No 894476 — InSPiRED — H2020-MSCA-IF-2019

How geomorphology shaped policy

Advances in system understanding of the Mekong delta reveal large anthropogenic impacts and drive policy change

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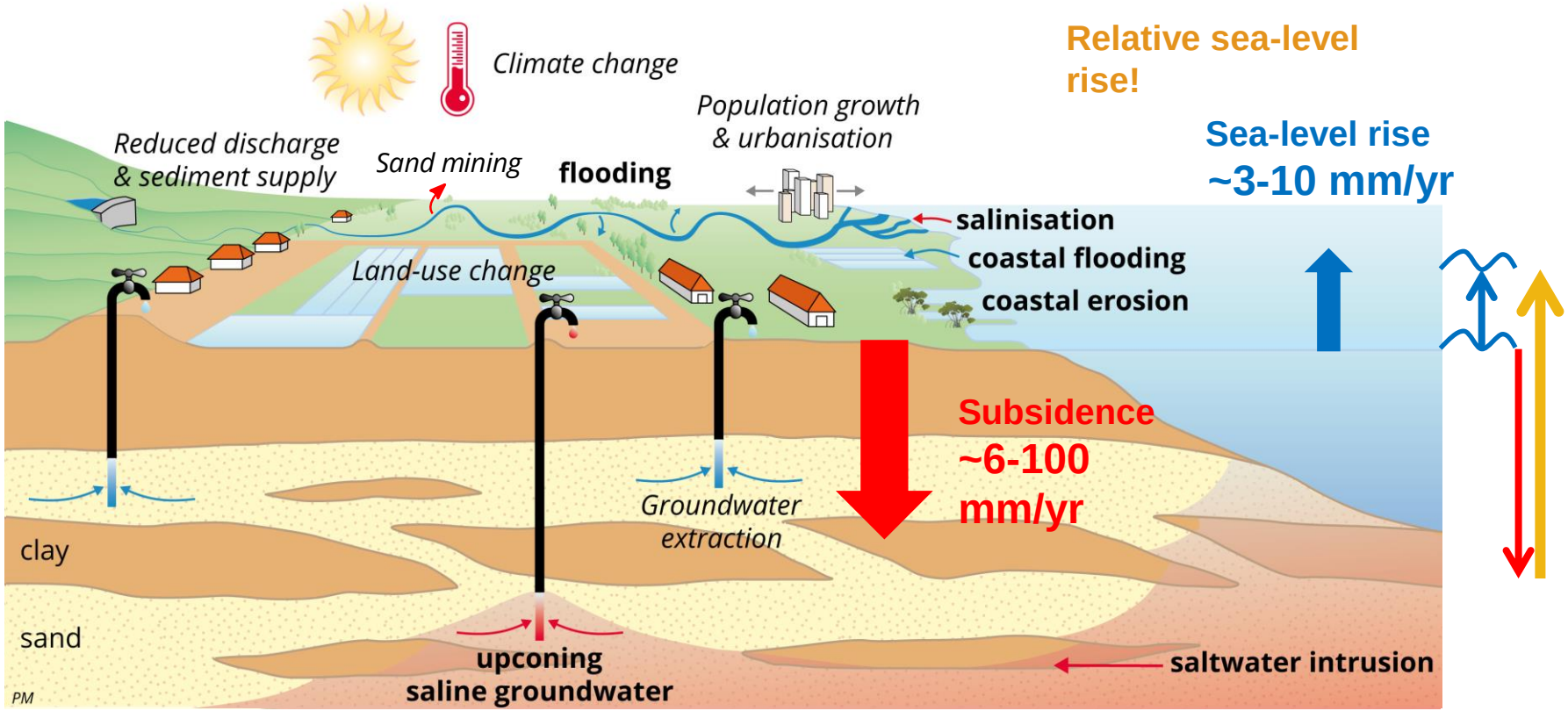
Human changes and consequences in delta systems



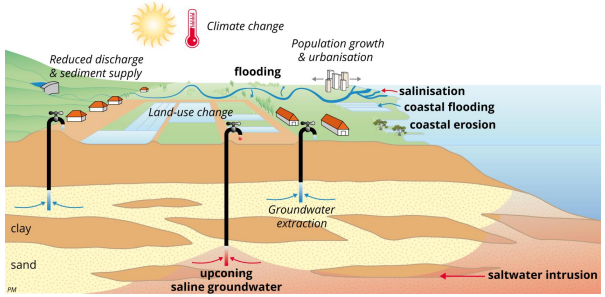
Minderhoud, 2019

Changes in the Mekong delta – A story of Sand and Water

The Mekong delta has experienced rapid and accelerating environmental changes in the past decades(s).

Overview of recent geomorphological research by several research groups that advanced our system understanding:

- Research showed the impacts of upstream changes, like **dam building** (a.o. Kondolf et al., 2014) and changing **cyclone activity** (Darby et al,. 2016) and downstream changes, **coastal erosion** (a.o. Anthony et al., 2015) on the delta.
- Other studies revealed the impacts of human activities within the delta itself driving geomorphological changes – mainly related to the overexploitation of **sand** and **water**.
- **Sand** mining (a.o. Brunier et al., 2014) from the river bed causes **river bank erosion** (a.o. Hackney et al, 2020) and deepening of the estuary channels increases **tidal amplitude and salinity intrusion** (a.o. Eslami et al., 2019)
- Overexploitation of **groundwater** accelerated **land subsidence** (o.a. Erban et al., 2014; Minderhoud et al., 2017,2020) and causes increased **salinization** in the subsurface (a.o. Pham et al., 2019, in prep)

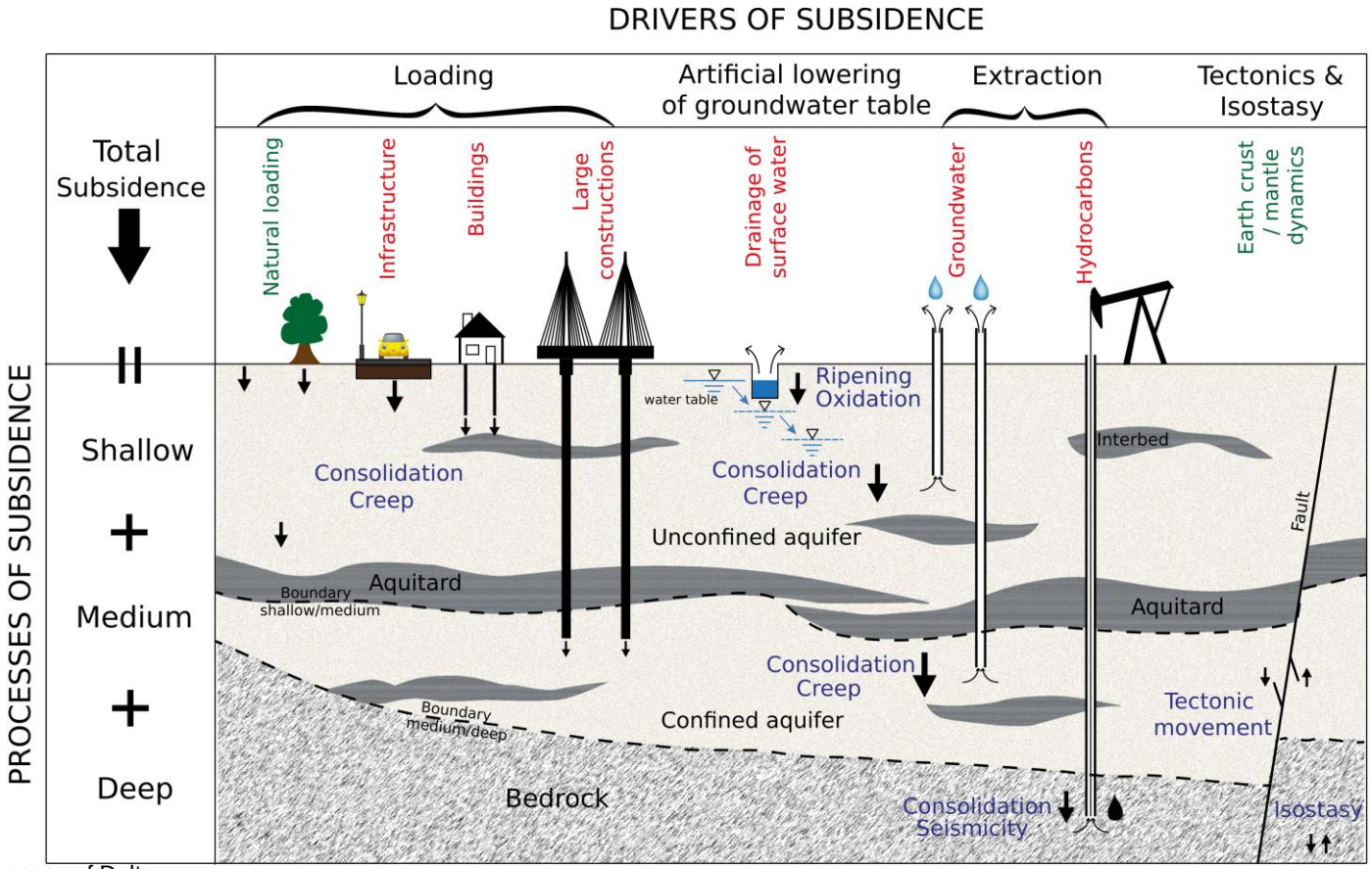


Processes and drivers of delta subsidence

Land subsidence is natural process in deltas.

Land subsidence can be **accelerated** by human activities that increase physical loading or change the hydrogeological situation

Total subsidence is the cumulative effect of all processes

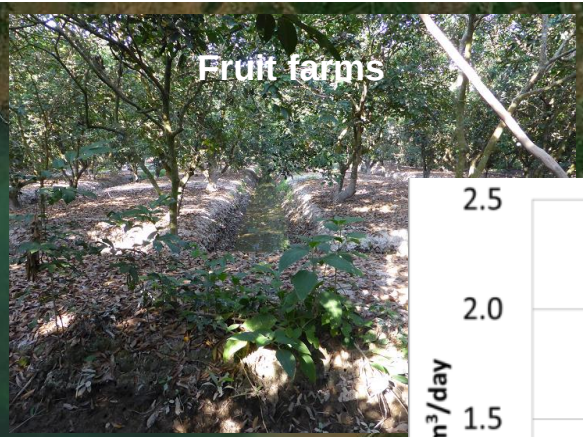


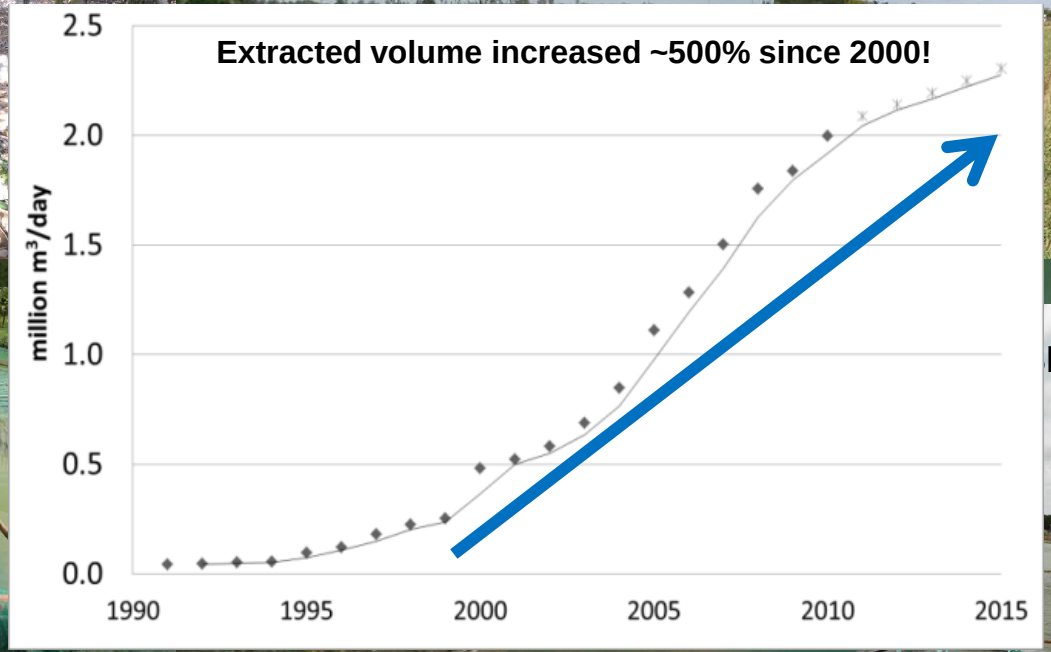
Sinking d consequences of Delta subsidence

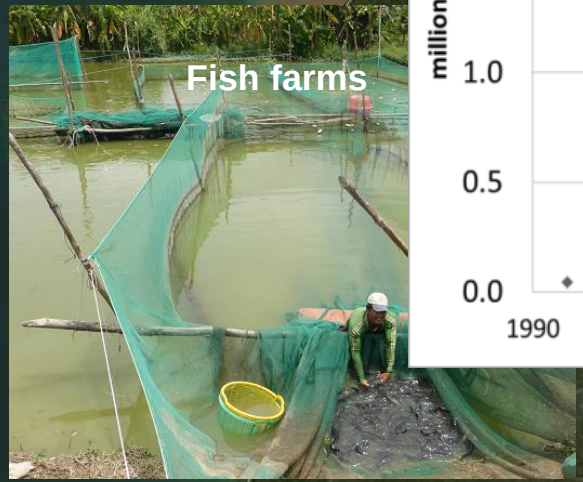
Minderhoud et al. 2015; Minderhoud, 2019

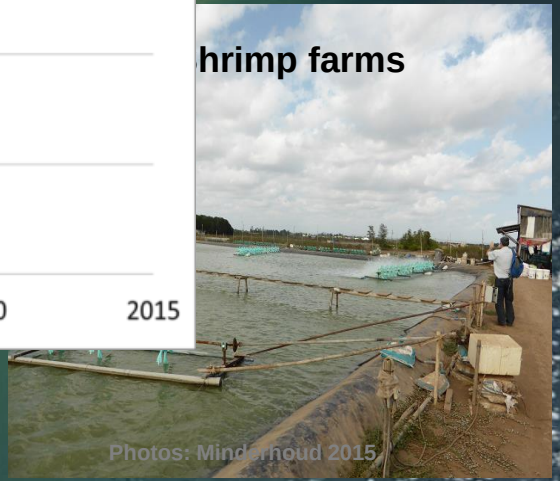
Colourcode: Process Natural driver Antropogenic driver Subsidence

Groundwater extraction in the Mekong delta





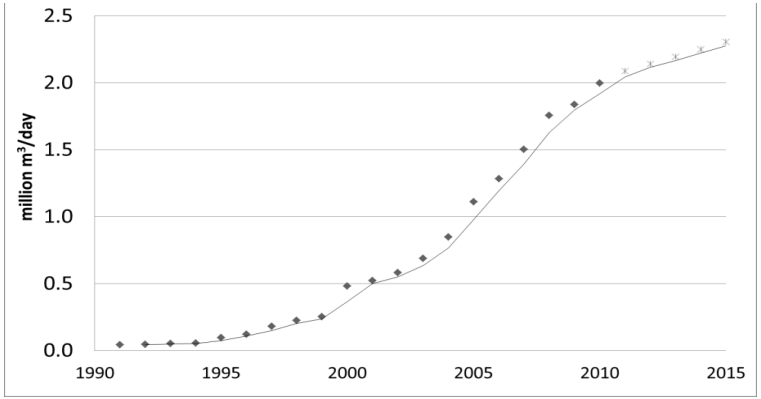




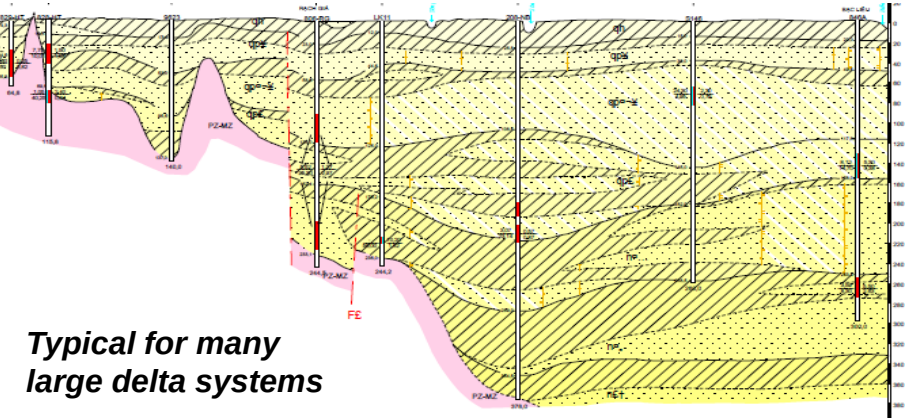
Photos: Minderhoud 2015

Groundwater extraction and hydraulic heads

Groundwater extraction in the Mekong delta

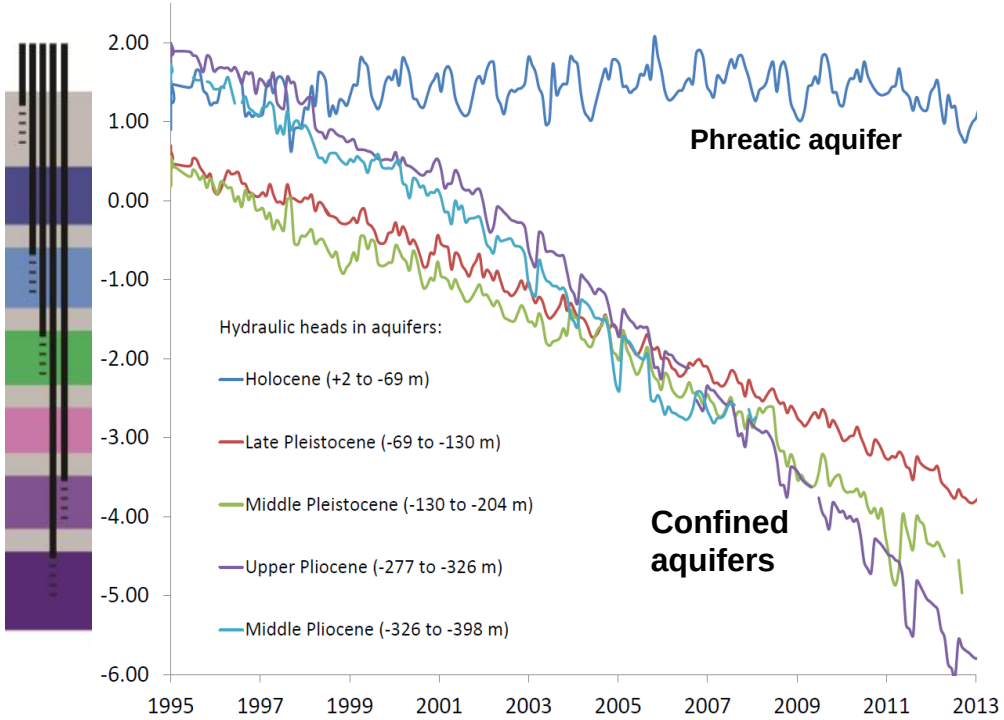


Multi-aquifer system of the Mekong delta



Typical for many large delta systems

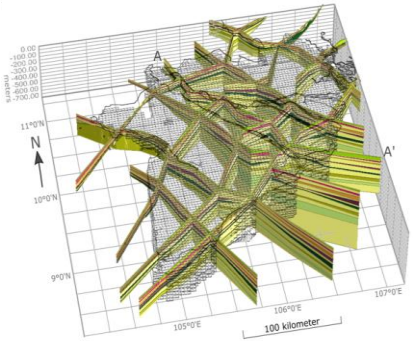
Monitoring wells near Can Tho
Representable for the situation in the Mekong delta



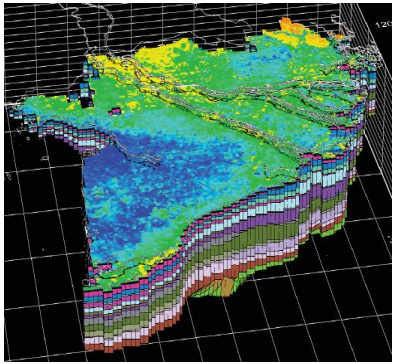
Minderhoud et al., 2017

3D hydrogeological model with subsidence module

Input data

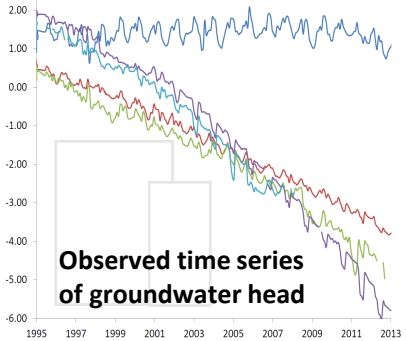


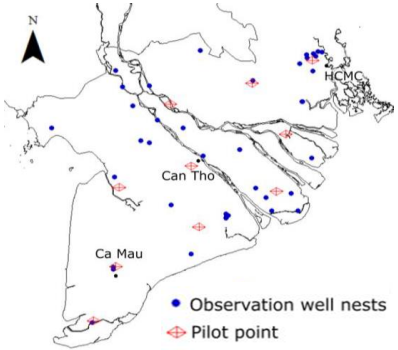
Geological borelogs and cross-sections



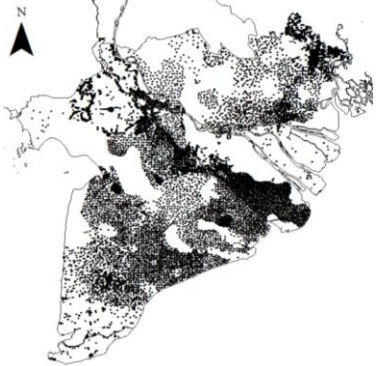
3D subsurface

Hydrogeological calibration

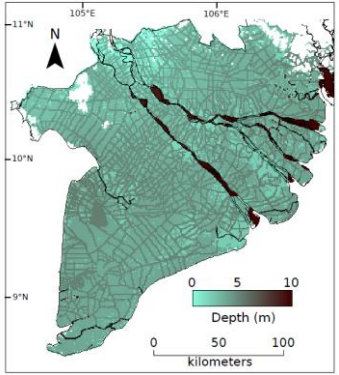




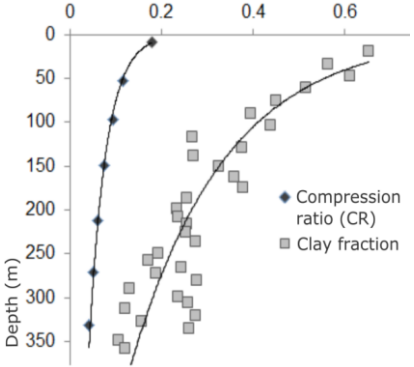
Subsidence module



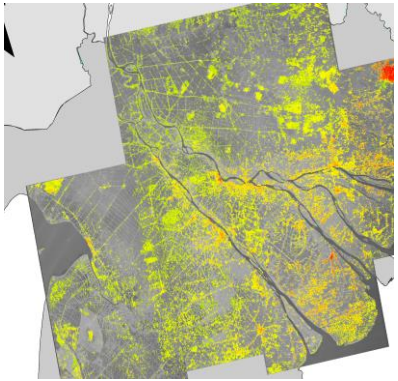
Location, depth & rate of groundwater extractions



Surface water system



Geotechnical parameters based on field data

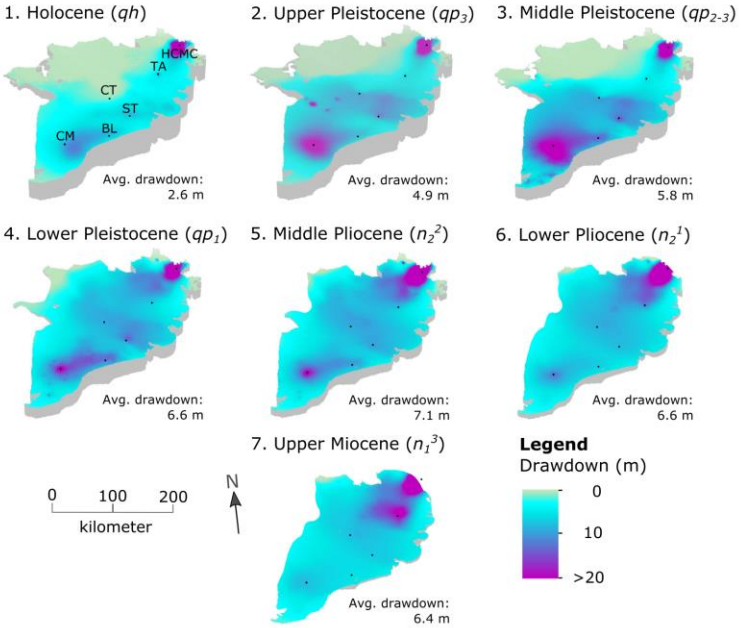


Validation: InSAR-derived subsidence (Erban et al., 2014)

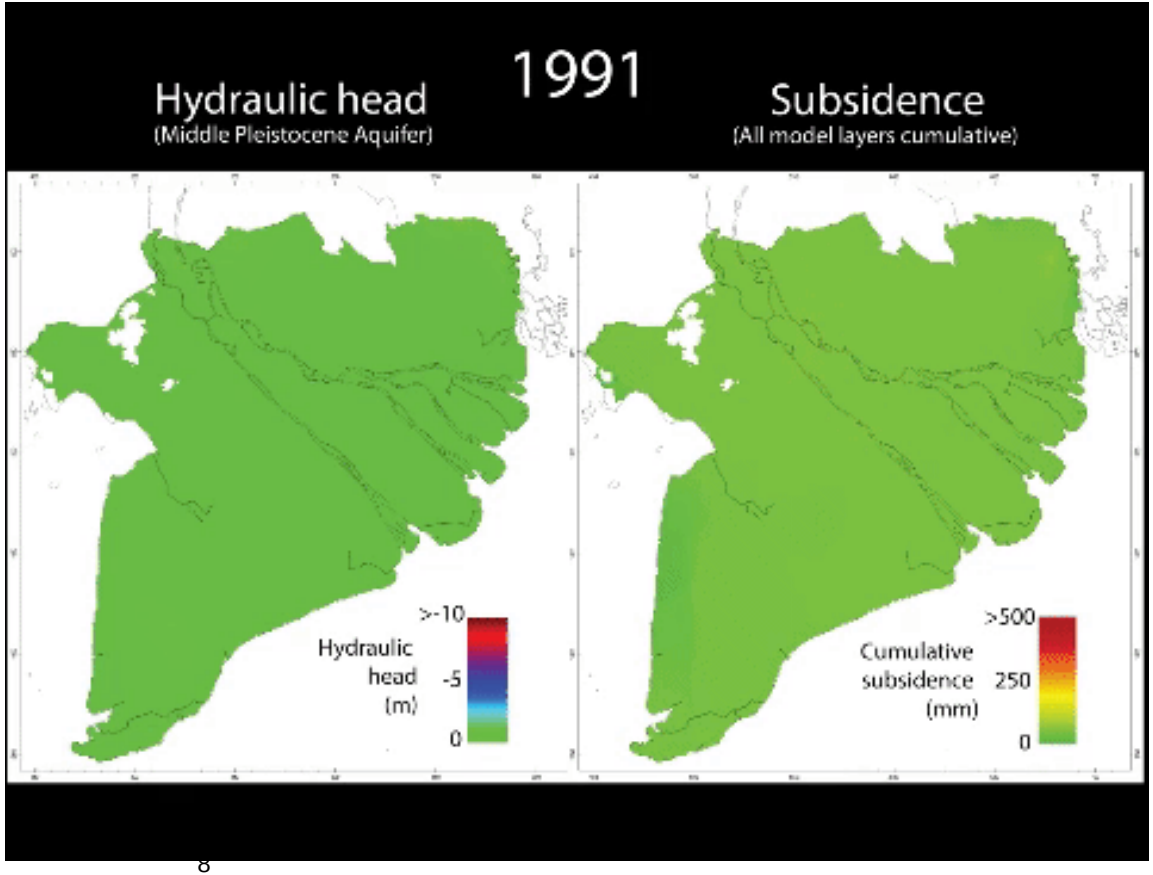
Minderhoud et al., 2017 - Environmental Research Letters

25 years of simulated groundwater extraction

Water level in the aquifers

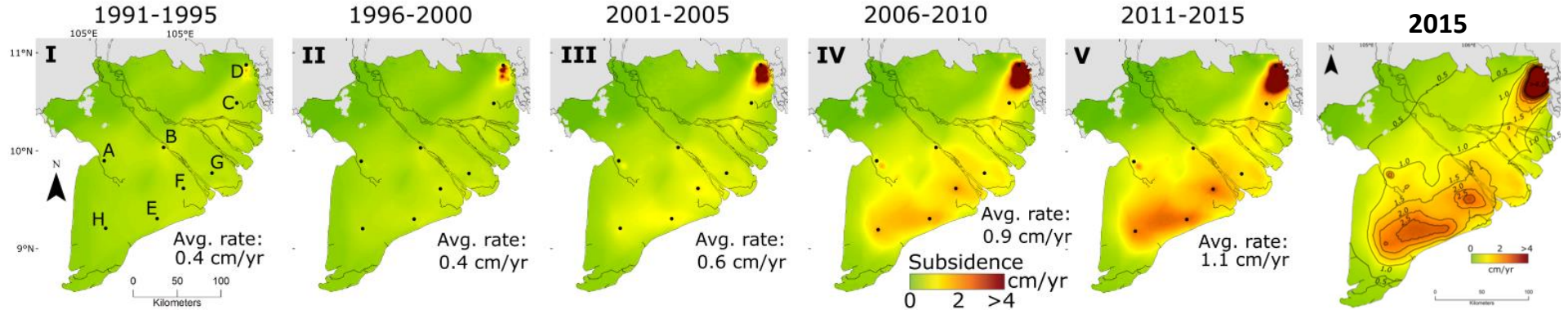


Groundwater extraction is much larger than groundwater recharge



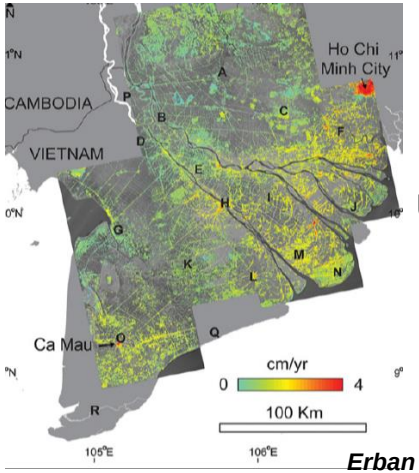
Minderhoud et al., 2017 - Environmental Research Letters

Extraction-induced subsidence is accelerating!



Minderhoud et al., 2017 - Environmental Research Letters

Groundwater extraction-driven subsidence exceeds absolute sea-level rise by a magnitude!



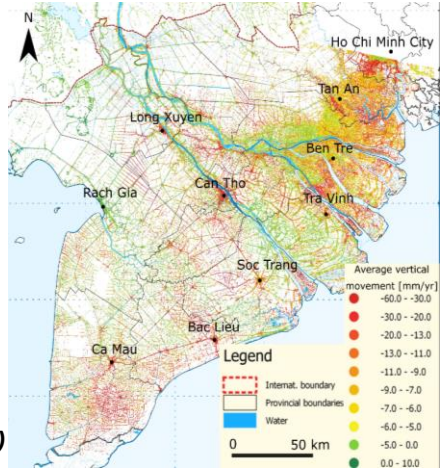
Erban et al., 2014

InSAR-derived subsidence rates confirm modelled acceleration

<u>2006-2010:</u>
Up to 2-3 cm/yr

<u>2014-2019:</u>
Up to 5-6 cm/yr

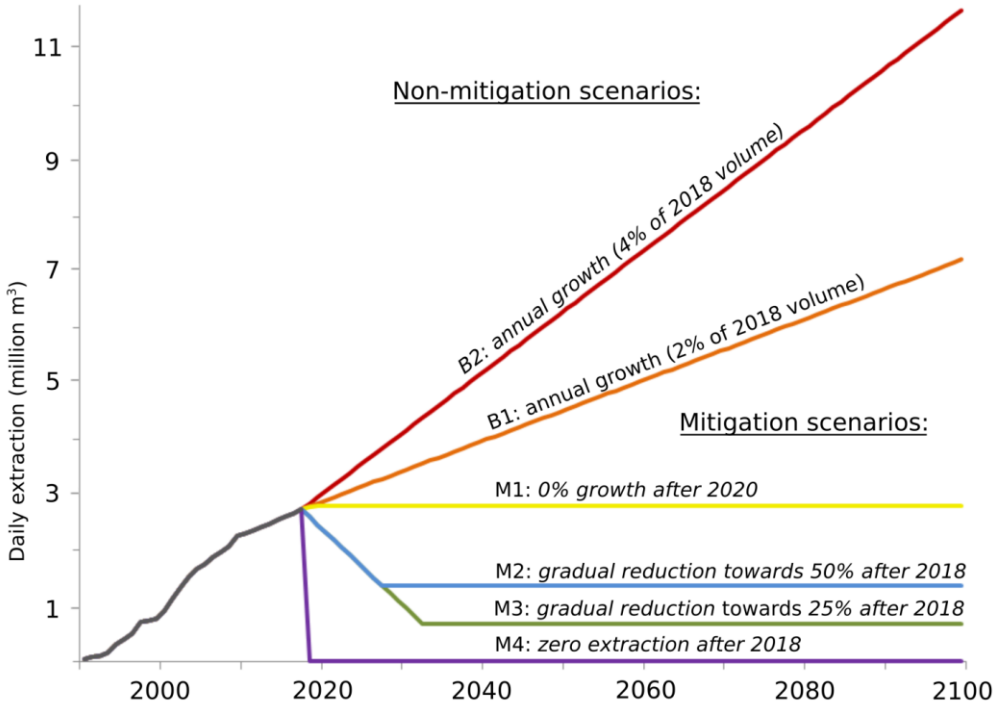
Groundwater overexploitation affects almost the entire delta!

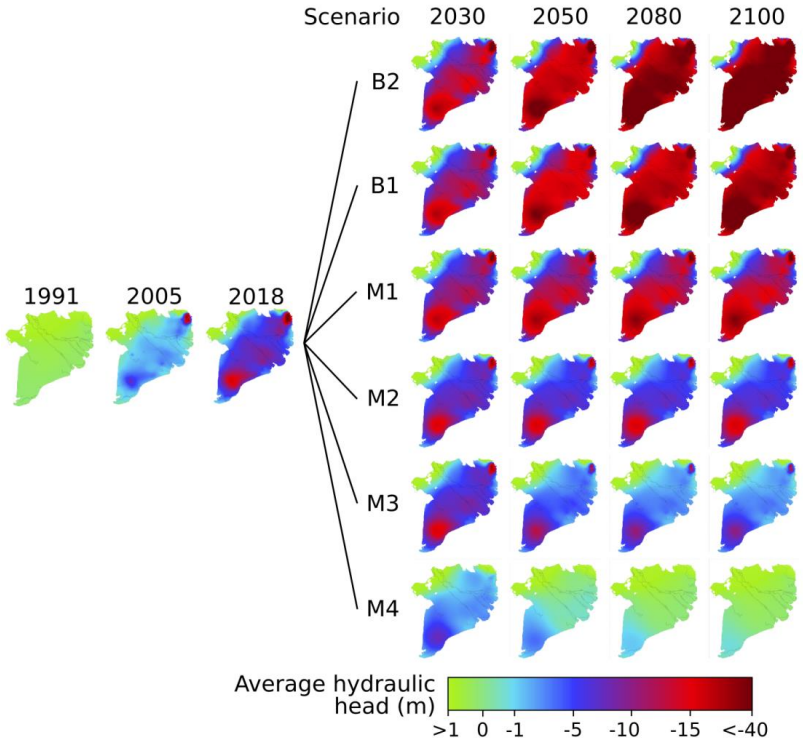


EU Copernicus EMSN062 (2019)
Minderhoud et al., 2020

Mitigation: Knowing what the future may bring

Pathway approach to explore possible futures following different extraction scenarios → link with socio-economical system

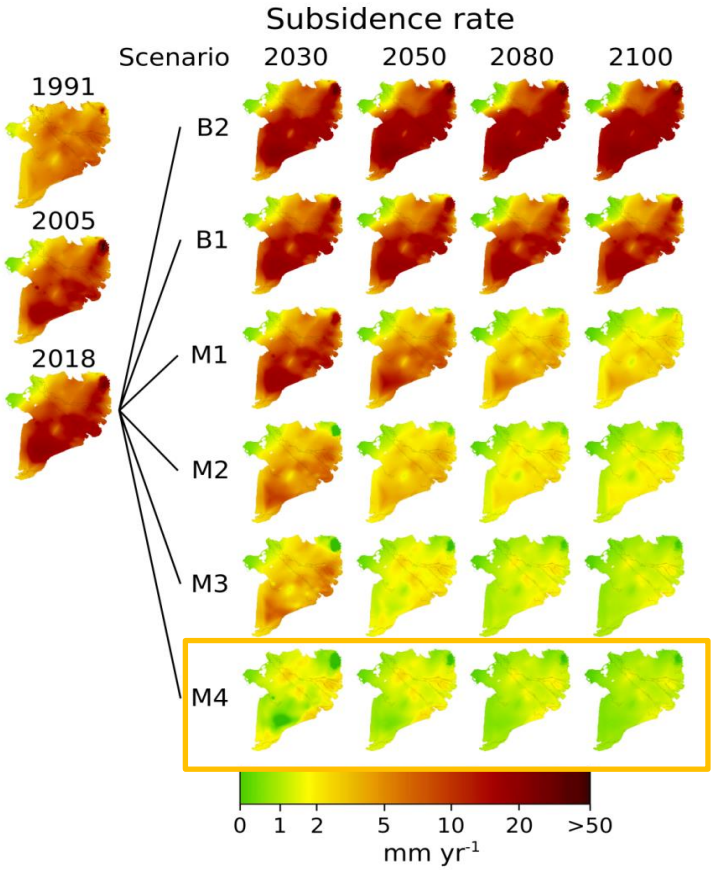


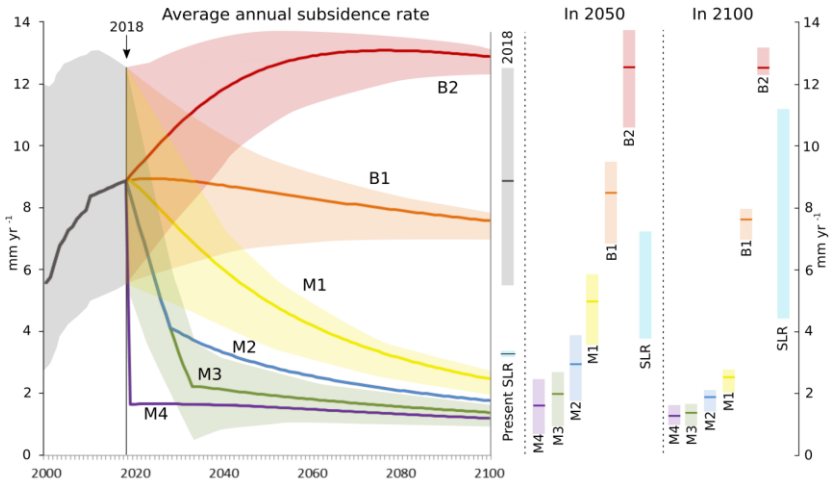


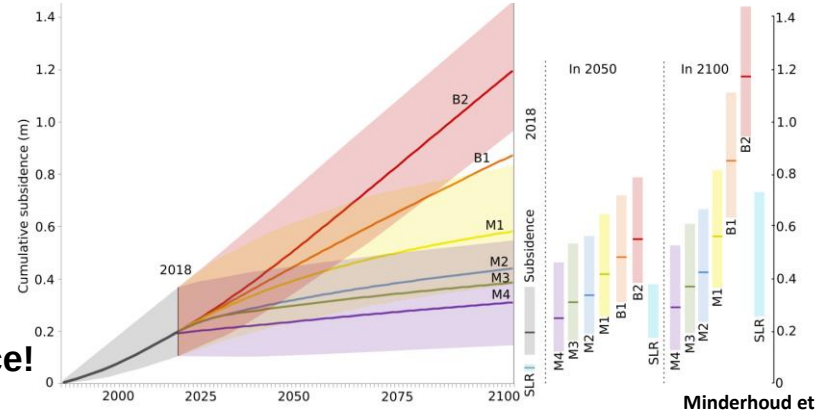
Sinking consequences of Delta subsidence

Minderhoud et al., 2020

Future extraction-induced subsidence





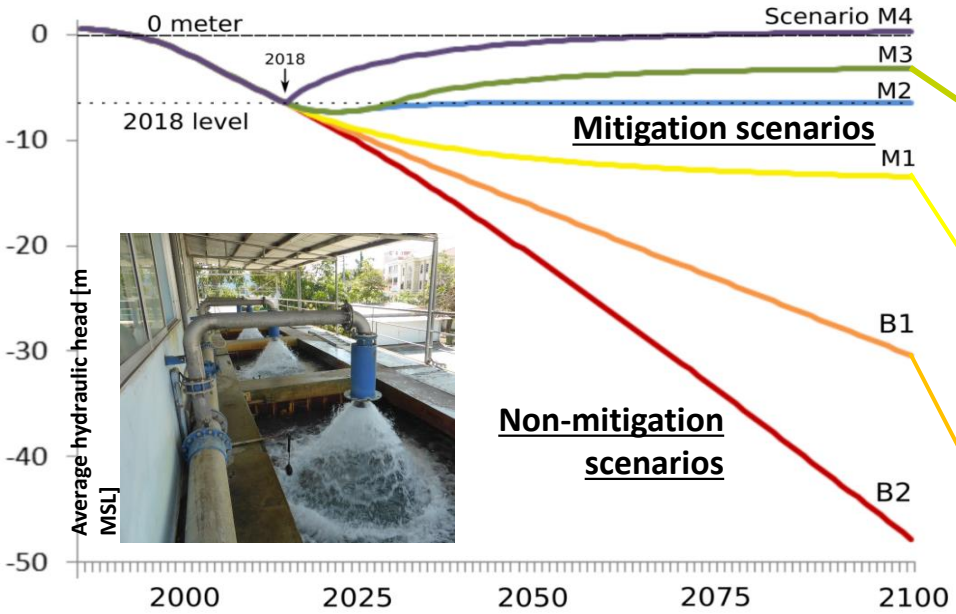


Zero extraction still result in ongoing subsidence!

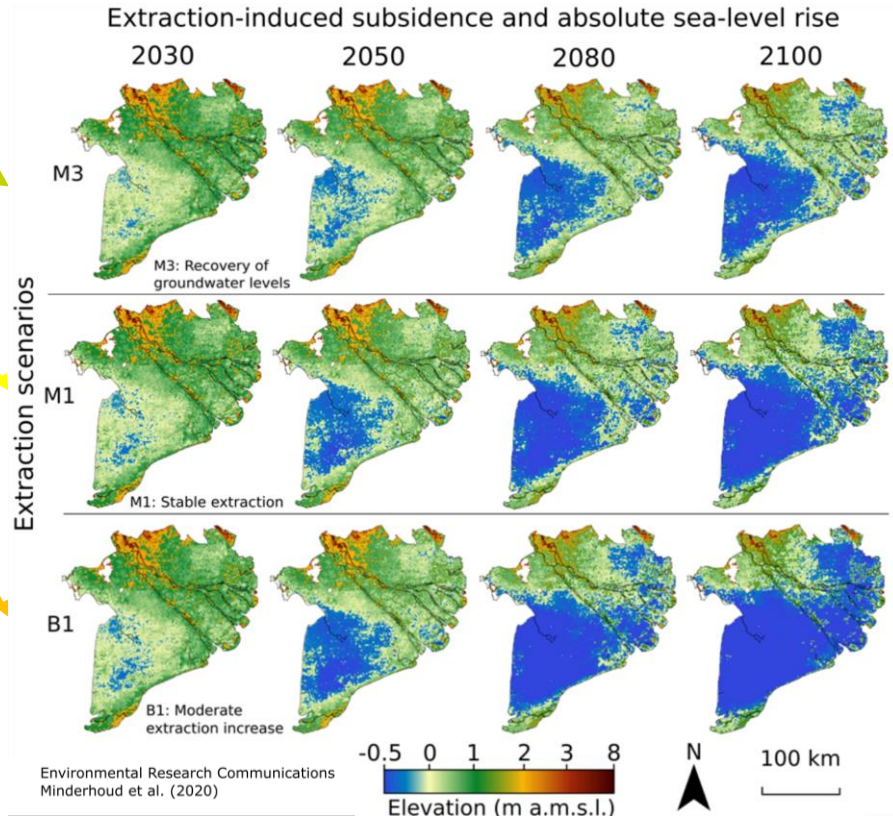
Minderhoud et al., 2020

The decisions of today will determine the status of the delta tomorrow

Scenarios of future groundwater extraction pathways



Projected future elevation of the delta



Key message:

Fresh groundwater is not a free resource!

You 'pay for it' with elevation and salinization

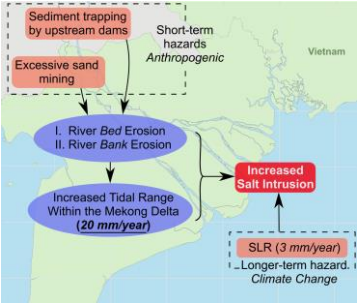
- ***Elevation projections assume SLR according to RCP 4.5 projections.***
- ***Elevation gain through sediment accumulation is assumed to counterbalance natural compaction***

Minderhoud et al., 2019; 2020

Rise and Fall project

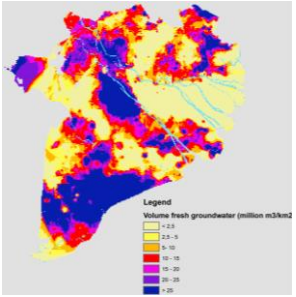
Rise and Fall research program (2014-2019): Towards strategies for the subsiding Mekong Delta facing increasing salt water intrusion

Main results:



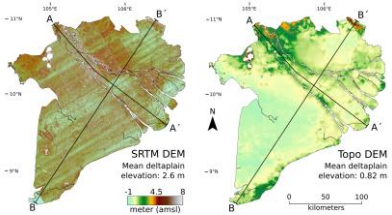
River bed deepening enhanced tidal amplitude and salinity intrusion

Eslami et al., 2019



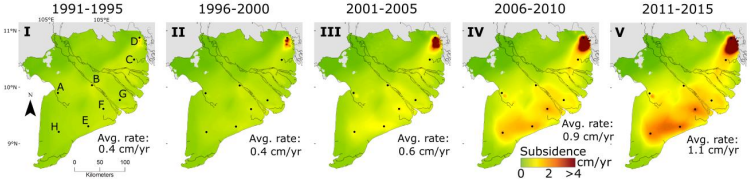
Quantification of fresh groundwater volume and rate of salinization

Pham, V.H. Oude Essink, G. (in prep)



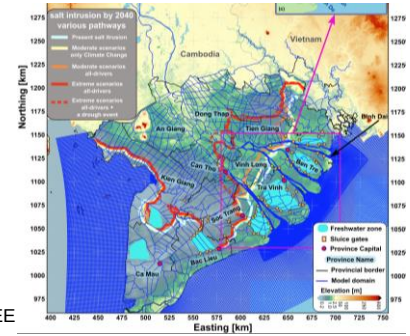
Delta elevation much lower than used in previous SLR assessments

Minderhoud et al., 2019



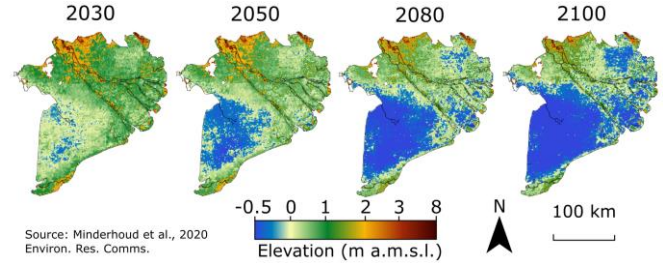
Groundwater extraction accelerated subsidence, exceeding sea-level rise by a magnitude!

Minderhoud et al., 2017



Estuarine salinity intrusion:
First integration of numerical models on climatic, anthropogenic, local, and regional "drivers of exposure. (SLR, sand mining, subsidence, droughts)

Eslami et al., accepted NCEE



Continued groundwater extraction will cause large parts of the delta to fall below sea-level in decades

Minderhoud et al., 2020

How research shaped policy
Land subsidence in the Mekong delta

Rapidly changed policy regarding land subsidence and groundwater extraction:

- Before 2017, there was no **wide-spread awareness**, **data or policy** on subsidence and it did not appear in any national policy document about the Mekong delta.
- June 2017 – **Paper** on the relation between groundwater extraction and subsidence was published and presented to the VN government – creating lively **discussions and debates**.
- In November 2017 – **Resolution 120** - on Sustainable and Climate-Resilient Development of the Mekong Delta of Viet Nam – (*land subsidence was mentioned for the **first time***).
- 2019 – Ministries launch **several initiatives** to investigate and mitigate subsidence in the Mekong delta.
- 2020 – Provinces in the Mekong delta are tasked to delineate **groundwater protections zones** (no extraction) in areas where groundwater depletion causes subsidence and salinization.

In four years the awareness that **groundwater extraction causing subsidence** has increased massively and the topic is no longer very sensitive.

<u>Exceptionally rapid policy change in the desired direction!</u>

How research shaped policy
Land subsidence in the Mekong delta

Lessons learned: crucial key moments and conditions (*what we have been told*):

- **Long term/full-time commitment** (5 years) and extensive investments in build trust and cooperation (and access data).
- Good relation/cooperation with partners in VN from the start, both at **local level** and at the **central government**.
- Early and ongoing cooperation with the Dutch **Embassy** → Media attention and communications with VN government
- The research was presented and discussed twice at a **bilateral meeting** of the Dutch and Vietnamese government (2017: including VN Vice-Prime Minister and 2019: including both Prime Ministers).
- Consistent and transparent **communication**
- **Rigorous science**. Continuous focus on rigor scientific results and their uncertainties.

Thank you for your attention!

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