On the Disaster Risk Reduction of Land Subsidence in Indonesia's Northern Coastal Areas of Java

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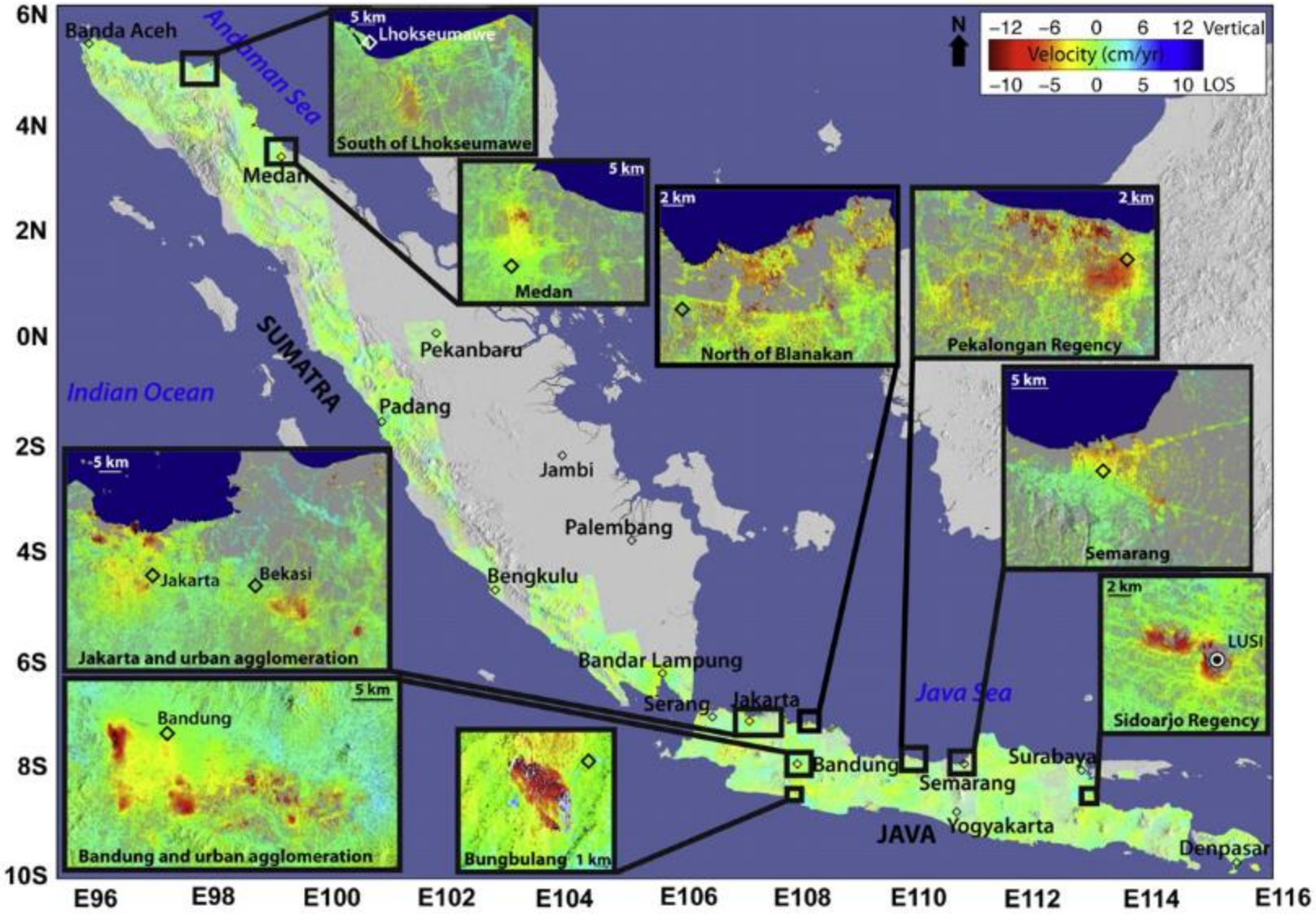
GM6.5 Session
Coastal subsidence: natural and anthropogenic drivers
Presentations | Thu, 26 May, 08:30–10:00 (CEST)

Several Locations of Land Subsidence in Indonesia



Averaged 2007-2009 LOS velocity map of Sumatra, Java, and Bali, Indonesia, from **ALOS InSAR time-series** analysis, overlaying SRTM V4 DEM.

It uses over 900 SAR images from 33 ascending tracks acquired by the ALOS satellite between 2007 and 2009, to cover an area of 500,000 km in Sumatra, Java and Bali.

Ref: *Chaussard, E., F. Amelung, H.Z. Abidin, S-H Hong* (2013). "Sinking cities in Indonesia: ALOS PALSAR detects rapid subsidence due to groundwater and gas extraction", *Remote Sensing of Environment*, Elsevier, Vol. 128, pp. 150–161.

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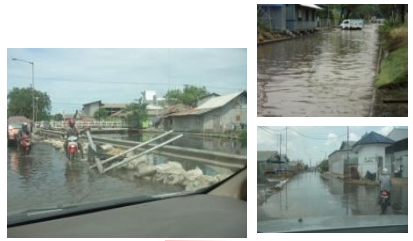
Several Locations of Land Subsidence in Java


Tanggerang

Jakarta



Blanakan, Indramayu




Pekalongan


Demak


Semarang

Heri Andreas et al. (2016)

Typical rates of observed subsidence in Java: 3–10 cm/year

The rate of subsidence varies both spatially and temporally.

Impacts of land subsidence can be seen in the forms of coastal inundation, coastal flooding, and sinking & cracking of infrastructures.

Lead to infrastructural, economic, environmental and social losses.

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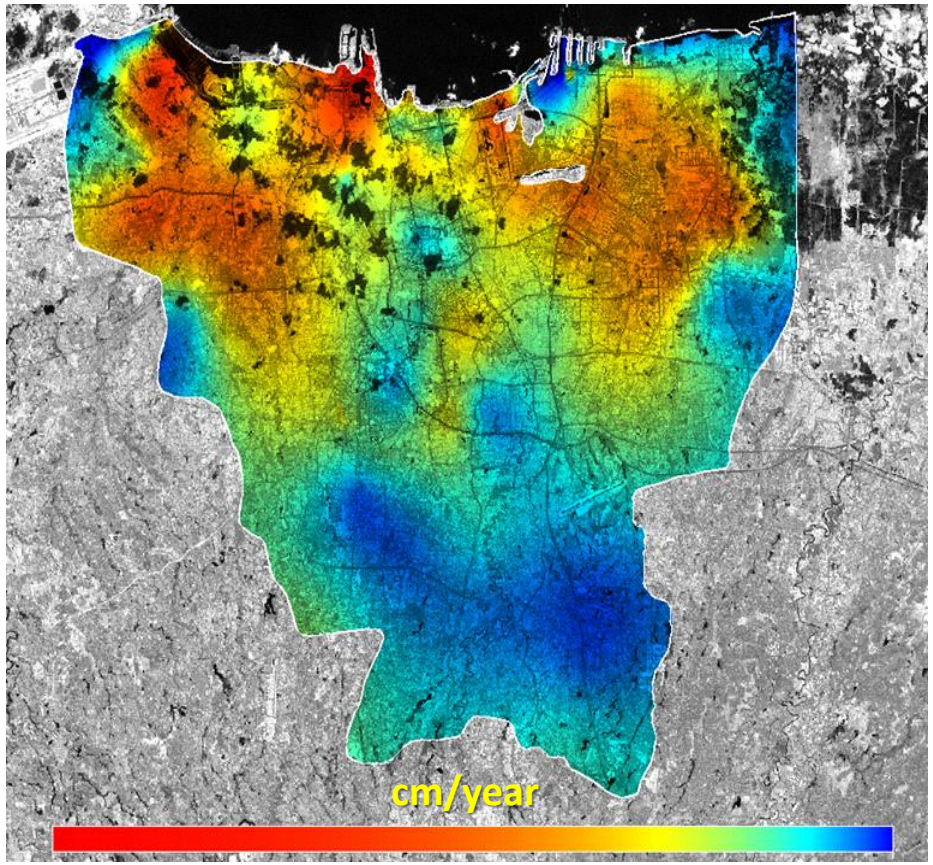
Examples of Observed Subsidence Rates in Jakarta

(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 - 2016
3	InSAR	1 - 12	3 - 10	2006 - 2010
		up to 5	3 - 5	2016 - 2020
4	TLS di Pantai Mutiara	3 - 20	11 - 12	2011 - 2013



from Leveling, GPS and InSAR results (1991 - 2010)

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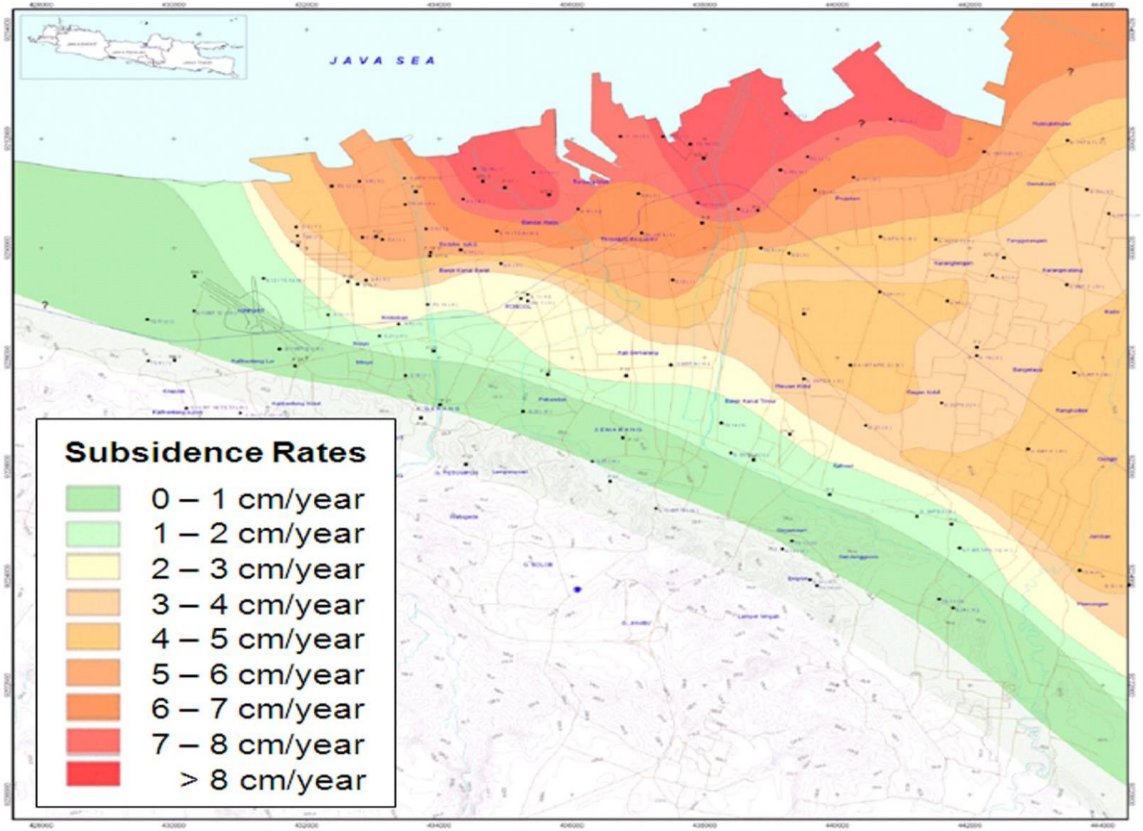
Examples of Observed Subsidence Rates in Semarang

(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 - 2016
3	PS InSAR	1 - 10	3 - 8	2002 - 2006
		1 - 7	3 - 6	1996 - 2006
		up to 8	3 - 6	2016 - 2020
4	Microgravity	1 - 15	2 - 10	2002 - 2005
5	Geometric-Historic	1 - 13		2012

The land subsidence rates in Semarang provided by the above monitoring methods are generally in the same range, namely 2 to 10 cm/year.



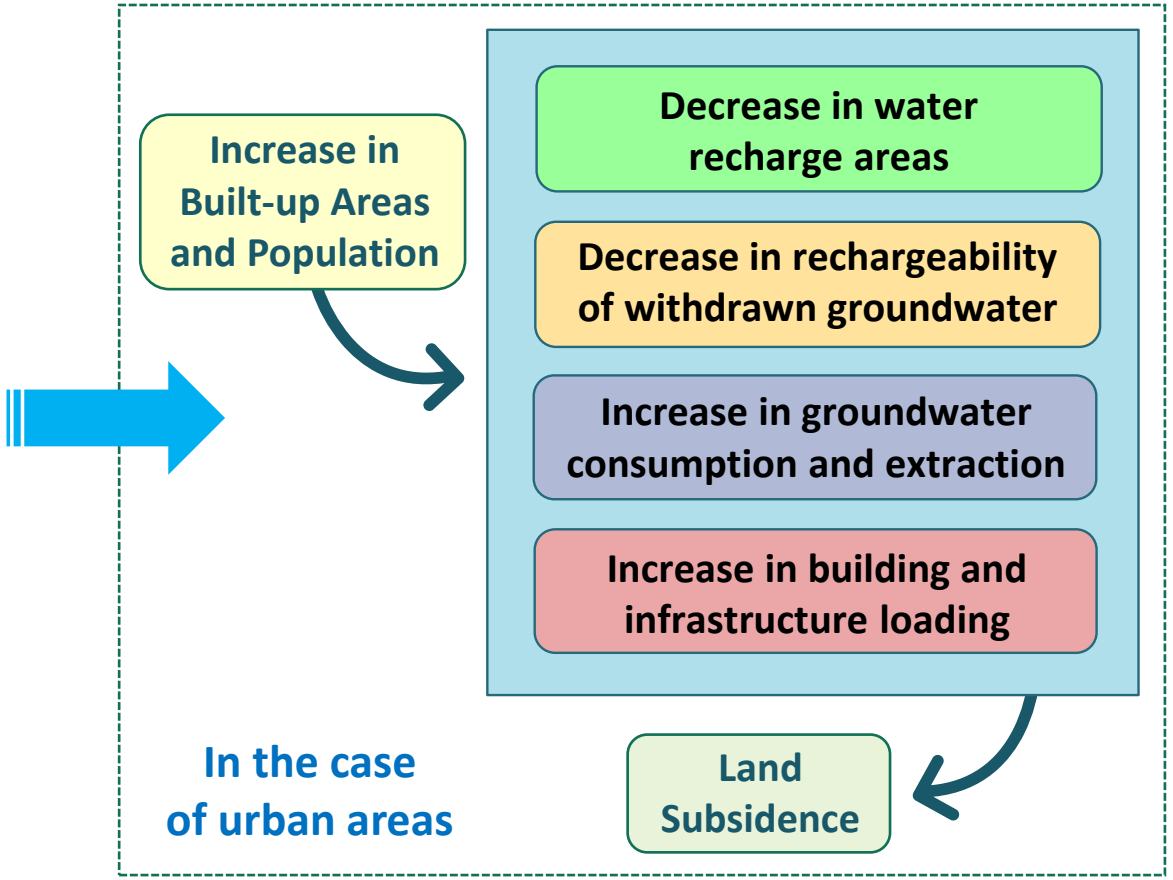
Subsidence Rates in Semarang (2002 to 2006) from PS InSAR; courtesy of Geological Agency Bandung, after *Murdahardono et al.* (2009).

Causes of Land Subsidence

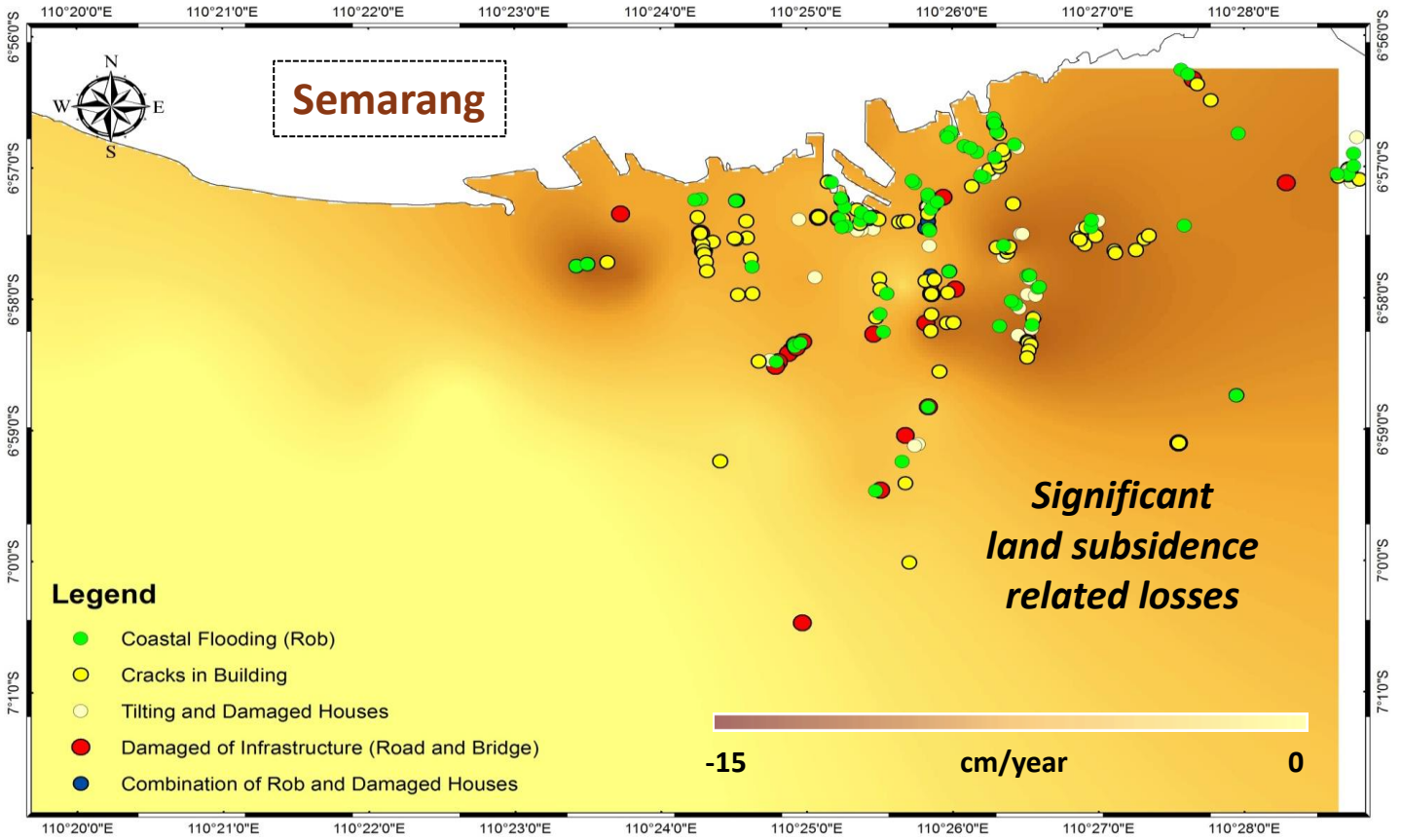
According to several studies, the following are possible causes of land subsidence in several Indonesian regions (including urban areas):

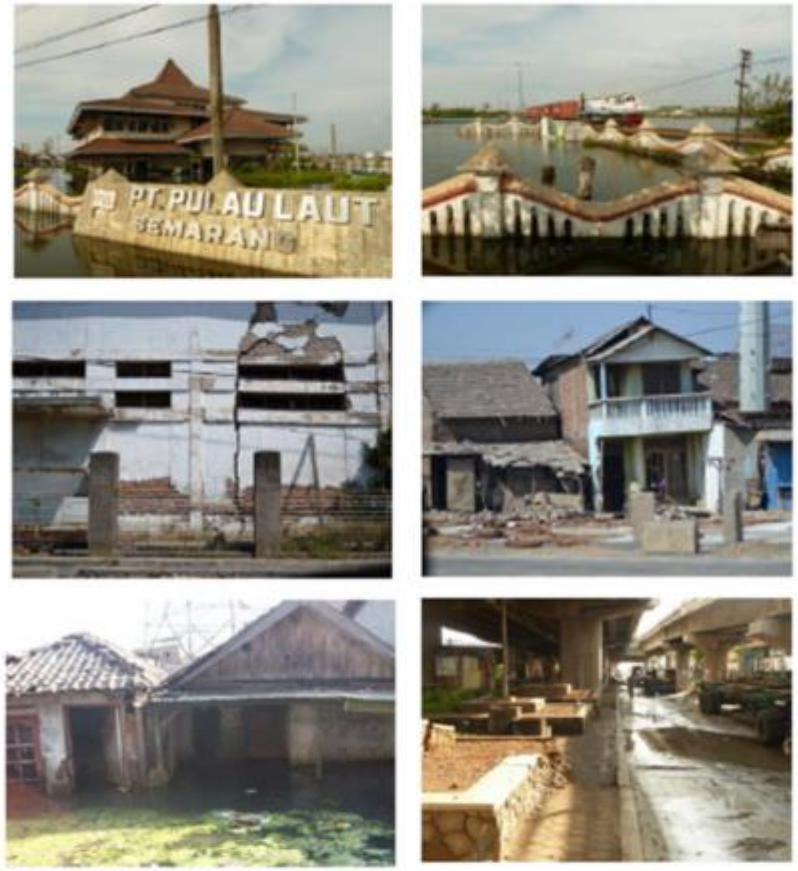
ANTHROPOGENIC
1. excessive groundwater extraction.
2. load of buildings and constructions (i.e. settlement of high compressibility soil).
NATURAL
3. natural consolidation of alluvium soil.
4. tectonic activity.

Land subsidence is usually caused by combination of these factors.



Examples of Land Subsidence Impacts in Coastal Area





Ref: Abidin, H.Z., H. Andreas, I. Gumilar, T.P. Sidiq and Y. Fukuda (2012). "Land subsidence in coastal city of Semarang (Indonesia): characteristics, impacts and causes", *Journal of Geomatics, Natural Hazards and Risk*, DOI:10.1080/19475705.2012.692336.

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Several Impacts of Land Subsidence

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

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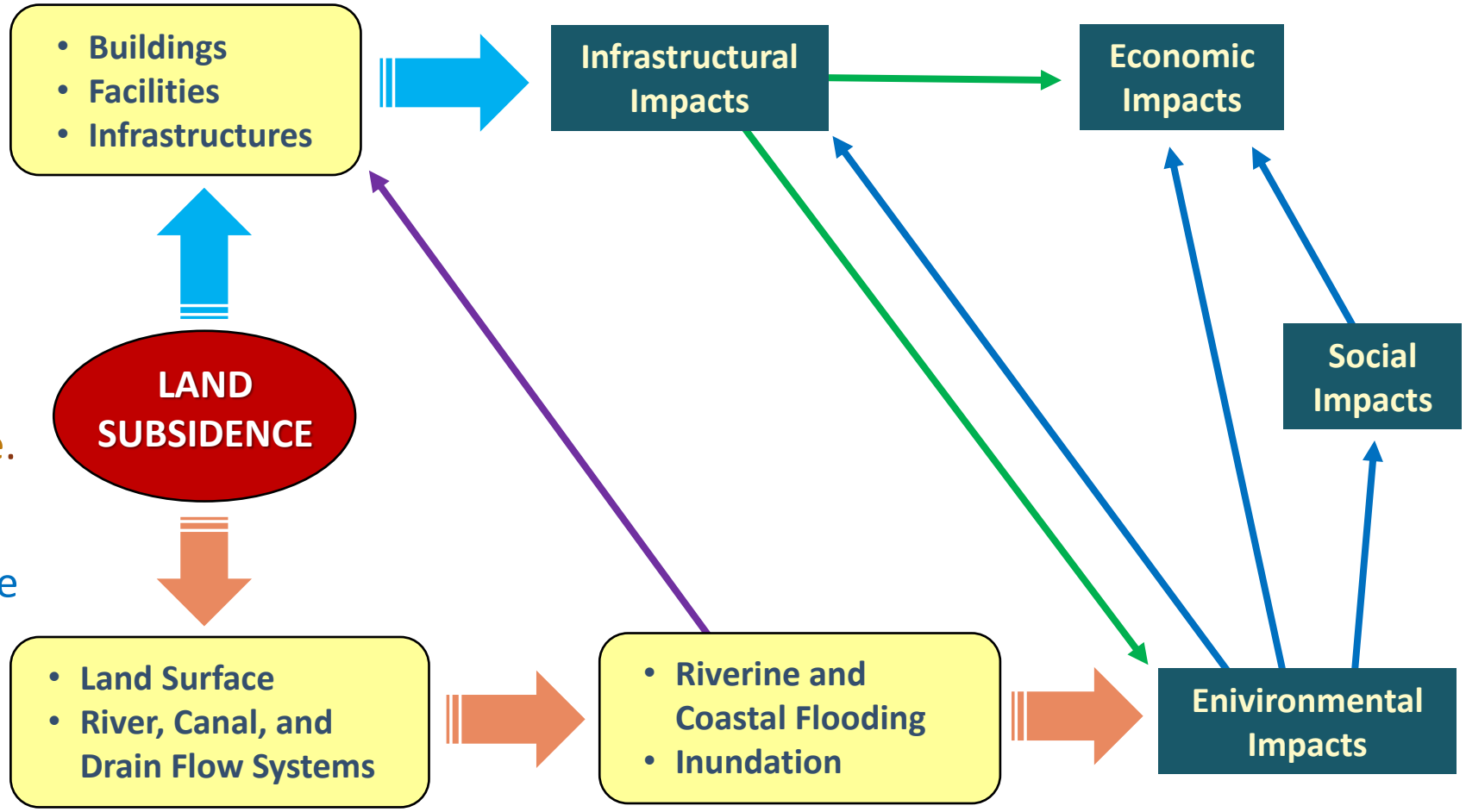
Ref: Abidin, H. Z., Andreas, H., Gumilar, I., and Brinkman, J. J. (2015). "Study on the risk and impacts of land subsidence in Jakarta", Proceedings of IAHS, Vol. 372, pp. 115-120, doi:10.5194/piahs-372-115-2015.

The Interconnected Impacts of Land Subsidence

- The majority of these impacts are caused **indirectly** by land subsidence in the affected areas.
- Several are **directly** related to subsidence.
- Furthermore, these subsidence effects are **interconnected.**



Ref: Abidin, H.Z., H. Andreas, I. Gumilar, and I. R. R. Wibowo (2015). "On correlation between urban development, land subsidence and flooding phenomena in Jakarta". *Proceedings of IAHS*, Vol. 370, pp. 15–20, proc-iahs.net/370/15/2015/, doi:10.5194/piahs-370-15-2015.

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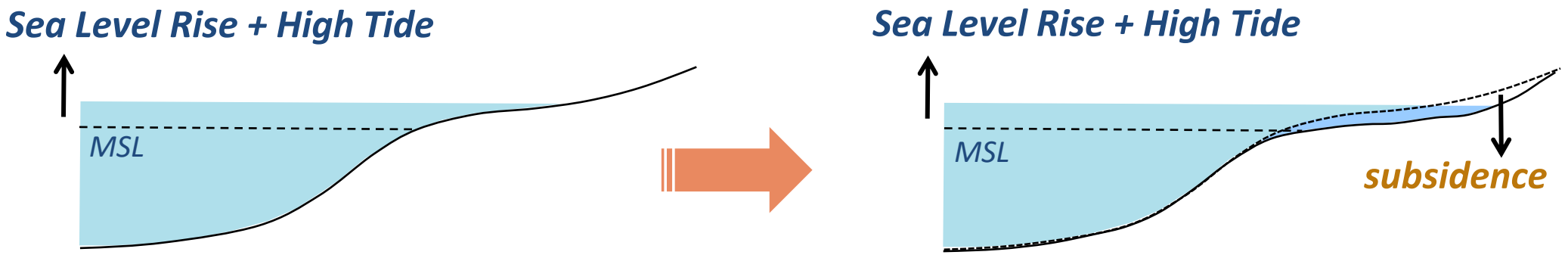
Coastal Subsidence and Flooding



Coastal flooded area (without subsidence)

Ref: Abidin et al. (2015)

Coastal flooded area (with subsidence)

Keep an eye out for subsidence along North Java's coastal areas.

Sea Level Rise:
0.1 – 0.5 cm/year (IPCC)

Coastal Subsidence:
3 - 10 cm/year

- *Tidal Flooding*
- *Surface water degradation*
- *Environmental degradation*
- *Decrease in livelihood quality*

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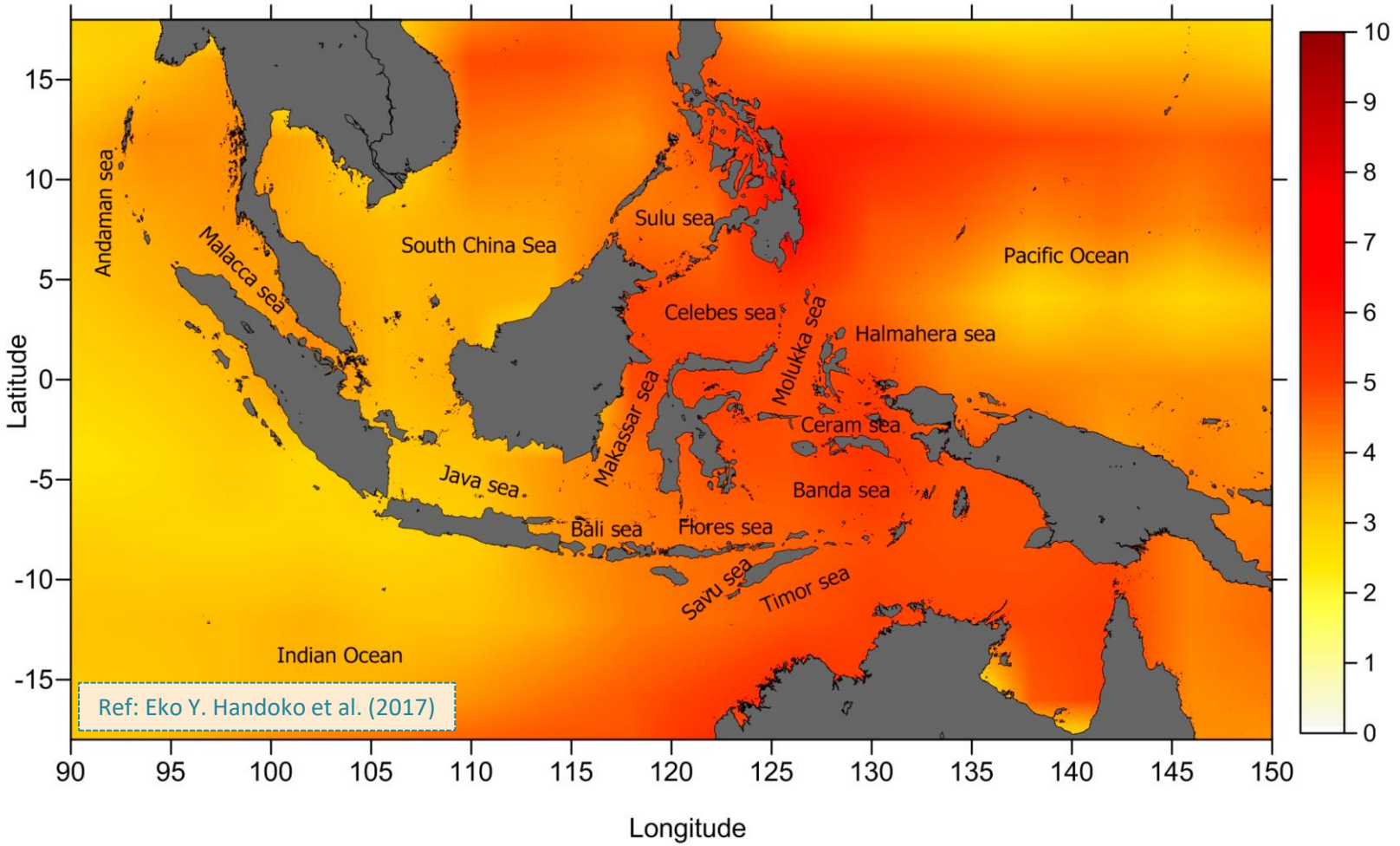
Sea Level Rise in mm/year (1993-2015)

from Satellite Altimetry

The map of sea level trend (unit in mm/year) around the Indonesian seas, estimated from three different satellite altimeters (T/P, Jason-1 and Jason-2) over 1993 to 2015 period.

Between 1993 and 2015, **sea level rise** in Indonesian waters ranged between 2 and 7 mm/year.



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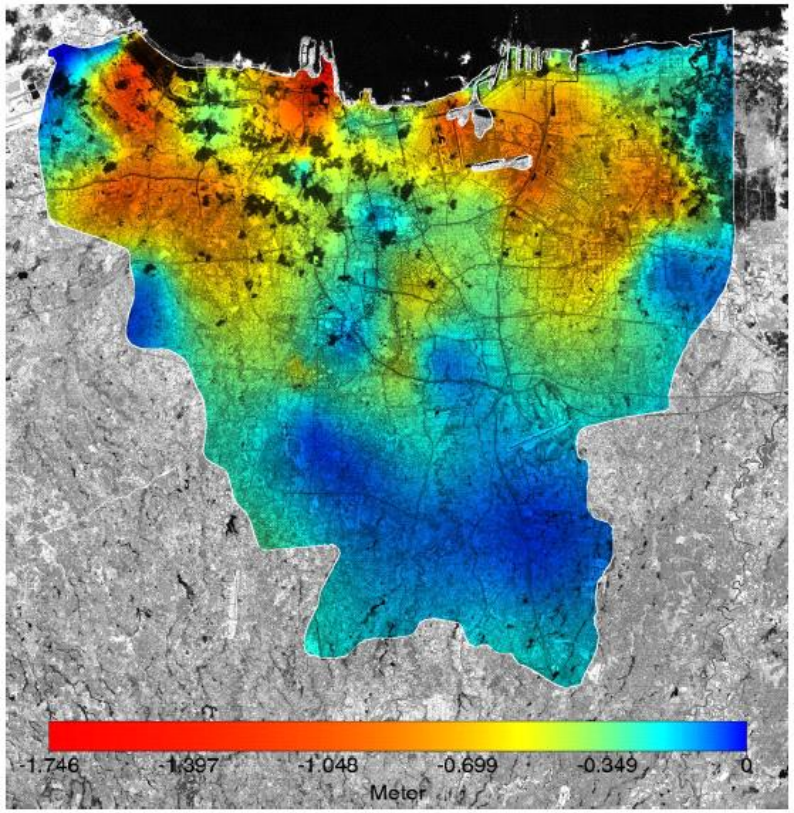
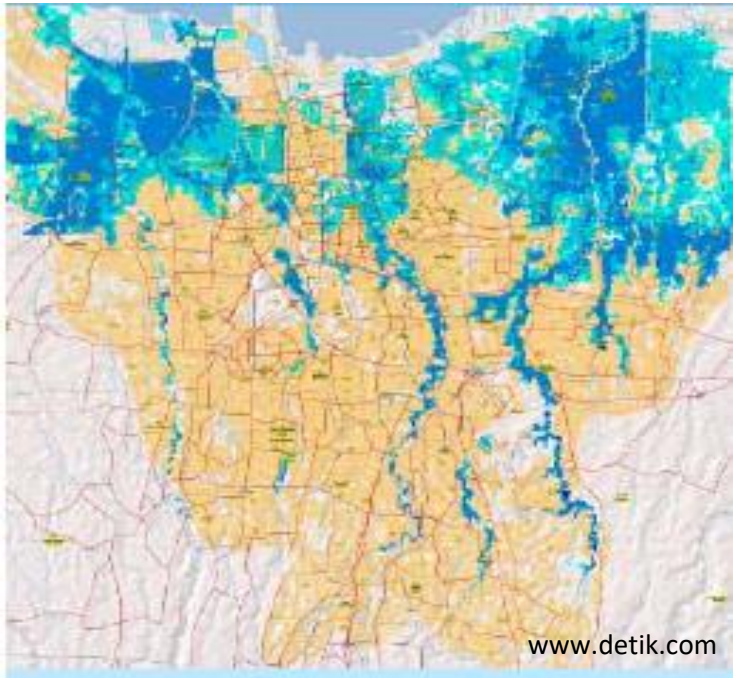
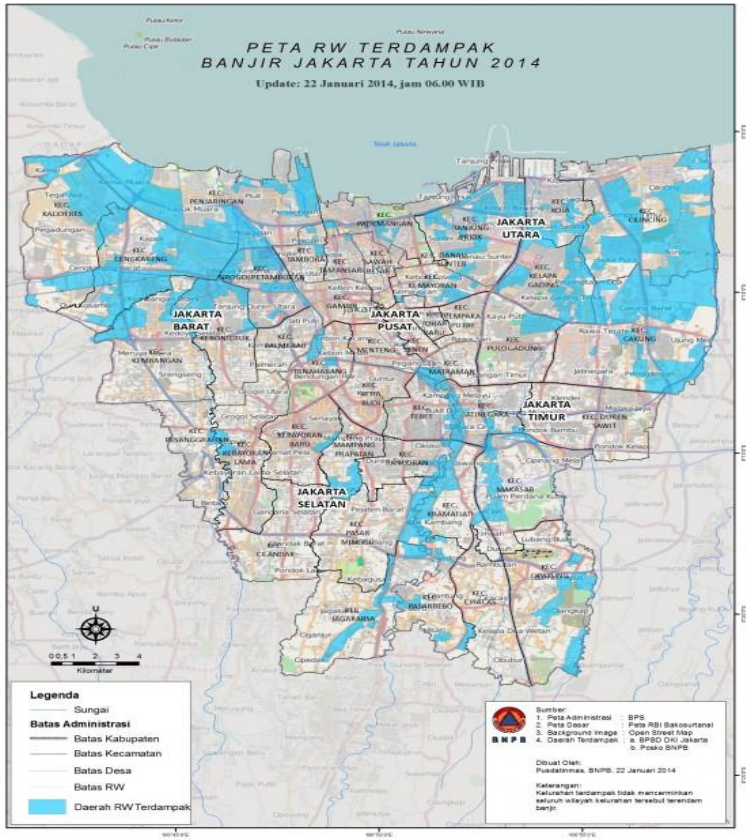
Land Subsidence and Flooding in Jakarta



GPS-derived subsidence (2000-2011)



Flooding of 2007



Ref: geospasial.bnpb.go.id

Flooding of 2014

Inland and **coastal** flooding and inundation are both affected by land subsidence.

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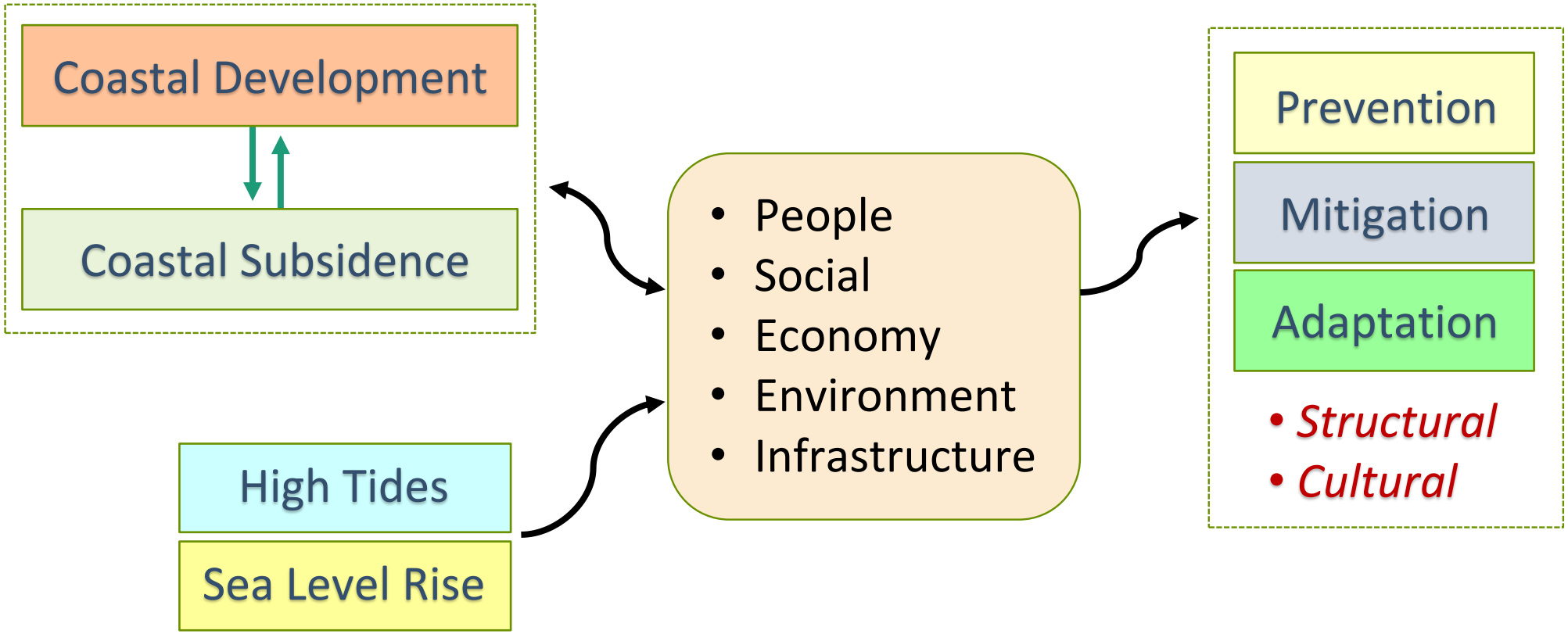
Ref: Abidin, H.Z., H. Andreas, I. Gumilar, and I. R. R. Wibowo (2015). "On correlation between urban development, land subsidence and flooding phenomena in Jakarta". Proceedings of IAHS, Vol. 370, pp. 15–20, proc-iahs.net/370/15/2015/, doi:10.5194/piahs-370-15-2015.

Coastal subsidence and coastal flooding is part of larger system



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Example: Semarang's Mitigation and Adaptation Plan

From: https://www.wetlands.org/casestudy/future-proofing-cities-asia-water-leverage-resilient-cities/

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DPSIR Scheme for Land Subsidence in Indonesia

DRIVERS (D)

- Urban development: increase in built-up areas, population, and economic and industrial activities.
- Natural consolidation of alluvium soil.
- Tectonic activity.

PRESSURES (P)

- Surface water supply is insufficient.
- Increase in groundwater consumption and extraction.
- Increase in building and infrastructure loading.
- "Wicked" policy problem of land subsidence.

STATE (S)

- Several coastal cities in North Java experience significant subsidence.
- Typical subsidence rates of about 3 to 10 cm/year.
- The rate of subsidence varies both spatially and temporally.

IMPACTS (S)

- (Inland and coastal) inundation and flooding.
- Cracking, tilting, and damage of houses, building, and infrastructures.
- Surface water degradation.
- Environmental degradation.
- Decrease in livelihood quality.
- Lead to infrastructural, economic, environmental and social losses.

RESPONSES (S)

- Establishment of a monitoring system for land subsidence.
- Sustainable urban and coastal development.
- Subsidence-aware spatial planning.
- Groundwater extraction regulation.
- Gradual implementation of a zero-groundwater strategy.
- Building and infrastructure codes.
- Coastal dyke construction.
- Flood management and control.
- Sea water intrusion control.

✓ Preventation.
✓ Mitigation.
✓ Adaptation

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Thank you for your attention