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"Climate Change Impacts and Adaptation for Coastal Transport Infrastructure in the Caribbean"

Examples of sea level rise adaptation from ports in Japan and Indonesia

By

Miguel Esteban

University of Tokyo, Japan

Examples of sea level rise adaptation from ports in Japan and Indonesia

Miguel Esteban
Associate Professor,
The University of Tokyo (Japan)

Summary

- **Adaptation to Sea Level Rise in islands (Philippines) – why I think people are not going to relocate***
- **Adaptation to Land Subsidence of Ports in Jakarta, Indonesia**
- **Adaptation to Land Subsidence of Ports in Tohoku, Japan**

*At least not because of SLR. Hurricanes, well, that is a slightly different story…

Sea Level Rise Adaptation: Learning from >0.5m “rise” in the Philippines (possibly up to 1.0m)

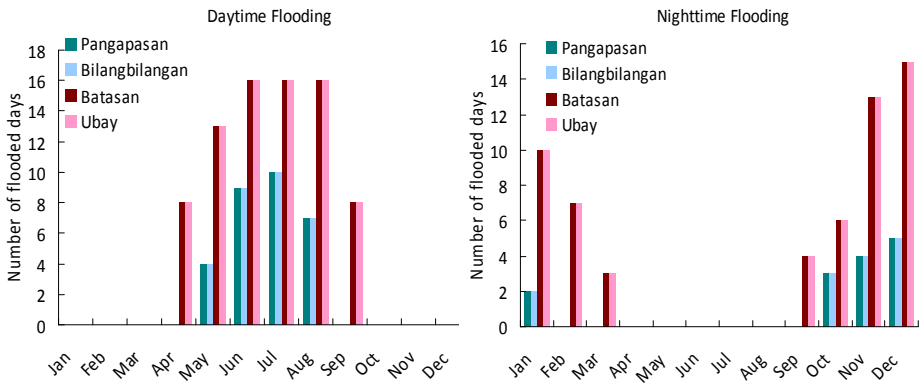
(Think of my presentation as a Time Machine into the Future!)

Coral Islands off Bohol, Philippines

Consequences of ~0.5-1.0m subsidence due to the 2013 Earthquake

Island	Highest elevation (m)	Area (m^2)	Cross-section (m)	Built environment	Flooding situation	Severity
Batasan	**2.28**	**58,296**	**47.4**	From the start, ground raised using coral stones; houses built up to the sea	• **Before earthquake: Flooded during strong typhoons** • **After earthquake: Completely flooded during spring tides (e.g. 1 hour daily floods for 1 week around new and full moon)**	**2**
Ubay	**2.15**	**14,638**	**84.8**			**1**
Pangapasan	1.91	20,694	71.1			**3**
Bilangbilangan	1.99	16,668	100.3	Ground not raised; Has beach, with some areas lined with seawall; houses built well within grounds		**4**
Mocaboc	2.06	29,674	118.1		• Before and after earthquake: Houses near waterline occasionally flooded during very high tides (i.e. +2.0m) and typhoons. No perceived changes in flood levels before and after earthquake	**5**
Bagonbanwa	2.5	60,839	187.4		• Before and after earthquake: Not flooded	**6**

Flooding Severity



By 2100 global mean sea level will rise by 0.28m-0.98m, or higher, as numerous presenters have explained

(IPCC 5AR, 2013)

Current situation (Ubay Island, typical water levels) Coping?

Adaptation strategies (Batasan Island)

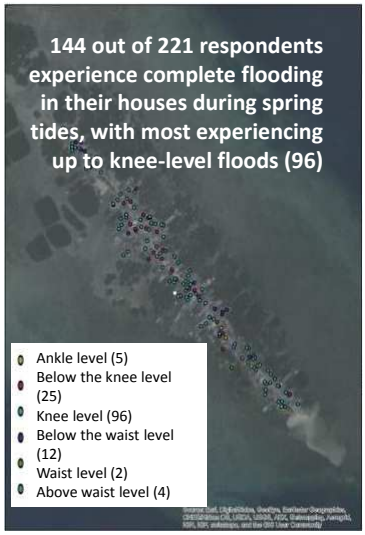
-Rising floors (using coral stones or rubbish)

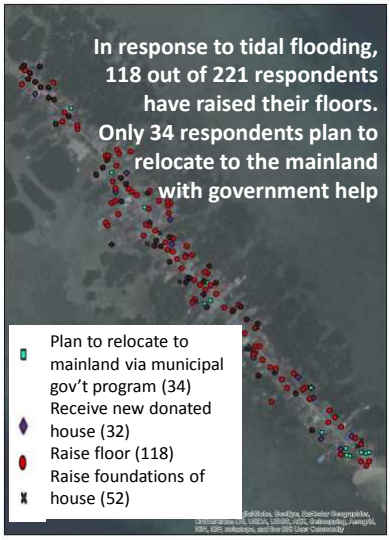
-Building seawalls (using coral stones)

-Houses on stilts

-Learning to live with flooding

Willingness to Relocate

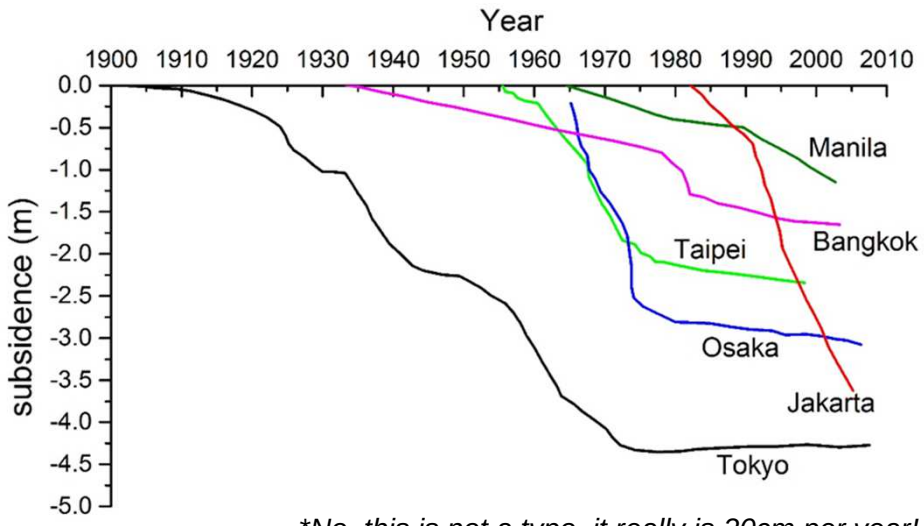




Jamero, L., **Esteban., M.** and Onuki, M. (2016) *"Potential In-Situ Adaptation Strategies for Climate-Related Sea-Level Rise: Insights from a Small Island in The Philippines Experiencing Earthquake-Induced Land Subsidence"*, J-SustaiN 4 (2) pp 44-53.

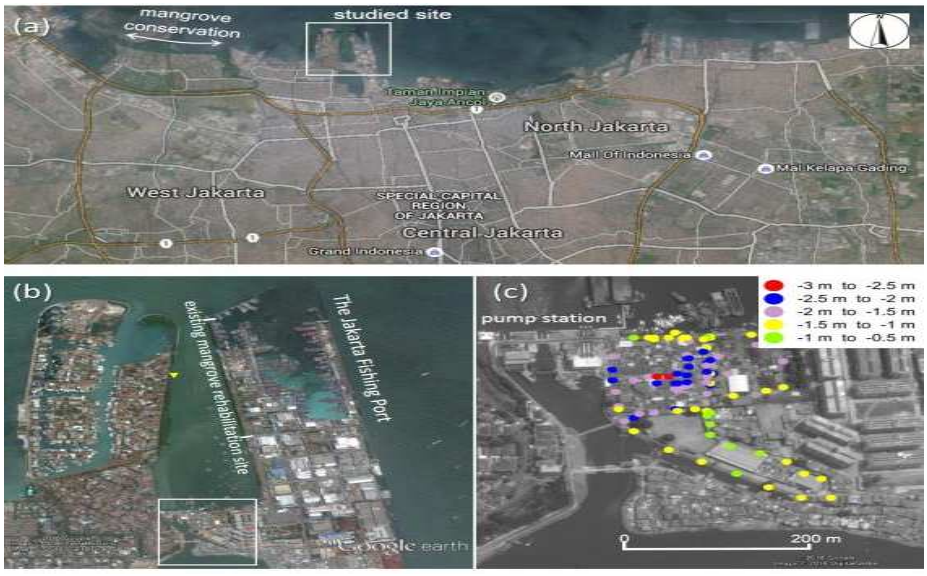
Sea Level Rise Adaptation: Learning from >5.0m "rise" in Jakarta

Reason: Groundwater Extraction (currently ~0.1-0.2 m* subsidence/year)



**No, this is not a typo, it really is 20cm per year!*

Study site: Coastal Jakarta (-0.5 to -3m below sea level)



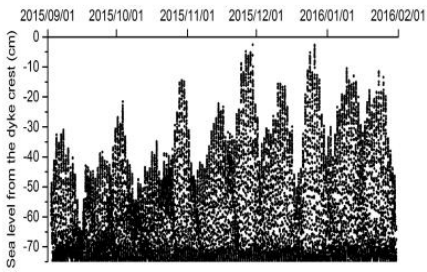
Adaptation (coping?): Building of Sea Dykes

2007 Flooding and Raising of Dyke

Pluit District suffered extensive inundation during a high tide on November 26, 2007

The thin dyke protecting the settlement was raised by about a meter after the 2007 event by the local government

However, sea levels almost reach the top of the dyke on a monthly basis (dike is being raised almost on a yearly basis…)



Sunda Kelapa Port (I)

Sunda Kelapa Port (III)

-Oldest in Jakarta

-52 ha of land area

-~7-10cm subsidence per year

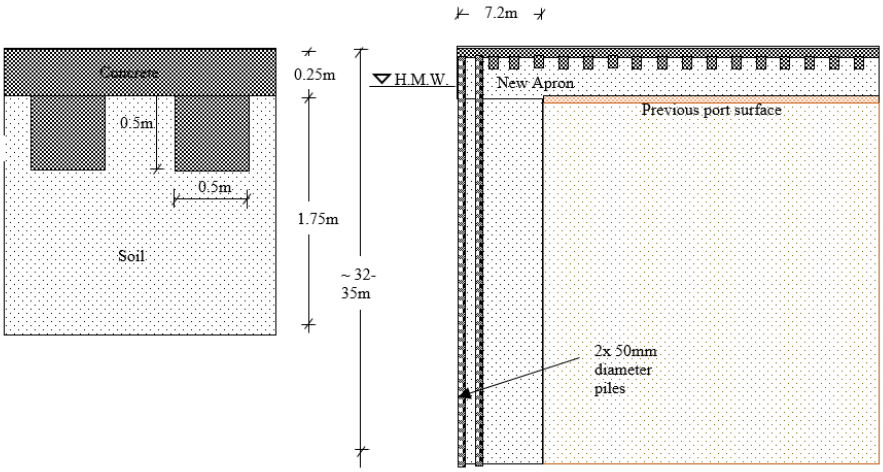
-20% of their annual income spent on adaptation

-Section by section the port elevates its wharfs (depending on the year)

-Adaptation measures do not consider earthquakes (Jakarta has low tsunami risk)

Adapting to land subsidence (I)

Countermeasures: piles 7.2m to the water side, piled soil on top of old surface, placed concrete.
Cost: Ground raising ~100USD/m^2 Piling, 4,000 USD/m run



Barriers to Adaptation

-The port believes there is no limit to how far up they can go using the technology they are using

-If their costs increase they will simply increase tariffs. It is a heritage port, and there are plans to consolidate all passenger transit there

-The government will ultimately have to pay

-Might be increasingly difficult for water to drain to sea (solved through pumps etc)

Sea Level Rise	Technological Limits	Cost-Benefit Limits	Financial Barriers	Social Conflict Barriers
+ 0.5m				
+ 0.51 - **1.0m**				
+ 1.01 - **2.0m**				
+ 2.01 - **4.0m**				
+ 4.01 - **8.0m**				

PPS Nizam Zahman Port (I)

PPS Nizam Zahman Port (III)

-Founded in 1984, largest fishing port in Indonesia

-52 ha of land area

-~7-12cm subsidence per year

-Port was raised in 2002 and then in 2012 (last time by +1.4m)

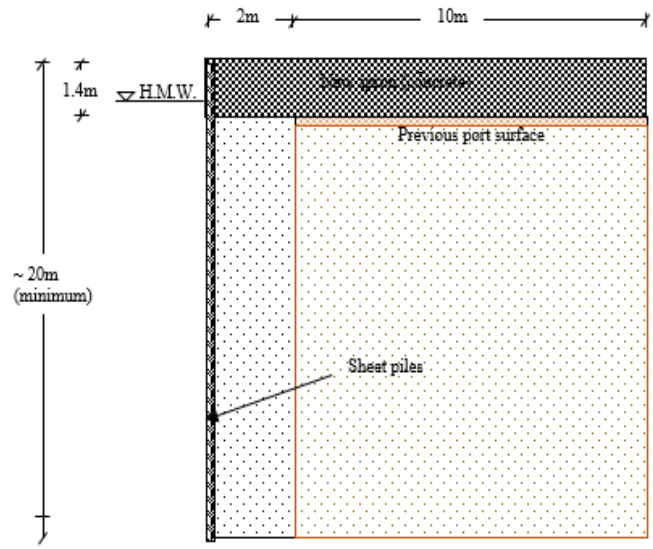
-Raising is done sequentially, first one part of the port, then the others

-Funding for raising was provided by JICA

Adapting to land subsidence (I)

-Port was raised by using sheet piles 2.0m from edge of old port, and then pouring 1.4m of concrete on top of existing port structure

-Thinking of moving to floating port?



Barriers to Adaptation

-The port believes there is no limit to how far up they can go using the technology they are using

-However, might be cost-effective to move to a floating port

-The government will ultimately have to pay (giving multiplier effects to economy)

-Nearby communities are happy to know that the ports are being raised.

Sea Level Rise	Technological Limits	Cost-Benefit Limits	Financial Barriers	Social Conflict Barriers
+ **0.5m**		Floating port better?		
+ 0.51 - **1.0m**				
+ 1.01 - **2.0m**				
+ 2.01 - **4.0m**				
+ 4.01 - **8.0m**				

Muara Angke Port (I)

Muara Angke Port (II)

-Fishing port

-Founded in 1977

-64 ha of land area

-~7cm subsidence per year (Water Resource Agency of Indonesia)

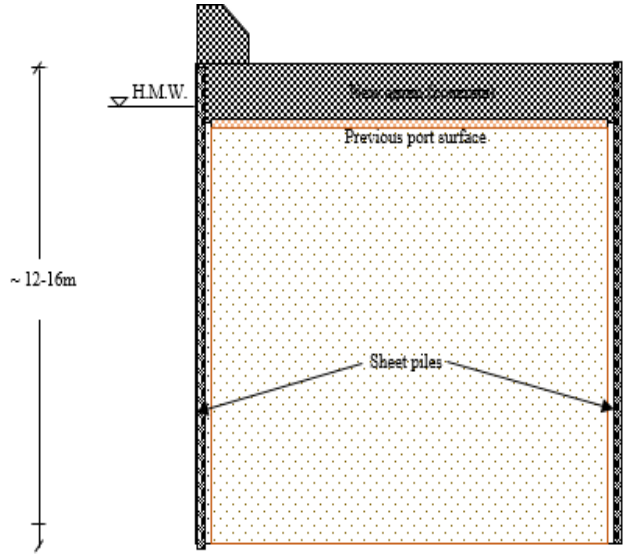
-Port was raised three times (2006, 2011 and 2014, about 40-50cm each time)

-Breakwaters also being submerged by the subsiding land

Muara Angke Port (I)

-Port was raised by using sheet piles right at the edge, and then pouring 0.4-0.5m of concrete on top of existing port structure

-Thinking of moving to floating port?



Barriers to Adaptation

-They can only raise port another 2-3 times before they reach limit of sheet piles. Then they have to move to something else (maybe deeper piles), or maybe floating ports (they are already experimenting with this)

-This will affect the cost of raising the ports (cost-benefit issues), but ultimately the government will have to pay.

-They noted how fishermen are not happy for ports to be elevated by too much each time, given that it is difficult to access ships.

Sea Level Rise	Technological Limits	Cost-Benefit Limits	Financial Barriers	Social Conflict Barriers
+ 0.5m				
+ 0.51 - **1.0m**	Sheet piling limit			
+ 1.01 - **2.0m**	Piles? Floating port			
+ 2.01 - **4.0m**	Piles? Floating port			
+ 4.01 - **8.0m**	Piles? Floating port			

Tohoku and Land Subsidence
(0.5 to 1m subsidence)

Ishinomaki Port

Ishinomaki Port (II)

-Industrial port

-Approx. 1.0m land subsidence as consequence of 2011 earthquake

-Design considerations are dominated by tsunami hazard in the area

-Earthquake countermeasures are very important (and costly).

-4,000 USD to elevate 1m^2 of port by one metre

Barriers to Adaptation

-No technological limits, though re-design would be necessary to adapt the design (new piles?) if going above an extra 1m of raise. Raixing ground by another half a metre would be maybe x10 more expensive, and a further metre could be x100 more expensive (earthquake measures)

-No cost-benefit assessments were conducted, but government would ultimately spend the money. However, over 4m would be make no sense from cost-benefit point of view.

-After 4.0m local residents might be happier to retreat

Sea Level Rise	Technological Limits	Cost-Benefit Limits	Financial Barriers	Social Conflict Barriers
+ 0.5m				
+ 0.51 - **1.0m**				
+ 1.01 - **2.0m**				
+ 2.01 - **4.0m**				
+ 4.01 - **8.0m**				

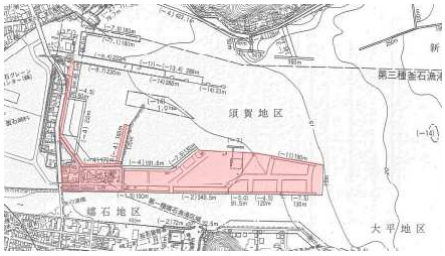
Kamaishi Port (I)

-Industrial port

-Approx. 1.0m land subsidence as consequence of 2011 earthquake

-Design considerations are dominated by tsunami hazard in the area

-360 USD to elevate 1m^2 of port by one metre (looks like unit rates only)



Summary of costs so far?

-Seems there is some disparity in costs

- Developing vs developed country
- Earthquake countermeasures
- Cost of materials to raise, vs inclusion of piling etc

Source	Cost/m^2 for 1 m raise	Notes
Kamaishi Port	360 USD	Does it include piling?
Ministry of Land, Infrastructure, Transport and Tourism	80 USD	Unit rates only. Hoshino et al. (2013)
Ishinomaki Port	4000 USD	Includes piling (for next 1m cost would be x 10!)
Sunda Kelapa	100 USD (+4000 USD/m run)	4000 USD/m run for piling, 100 USD/m^2 for ground elevation

Adaptation on a pharaonic scale? (Tsunami Layer 2 Measures)

Conclusions

- **Adaptation is possible… Jakarta and Japan have already done so!**
- **No significant barriers were identified by port authorities (at least for SLR <1.0m, and even for 2.0m)**
- **It is going to cost money….**
- **Adaptation will be sequential, as an when finance becomes available**
- **However, it is clear that communities are not going to move (at least not because of SLR, hurricanes are a different story!)**

東京大学
THE UNIVERSITY OF TOKYO

GPSS-GLI

Thanks for listening!