivity nature, since the quality of subsidence information derived from geometric-historic will strongly depend on how accurate the vertical displacement and the time period can be estimated from field measurement and historical (documented) and interview data by the field surveyors.
- Different field surveyor, which has different geometrical insight into the impacts of land subsidence in the field, and has different communication skill in interviewing peoples; can lead to different estimated subsidence rates at the same location.

Thank you