On Mapping and Evaluating the Impacts of Land Subsidence in Bandung Basin (Indonesia)

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FIG WORKING WEEK 2012
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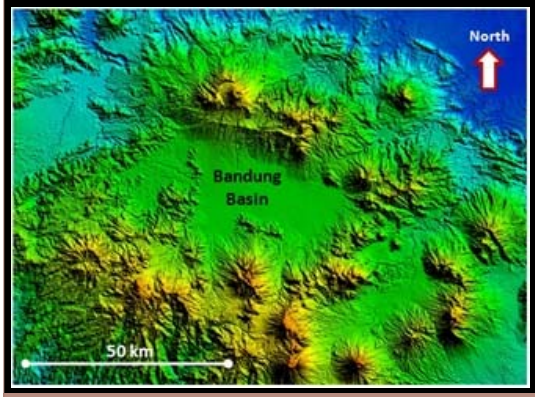
Rome, Italy

Institut Teknologi Bandung

BANDUNG
West Java
Indonesia



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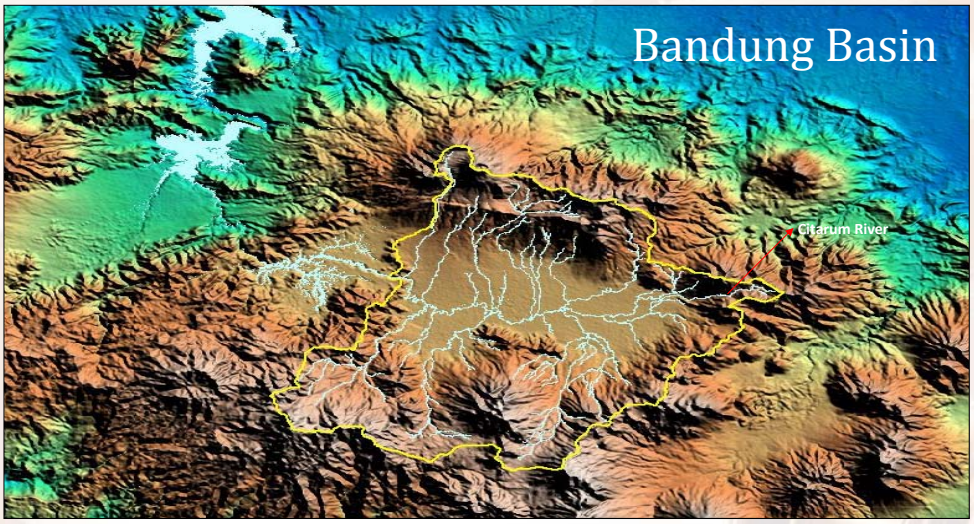

The central part has an altitude of about 665 m and is surrounded by up to 2400 m high volcanic terrain.

The catchment area of the basin and surrounding mountains covers approximately 2300 km², and the Citarum river with its tributaries form the main drainage system of the basin catchment.

Land Subsidence in Indonesian Cities

Observed land subsidence :

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

Expected land subsidence :

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

observed decrease in groundwater level

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Geodetic Methods for Land Subsidence Monitoring

City	Leveling	GPS	InSAR	Gravity
Jakarta	Since 1982	Since 1997	Since 2005	Since 2008
Bandung	Limited	Since 2000	Since 2007	Since 2008
Semarang	Since 1999	Since 2008	Since 2007	Since 2002

GRD of ITB mainly involved with GPS Surveys and InSAR.

Hasanuddin Z. Abidin, 2009

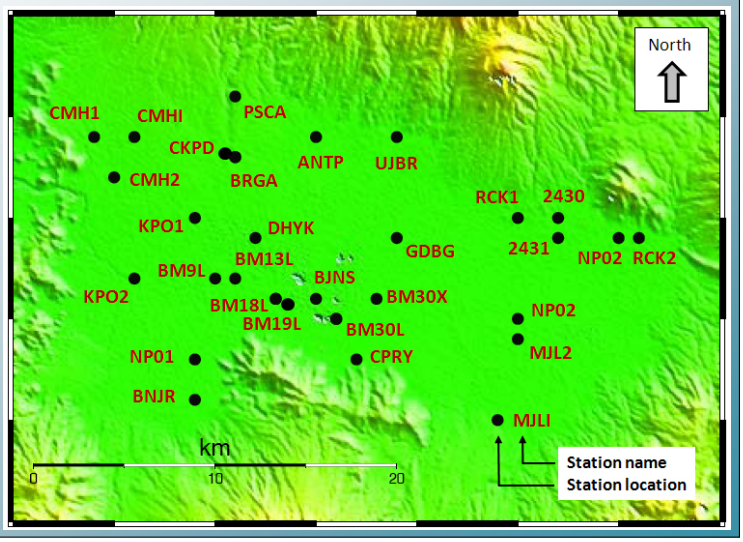
Types of Land Subsidence

- 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

GPS NETWORK FOR MONITORING LAND SUBSIDENCE in BANDUNG BASIN

S-1 : Feb. 2000
S-2 : Nov. 2001
S-3 : July 2002
S-4 : June 2003
S-5 : June 2005
S-6 : Augt 2008
S -7 : July 2009
S-8 : July 2010
S-9 : August 2011



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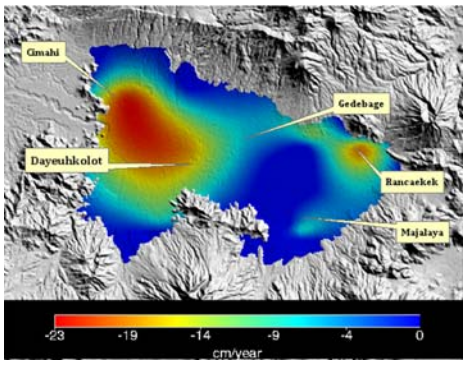
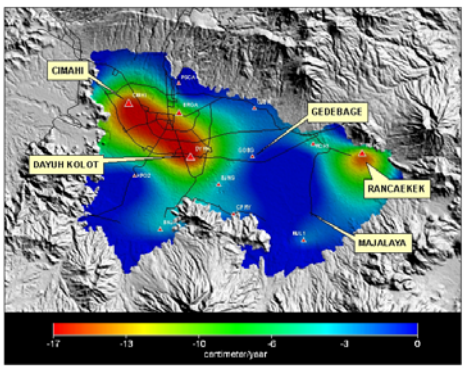
GPS-DERIVED LAND SUBSIDENCE IN BANDUNG (1)



Feb. 2000 – Nov. 2001



Nov 2001 – July 2002

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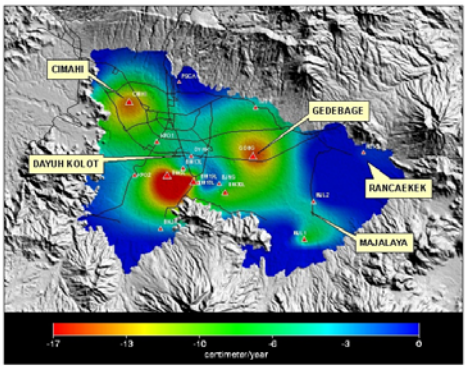
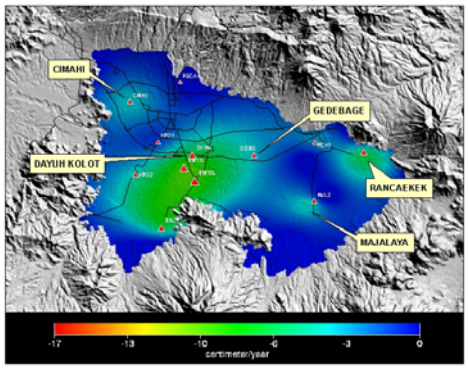
GPS-DERIVED LAND SUBSIDENCE IN BANDUNG (2)



July 2002 – June 2003



June 2003 – June 2005

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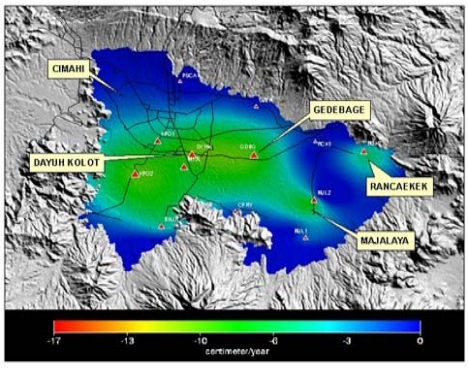
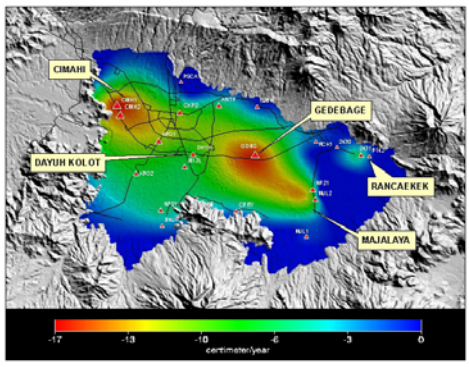
GPS-DERIVED LAND SUBSIDENCE IN BANDUNG (3)



June 2005 – Augt 2008



Augt 2008 – July 2009

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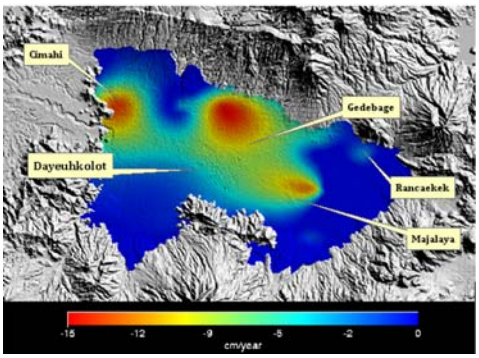
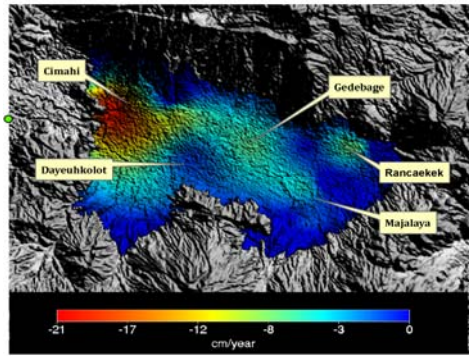
GPS-DERIVED LAND SUBSIDENCE IN BANDUNG (4)

BANDUNG SUBSIDENCE RATE
July 2009 – July 2010



BANDUNG SUBSIDENCE RATE
July 2010-August 2011



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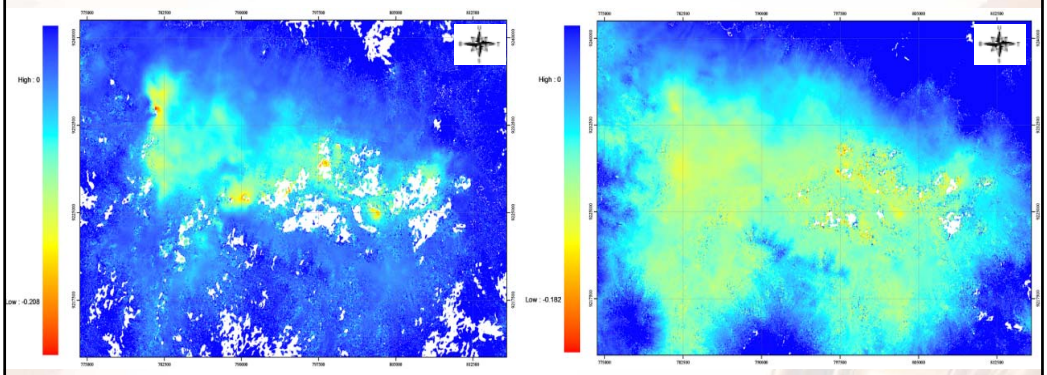
Land Subsidence measured by InSAR

There are 7 ALOS PALSAR images were processed in this case

No	Date	Orbit Direction	Sensor Type
1	06 March 2007	Ascending	Fine Beam Sensor
2	14 January 2007	Ascending	Fine Beam Sensor
3	18 April 2009	Ascending	Fine Beam Sensor
4	28 January 2009	Descending	Fine Beam Sensor
5	16 December 2009	Descending	Fine Beam Sensor
6	3 Mei 2010	Descending	Fine Beam Sensor

InSAR processing has been performed using GAMMA software

Land Subsidence derived by InSAR, 2008-2010



Jan – Dec 2009

Dec 2009 – Mei 2010

Assimilating GPS and InSAR derived subsidence

$$LS_{ij} = f_{ij} LS_{ij}^{InSAR}$$

$$f_{ij} = \sum_{k=1}^{N} W_{ij}^{k} fk(\theta, \emptyset)$$

$$W_{ij}^{k} = \begin{cases} \dfrac{\frac{1}{r_k^2}}{\sum_l \frac{1}{r_l^2}} & for\ r_k \leq 15\ km \\ 0 & for\ r_k > 15\ km \end{cases}$$

$$fk(\theta, \emptyset) = \frac{LS^{GPS}}{LS^{InSAR}}$$

LS_{ij} : Land subsidence valueat each point of the model grid (l, j)

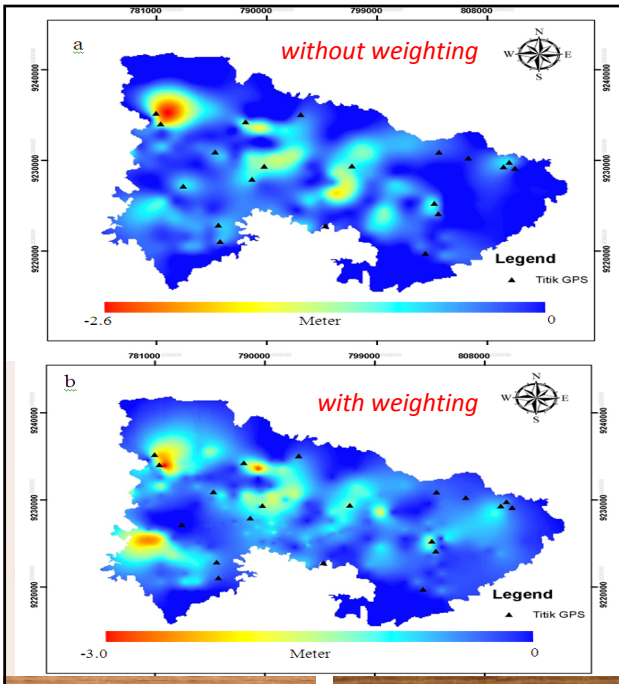
LS_{ij}^{InSAR} : Land subsidence value each point of the model grid (l, j)

W_{ij}^{k} : weighted coefficient with respect to distance r of the GPS station k (r_k) to the grid point

LS^{GPS} : Land subsidence derived by GPS

fk : The multipliers for each of the GPS stations

r_l : represent the distance of all relevant stations, i.e. the ones within 15 km (denoted with l)



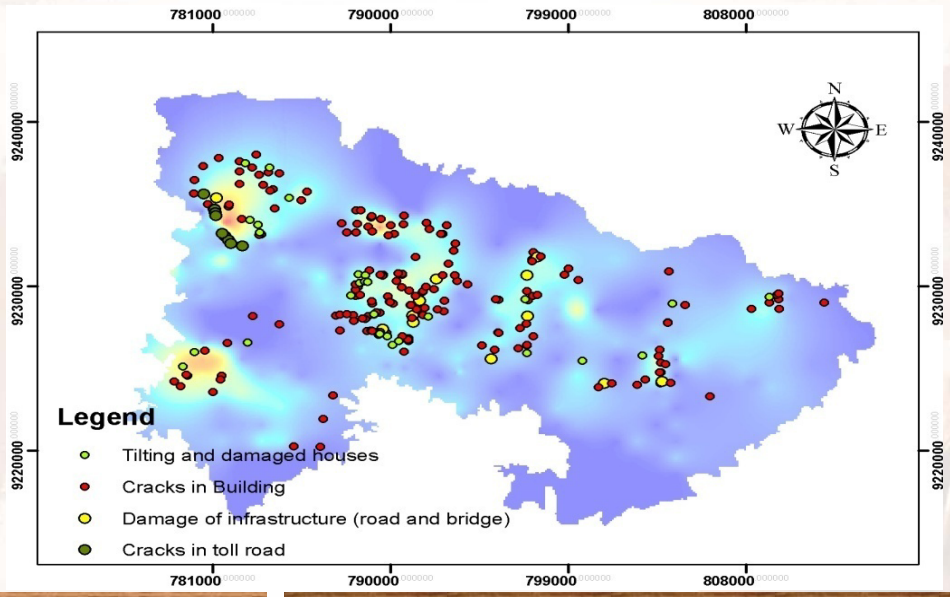
Assimilated GPS and InSAR Land Subsidence (1999 - 2010)

Mapping of land subsidence impact in Bandung Basin

Field survey has been done to map and evaluate the impacts of land subsidence in Bandung basin.

Field survey area focused in the large subsidence area and beside taking pictures we were doing some interview with local people.

Mapping of land subsidence impact in Bandung Basin



Impacts of Land Subsidence in Bandung (1)

A: Rancaekek, B: Leuwigajah, C: Ujungberung, D: Gedebage, E: Dayeuh Kolot, F: Leuwigajah

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Impacts of Land Subsidence in Bandung (2)

G: Dayeuh Kolot
J: Gedebage

H: Cimahi
K: Leuwigadjah

I: Gedebage
L: Dayeuh Kolot

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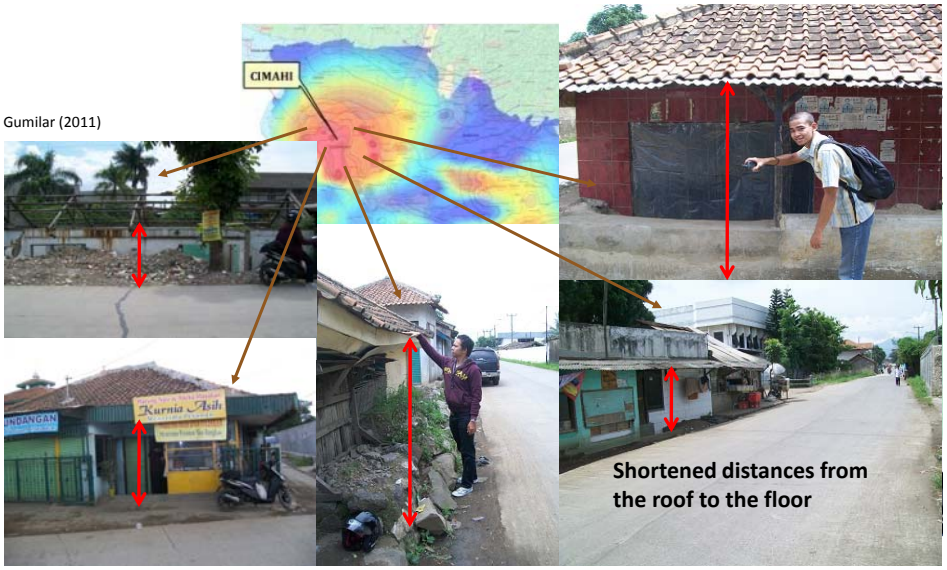
EVIDENCE OF LAND SUBSIDENCE IN BANDUNG **(Cimahi)**

Gumilar (2011)



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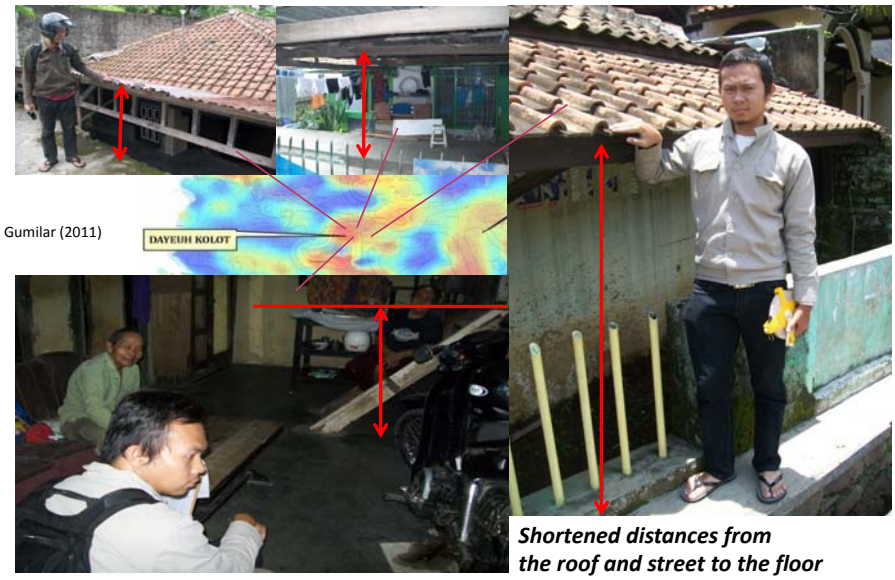
EVIDENCE OF LAND SUBSIDENCE IN BANDUNG **(Dayeuh Kolot)**



Gumilar (2011)

Shortened distances from the roof and street to the floor

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EVIDENCE OF LAND SUBSIDENCE IN BANDUNG **(Gede Bage)**

Shortened distances from the roof to the floor and the street to the floor

Gumilar (2011)

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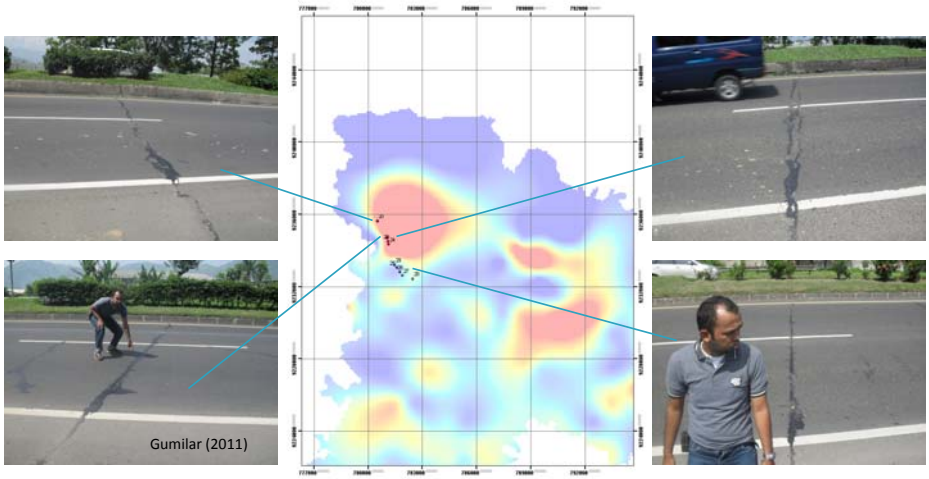
EVIDENCES OF LAND SUBSIDENCE IN BANDUNG BASIN



Crack on the highway (TOL Padalarang Cileunyi – Kilometer Pasirkoja)

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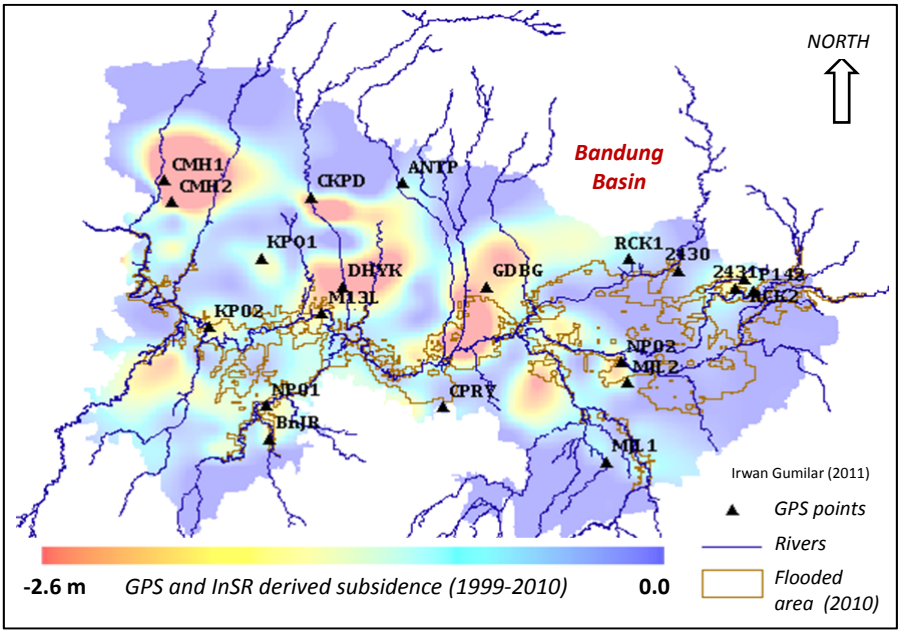
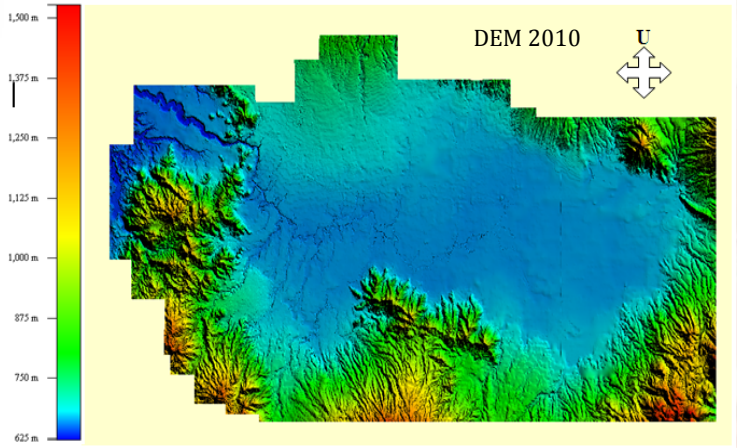
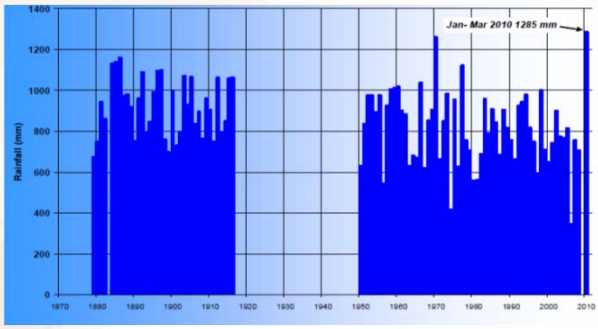
Land Subsidence and Flooding in Bandung Basin



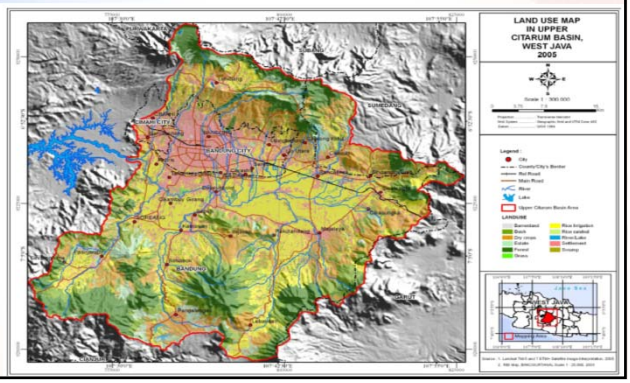
Modeling Flood in Bandung



The flooding area in Bandung Basin modelled by using SOBEK software from Deltares (Holland). Sobek software designed to estimate 2D flooding area. The input of this software are the rainfall data, geometry of Citarum river, land use, and Digital Elevation Model (EDM) in 2010.

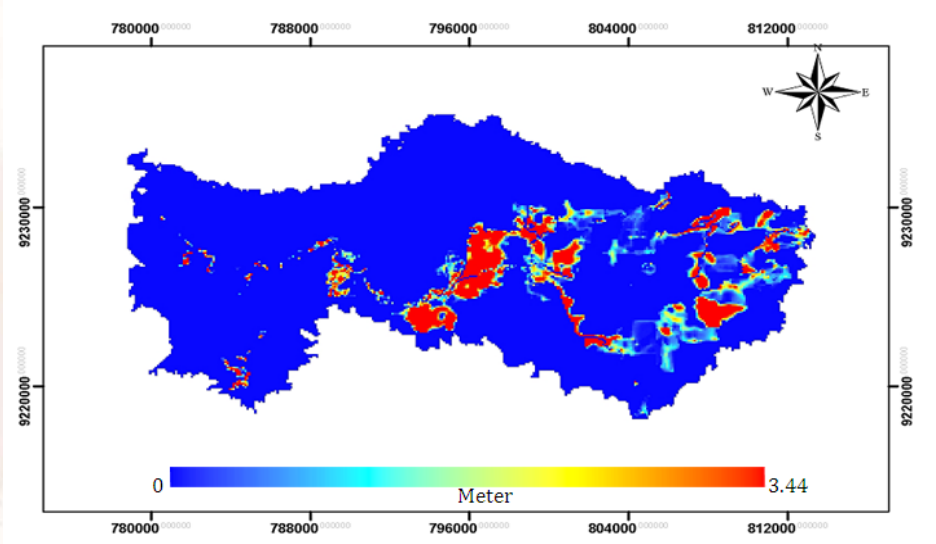


Rainfall data in Bandung basin in 1970-201 (PUSAIR dan Deltares, 2010)

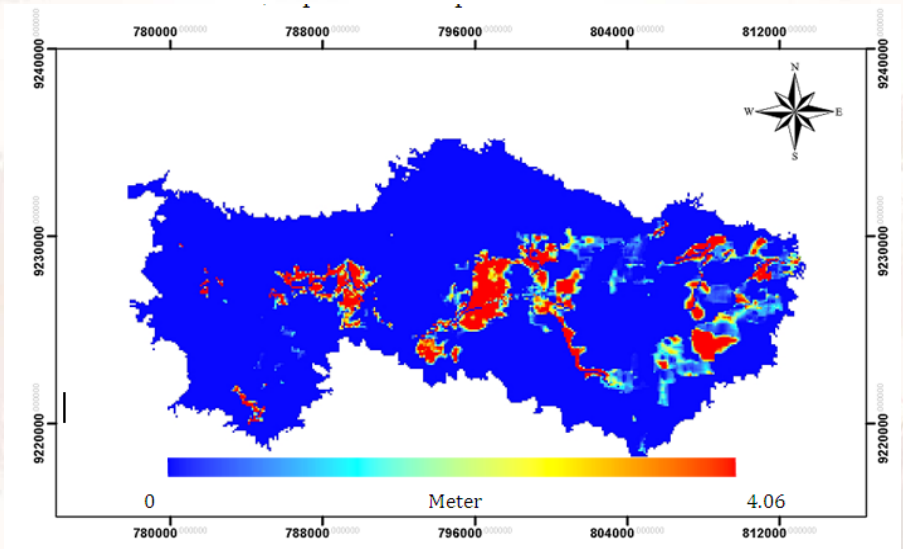


Land use map of Bandung Basin 2006 from Landsat image (PUSAIR dan Deltares, 2010)

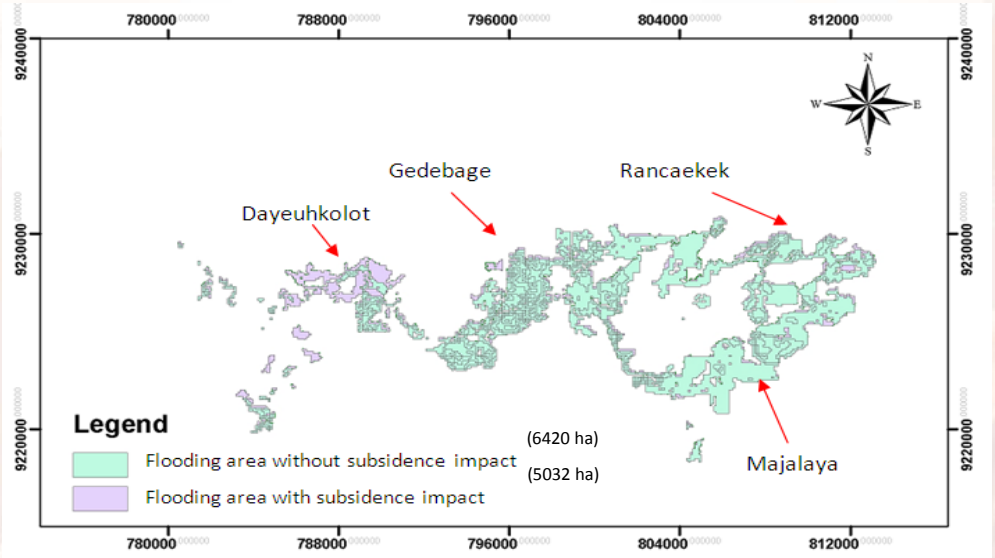
Flooding area 2010 and its depth without subsidence impact



Flooding area 2010 and its depth with subsidence impact



Differences in flooding coveragearea with and without subsidence impact



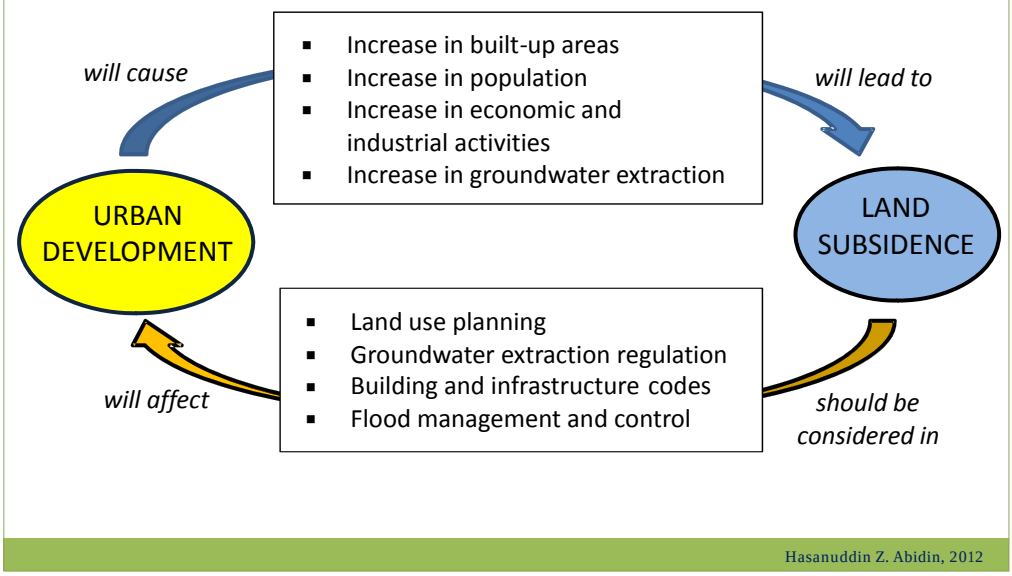
Closing Remarks (1)

- Significant subsidence in Bandung basin occurred in the textile industry area, where very large volumes of groundwater are usually extracted.
- Land subsidence in Bandung =

  f { excessive groundwater abstraction, building load (??), tectonics activity (??), natural compaction (?)}

- Further research is needed to clarify the real mechanism and pattern (spatial and temporal) of land subsidence phenomena in Bandung basin.

Closing Remarks (2)



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