Land subsidence in deltas: causes and impacts

Esther Stouthamer
Dept. of Physical Geography
Utrecht University
Delta’s

Day & Giosan 2008, Nature Geoscience
Subsidence: a local problem at global scale

Despite forest destruction, hydroelectric dam projects and more impacts upstream, the Amazon River delta is in relatively good health. Nearly 3 million people live on the delta but its sheer size stumps human impacts.

After farms and urban areas have taken their water allocations, the Colorado River slows to a trickle by the time it reaches its delta. Sometimes it stops flowing altogether and then no sediment is deposited.

The Po delta experienced a 6cm annual subsidence rate, due to sea-level rise and methane extraction. This reduction dramatically once methane extraction ended.

As deltas sink, the risk of flooding rises. In the Yellow River delta, saltwater intrusion has caused 5m-high storm surges.

In 2019, the Chao Phraya river flooded, swamping Bangkok and leaving much of the capital submerged for months. The city has been sinking for decades due to groundwater extraction. steep taxes on groundwater have slowed subsidence substantially.

The Aswan Dam traps nearly 98% of sediment flow downstream. Without those salts, the Nile Delta has compacted and sunk. Relative sea-level rise there is 4.8 millimeters every year.

The delta is home to over 100 million people making it the most populated on Earth. Effective sea-level rise is up to 18 millimeters per year. In 2027–28 substantial flooding affected the delta. Mekong, previously, Chao Phraya, Brahmaputra, Mahanadi, Krishna and Godavari. More than 100,000 died and more than a million people were displaced.

Like other deltas, farmers on the Mekong have cut down mangroves to create space for shrimp ponds. Surveys indicate roughly half the mangroves forests have disappeared. Mangroves helps prevent erosion and are important flood defenses.
Drivers of Subsidence

**Total Subsidence**

**Loading**
- Natural loading
- Infrastructure
- Buildings
- Large constructions

**Artificial Lowering of Groundwater Table**
- Drainage of surface water

**Fluid Extraction**
- Groundwater
- Hydrocarbons
- Earth crust dynamics

**Tectonics & Isostasy**

**Processes of Subsidence**

**Shallow**
- Autocompaction
- Consolidation creep

**Deep**
- Confined aquifer
- Consolidation creep
- Consolidation Seismicity
- Isostasy

**Colourcode:**
- Process
- Natural driver
- Anthropogenic driver

**Subsidence**

Minderhoud et al. 2015 NISOLS
Drivers are location specific!

Natural drivers
Low rates

- basin tectonics
- local tectonics
- loading

Climate change >> rates

- Groningen/part Wadden area

Human-induced drivers
High rates!

- drainage
- loading

- extraction groundwater
- Mekong delta

- extraction hydrocarbons

Spatial scale

Time scale

Naar: Stouthamer & Van Asselen 2015  IAHR
How much?

RSL Tokyo 4,5 m!
Impacts

- Floods
- Damage to buildings/infrastructure
- Salt water intrusion/availability of fresh water
- Stability of river- and sea dikes
- Land use (food production)
- Emission of GHG
- Loss of wetlands and biodiversity
- Health
- Economy (billions/yr!)
Flooding

> Flood risk

Undermining dike
Loss of:
- land
- biodiversity
Oil palm plantation, drained 20 years ago, already frequently flooded and being abandoned...