

Relative sea level rise

Climate impacts and subsidence

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Let's take a closer look at our surroundings

Inland cities,
extensive rice
production,
industries



Malolos

Hagonoy city



Pampanga
delta

Aroma beach



Quezon city

Manila

Aroma beach



Former coastline, beach
permanently underwater,
also during low-tide
conditions



Further inland, everything is inundated, and people live in strips along raised roads or embankments



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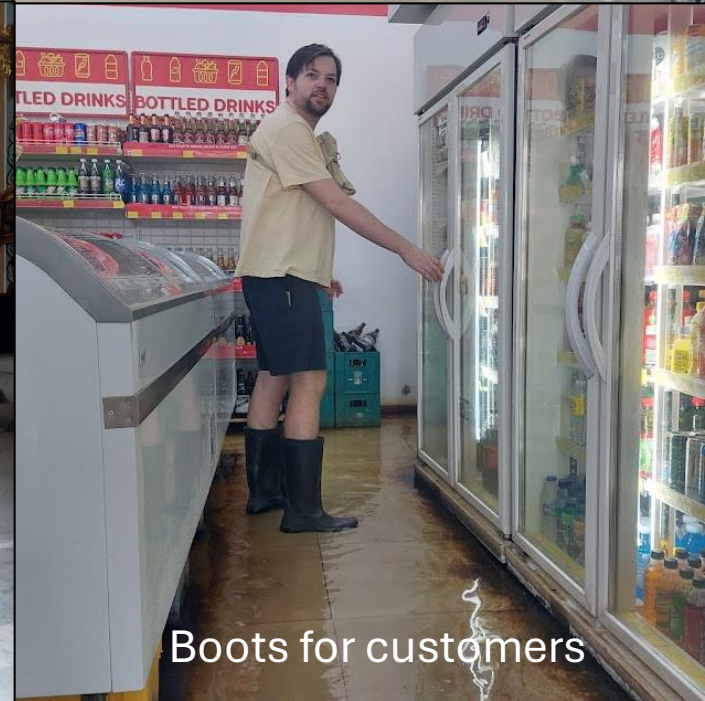
An aerial photograph of a flooded delta region. The water is murky brown and covers most of the landscape. Several small islands or patches of land are visible, each with a few houses. The houses have various roof colors, including red, green, and blue. Some houses are built on stilts. A long, narrow, elevated walkway made of concrete or stone runs through the water, connecting different clusters of houses. The walkway is bordered by a low wall. In the background, more houses and a larger body of water are visible. The overall scene depicts a community living in a flooded area, with some houses being new and others being older.

Drowned school buildings remain, new ones are erected next to them

Remaining delta dwellers build an elevated walkway to reach their house

Hagonoy city square,
roads and square are
being raised by ~1.5
meter





High school with several
drowned buildings



New building
Ground floor of a new building
already abandoned after 5 yrs
And still sinking ~10-15 cm/yr

Inundated primary school, children are frequently home-schooled as high tides flood the classrooms





Special type of 'raised'
tricycles roam the streets
to enable transport
during high tides

Aroma beach
20 km

Hagonoy city
10 km

Inland former rice
production area

2020



2022



Rice fields became
permanently drowned in a
matter of few years

2023



2024

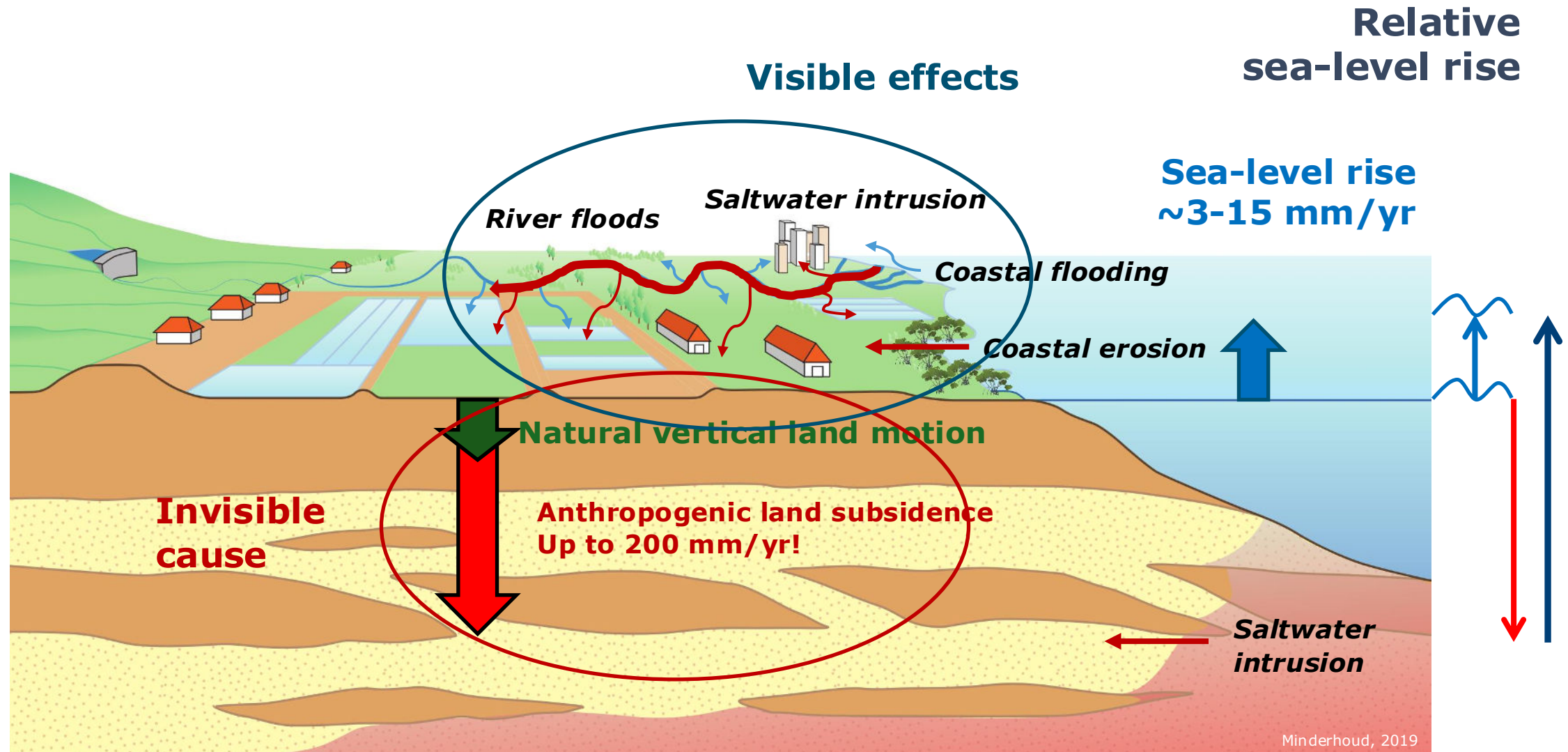


The vertical dimension



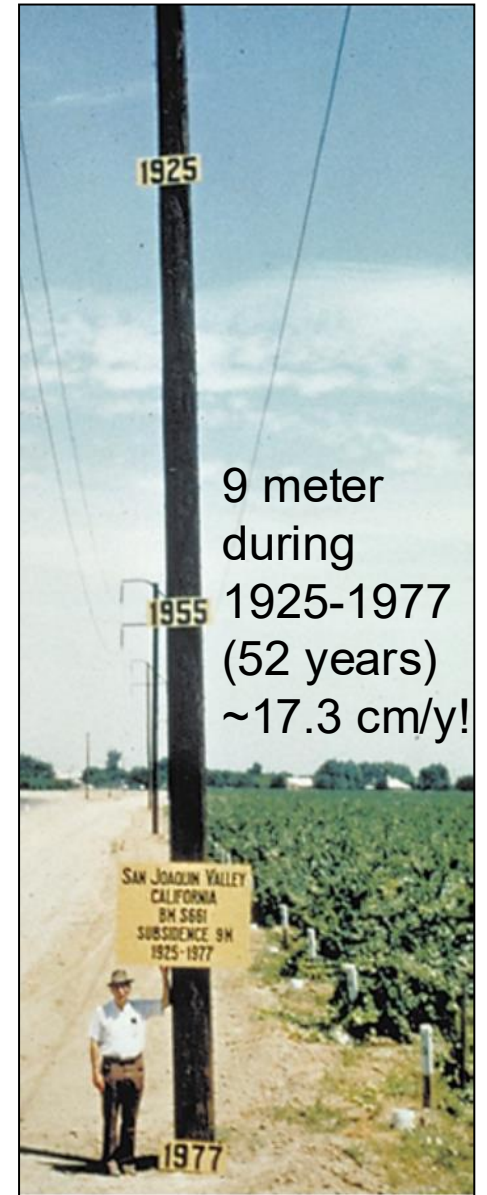
Pampanga delta, North Manila Bay, Philippines

Relative sea-level rise: Sea-level rise & sinking land



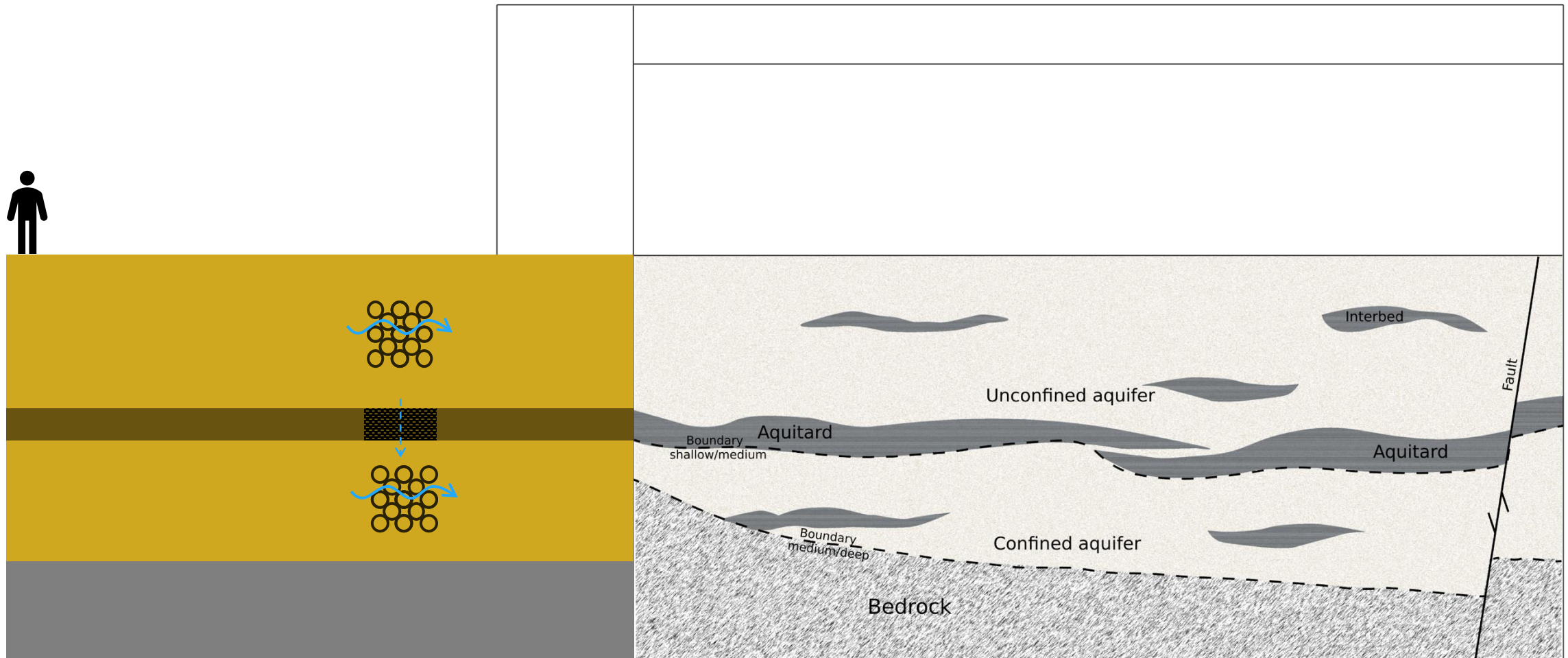
What is land subsidence?

- The gradual or sudden sinking of a land surface caused by subsurface movements of the earth materials
- Famous historical case: San Joaquin Valley subsidence, USA
 - One of the world's most productive agricultural regions
 - Large-scale groundwater exploitation for agriculture
 - One of the single largest alterations of the land surface attributed to humankind



Joseph F. Poland, 1977

Subsidence mechanisms in coastal lowlands

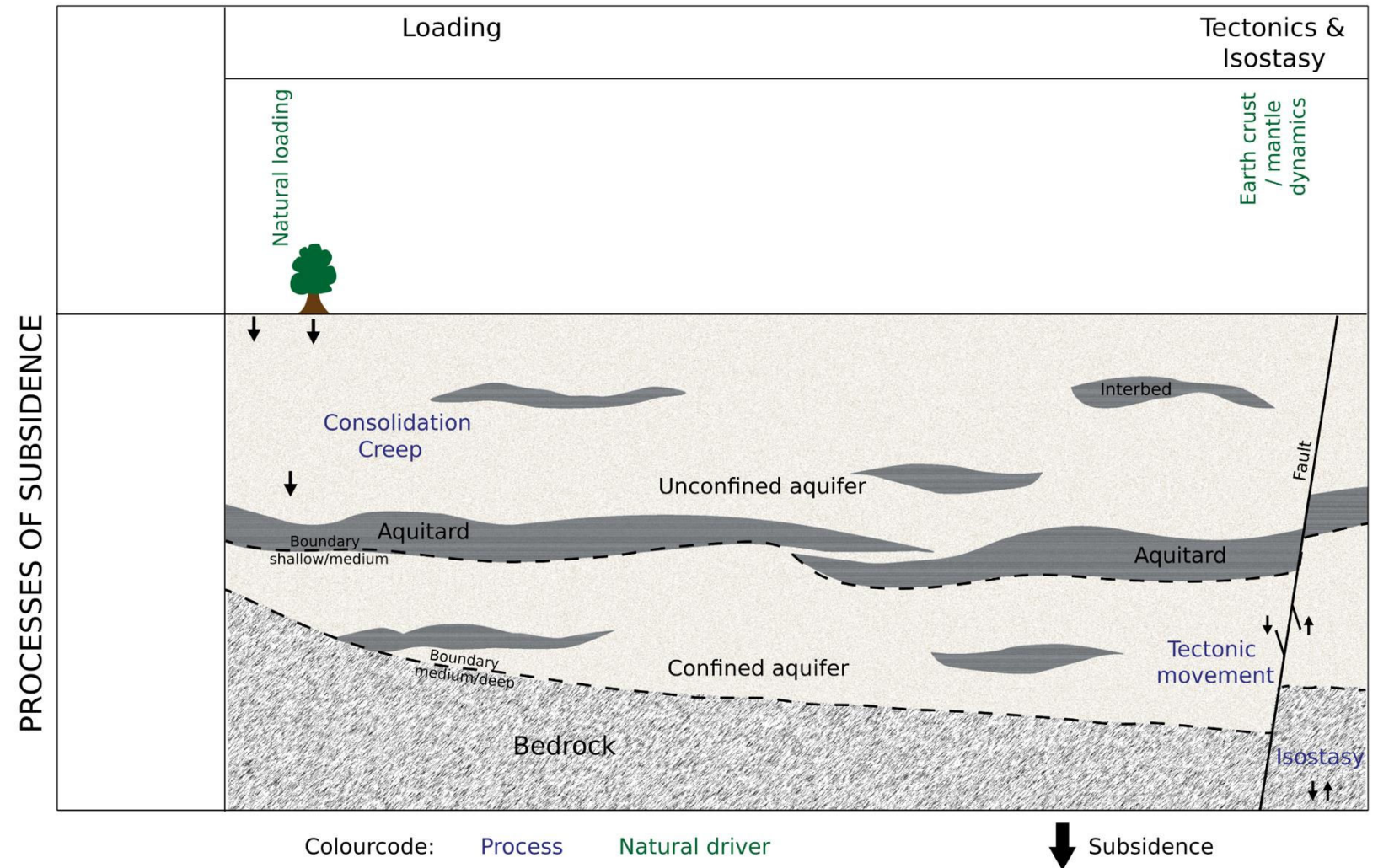


Subsidence mechanisms in coastal lowlands

DRIVERS OF SUBSIDENCE

Land subsidence is
natural process in deltas

*More sedimentation
→ more loading
→ higher rates of subsidence!*

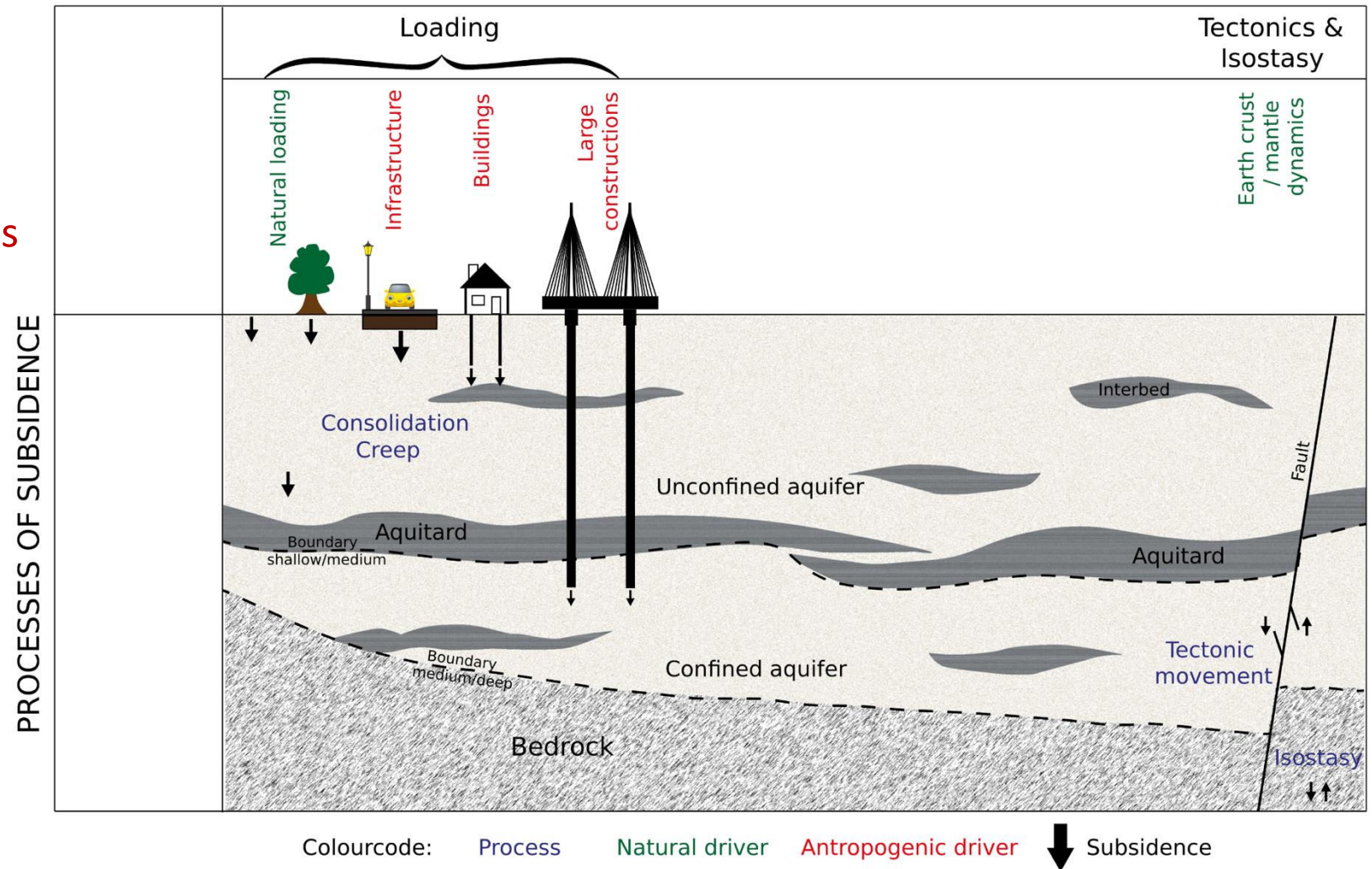


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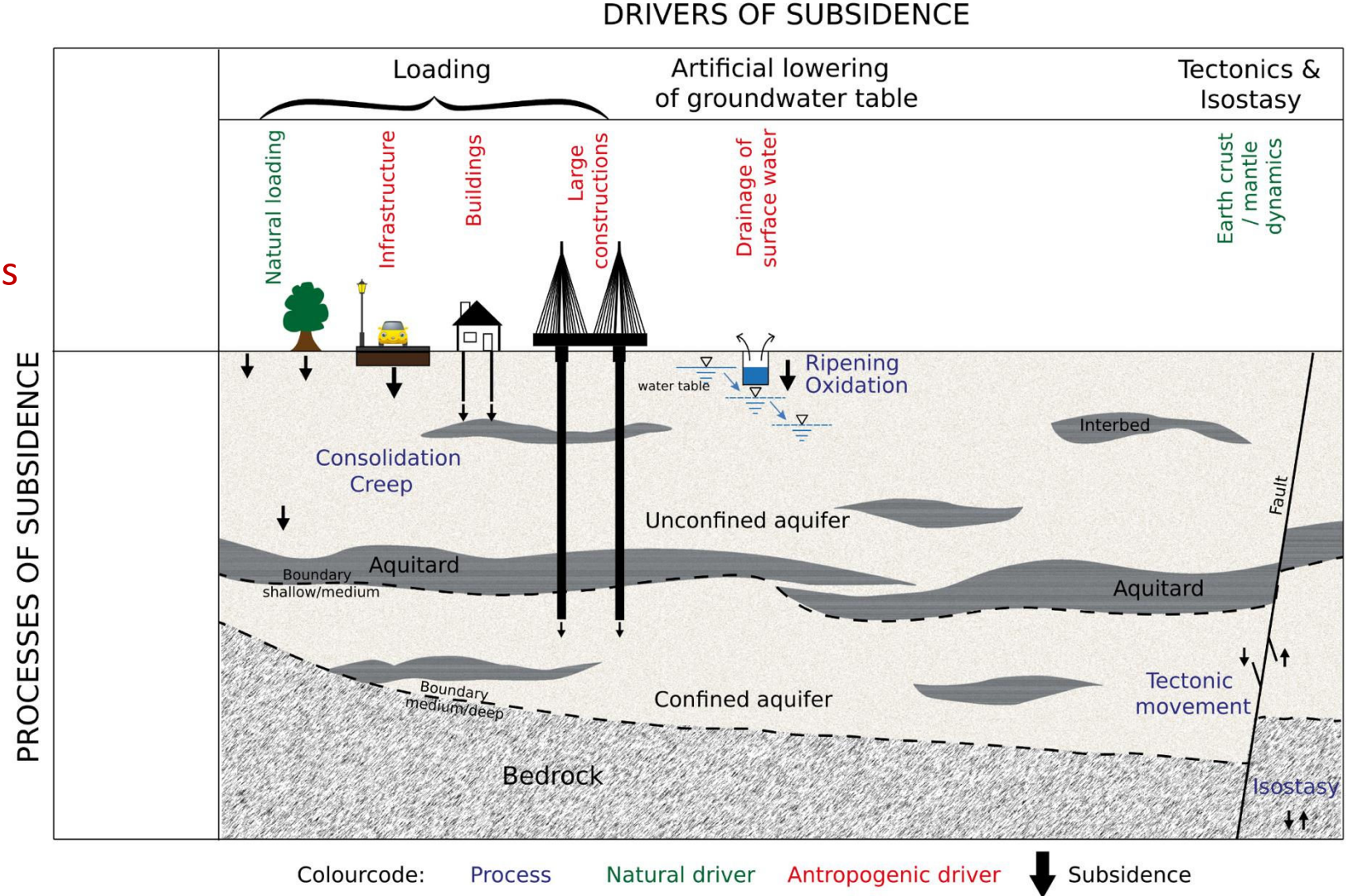
Land subsidence can be
accelerated by **human activities**
that increase **physical loading**



Subsidence mechanisms in coastal lowlands

Land subsidence is
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Land subsidence can be
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or change the **hydrogeological**
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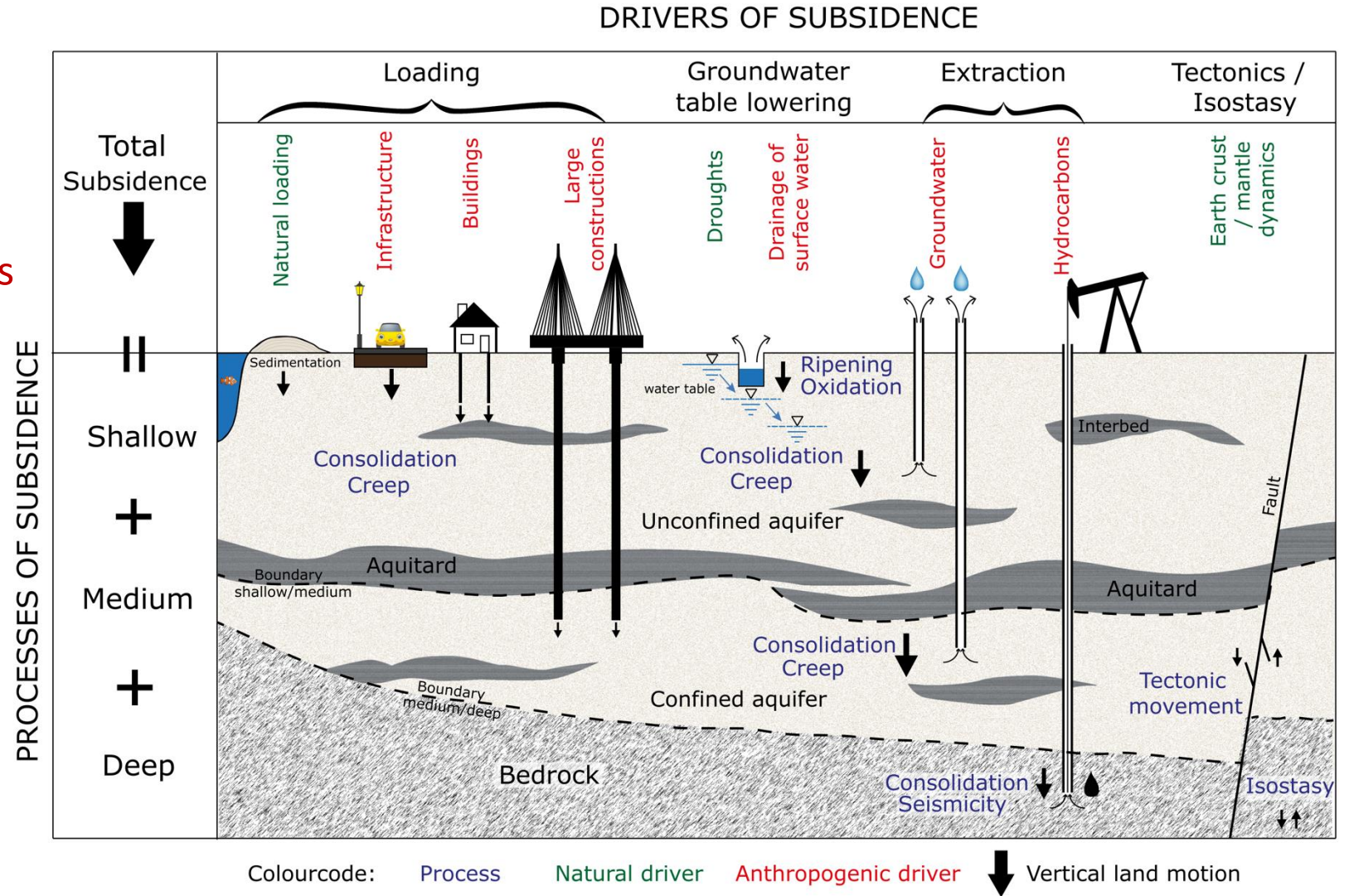


Subsidence mechanisms in coastal lowlands

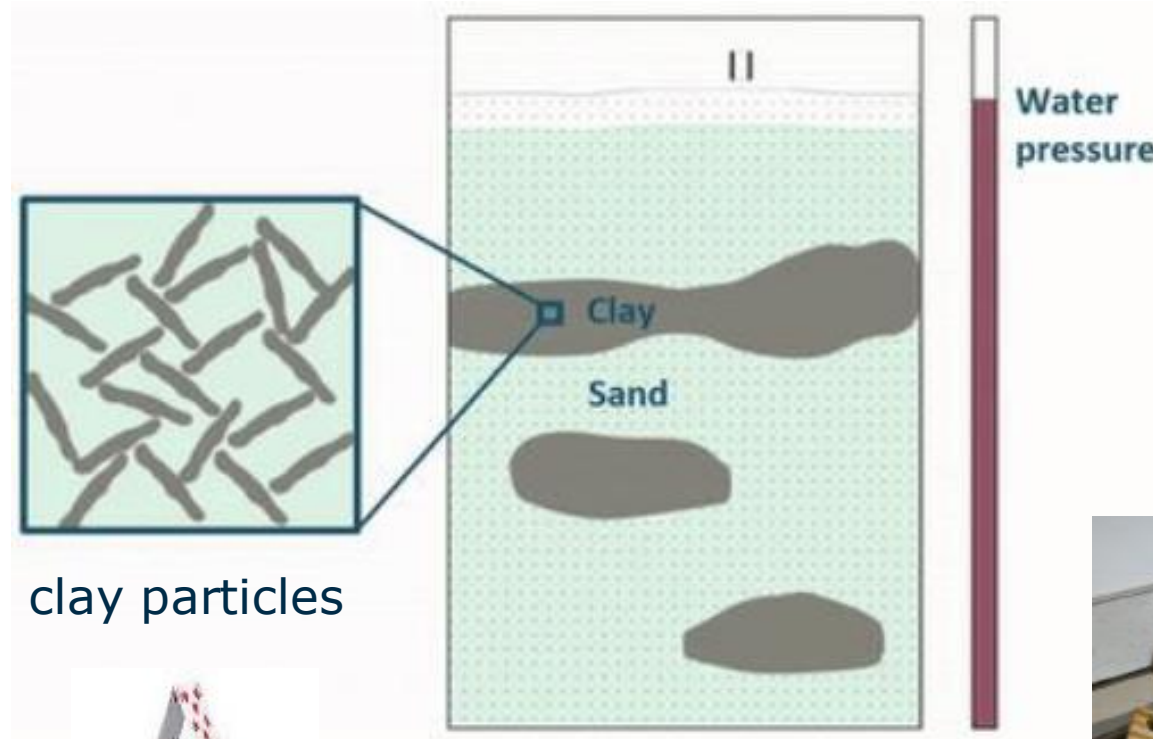
Land subsidence is
natural process in deltas.

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



How does groundwater extraction cause subsidence?



clay particles



Irreversible process!
Volume loss is permanent!



Natural "sedimentation"
of dishes in the sink



"reorientation"
of dishes

Go to wooclap.com and use the code **GFABGZN**



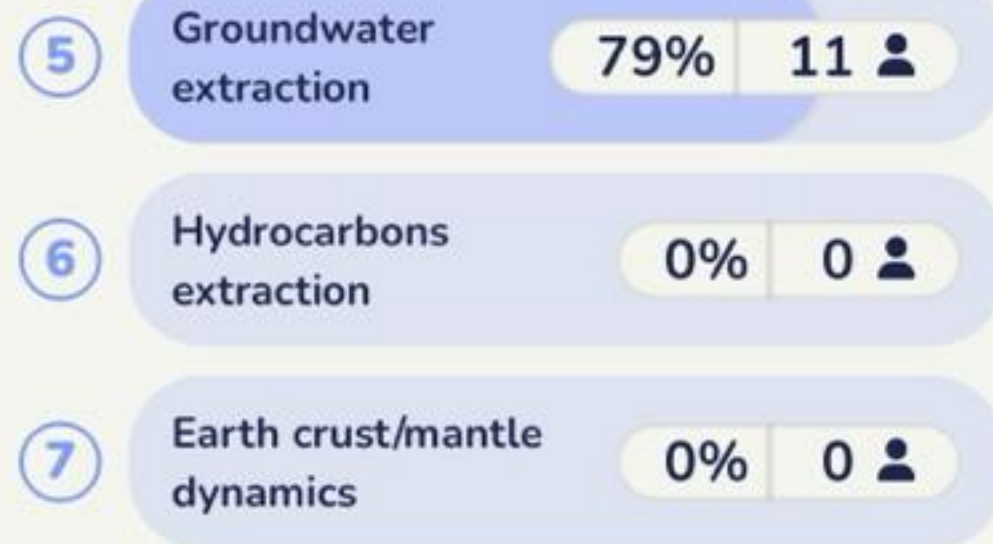
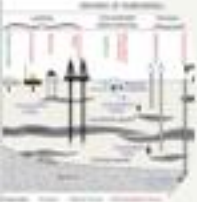
Which processes are happening in your case?



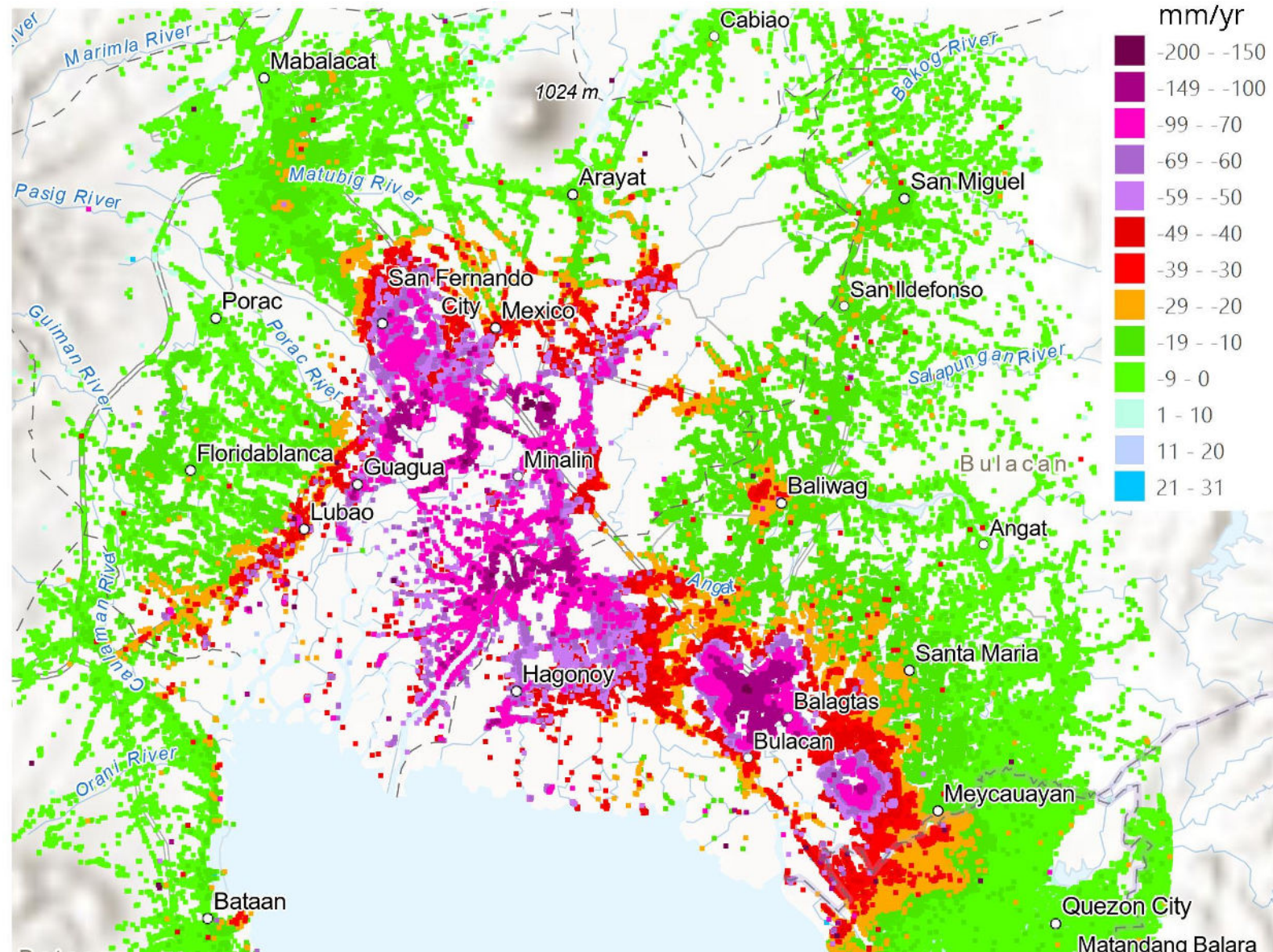
Go to wooclap.com and use the code **GFABGZN**



Which processes are being measured/do you have data for in your case?



INSAR estimated vertical land motion between 2015-2021



The rapidly unfolding NMBA catastrophe

- Rates have dramatically accelerated in two decades to rates up to ~20 cm/yr
- In recent years larger towns have sunken into the tidal range – with daily inundations with high tide
- Saltwater reaching far in land (up to 30 kilometer inland) – as of August 2024 over 80% of rice producing area has been lost
- Currently an estimated ~150.000-200.000 people are already directly impacted – this number may grow further to >1M in 1 to 2 decades

Current perception and actions taken

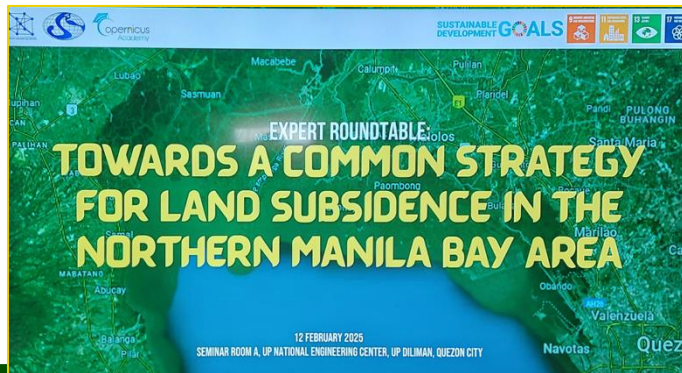
- Realization that the land is sinking was virtually almost absent (it is now gradually growing, but awareness remains very low).
- Many explanations for what is happening in the area which are (largely) unrelated
- Enormous efforts and capital is placed on adaptation measures (partial dykes, elevating roads, new buildings) – ‘giant ring dyke’
 - Zero attention for mitigation of land subsidence – without reduction of land subsidence– all adaptation efforts will be rendered ineffective in a matter of years:
 - False sense of security
 - Waste of resources – which could be use for mitigation

Every day the land subsidence crisis is not addressed it will grow worse

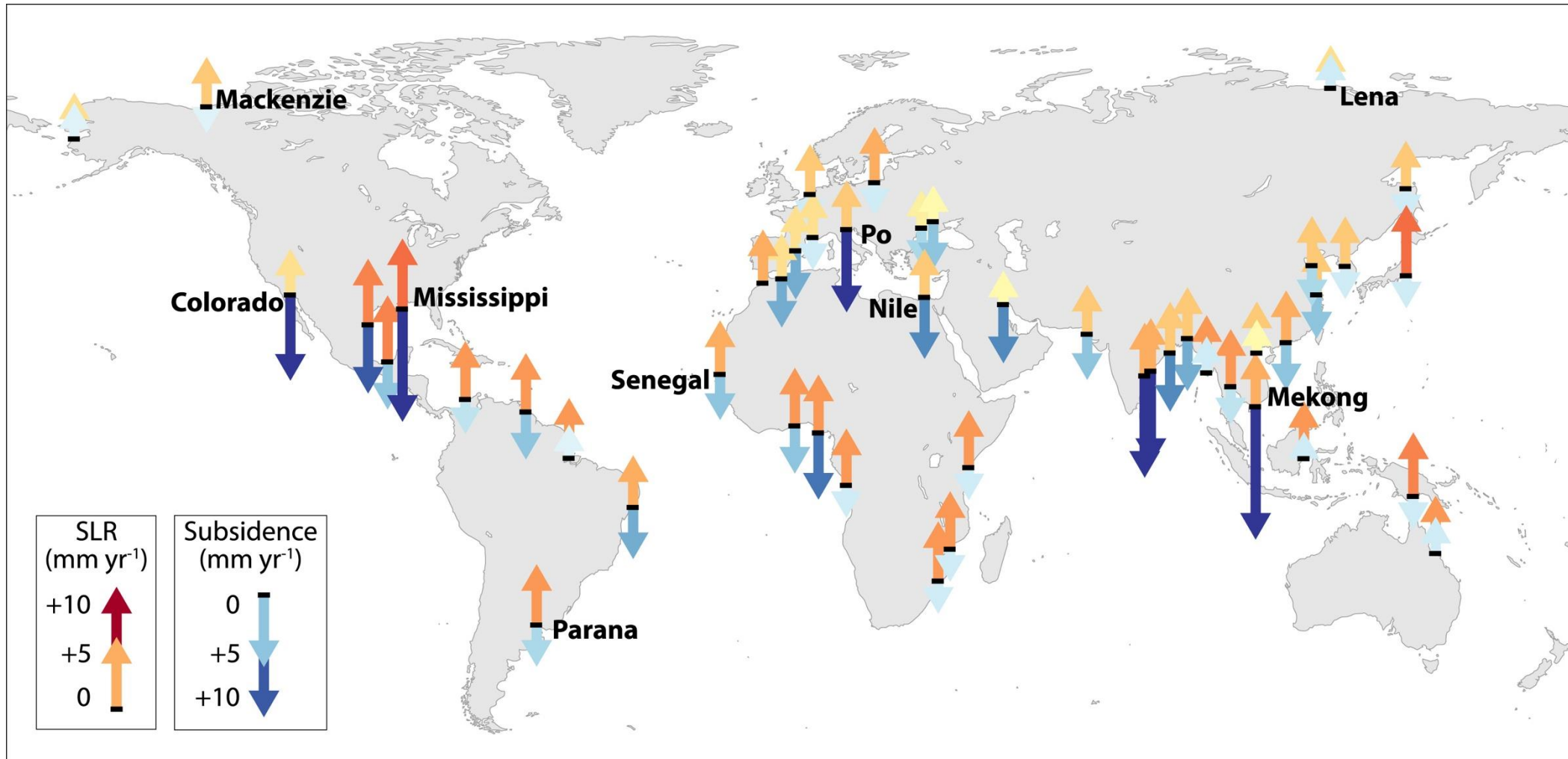
What was done since September 2024

Installation of multiple experimental low-cost GNSS stations to directly monitoring land subsidence at several locations (Prof. Reyes)

Data collection on geodetic GCPs, subsurface composition and groundwater system and dynamics by MSc students (UP & WUR)

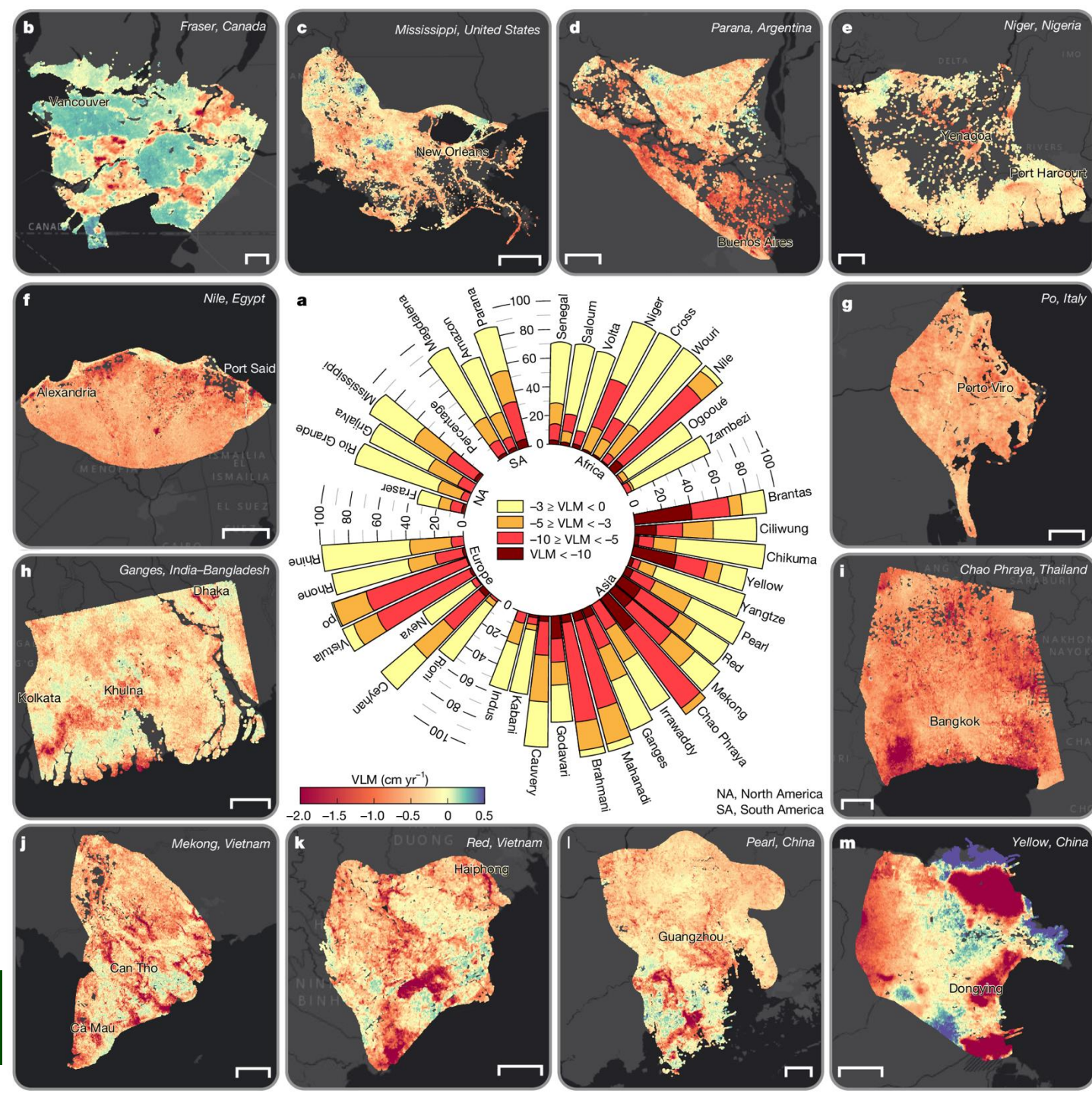


Global deltas threatened by relative sea-level rise



Dunn et al. (2023)

Vertical land motion in global deltas



Ohenhen et al. (2026)

The sinking Mekong delta

Highest subsidence rates measured in the delta

2006-2010

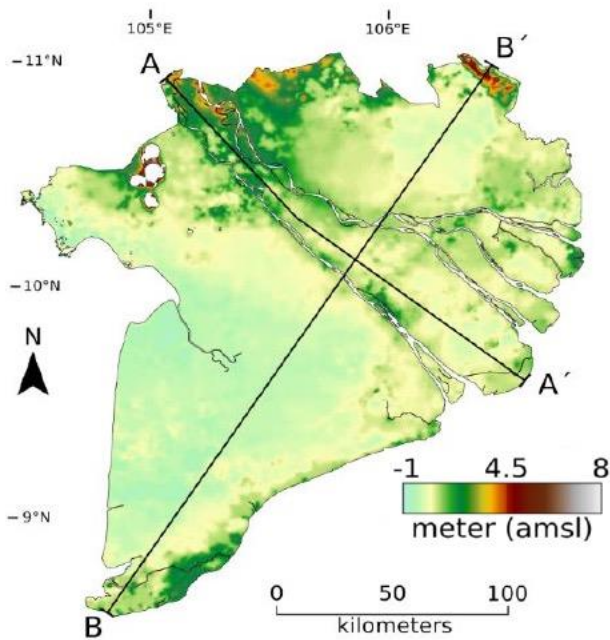
2-3 cm/yr

2014-2019

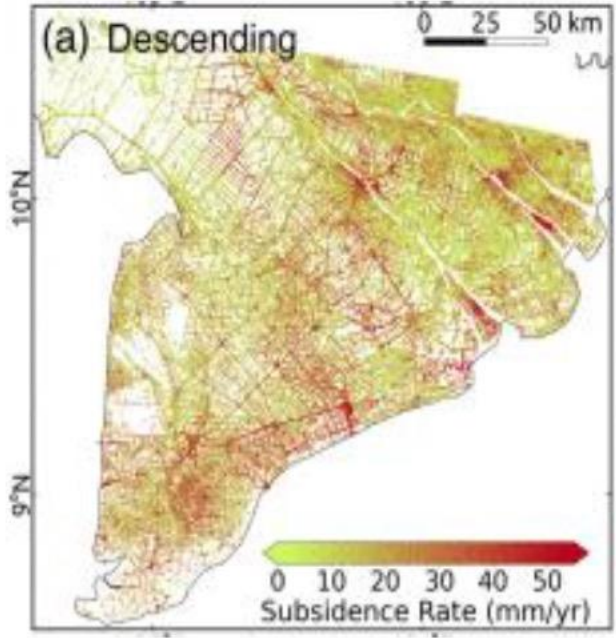
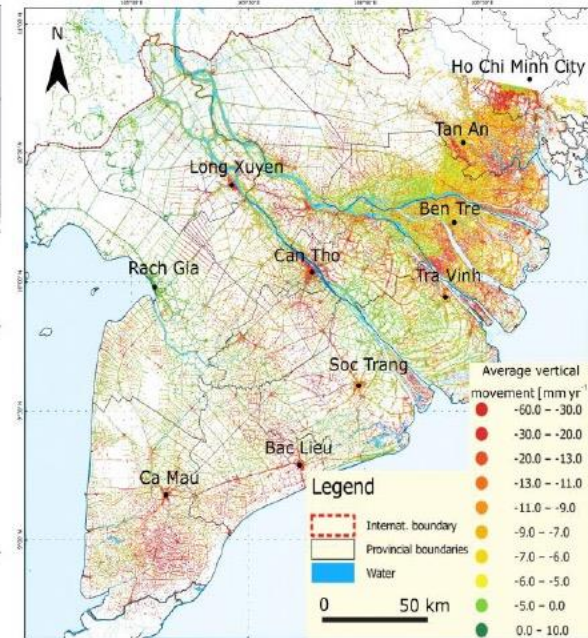
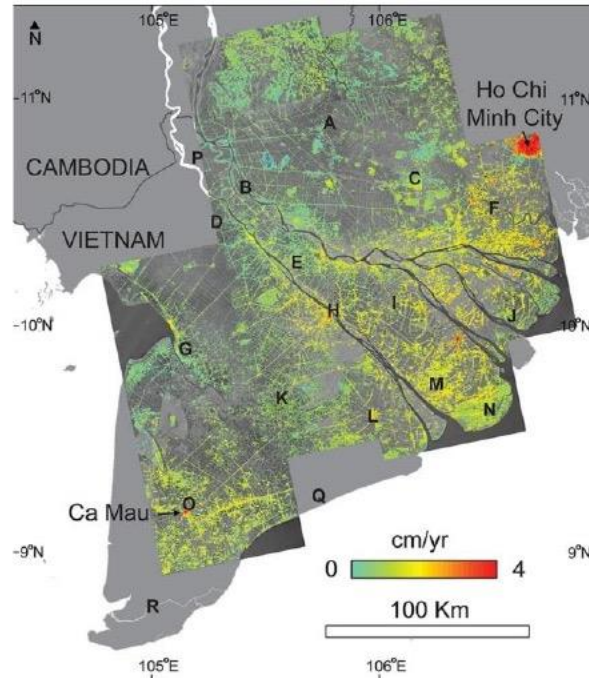
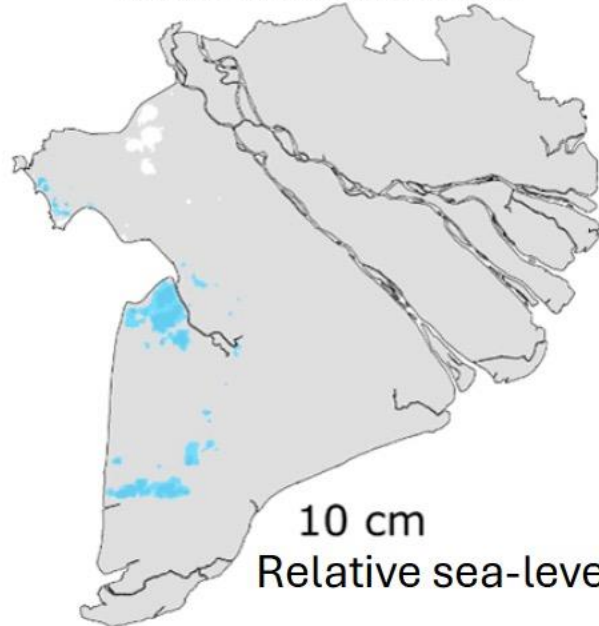
5-6 cm/yr

2017-2022

Up to 7 cm/yr

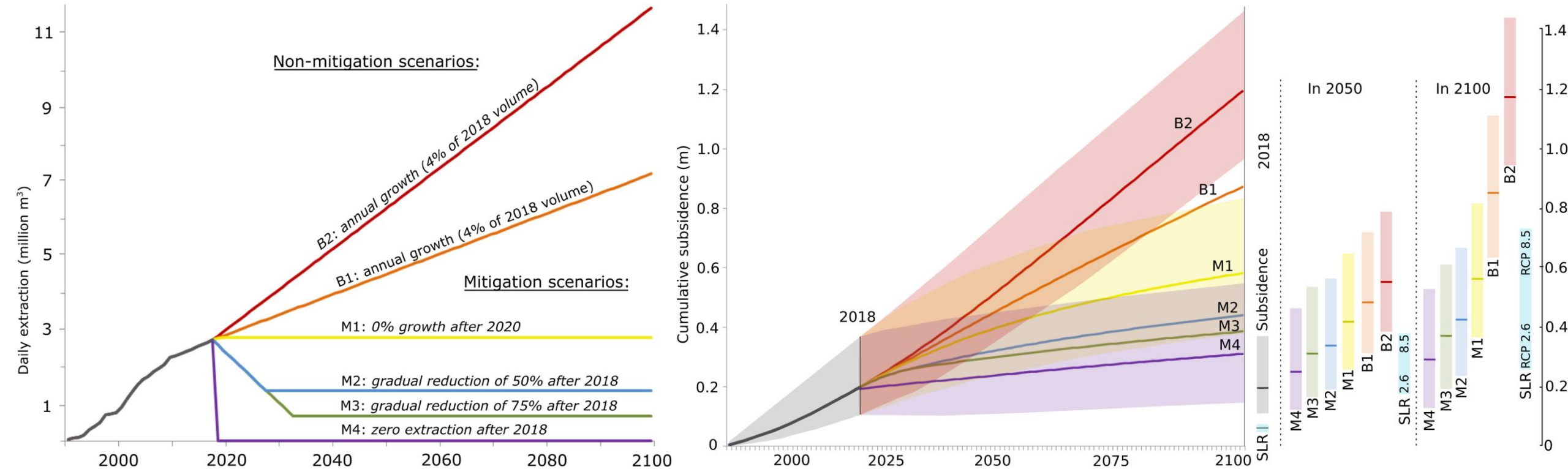


Area below mean sea level



Groundwater extraction is accelerating subsidence

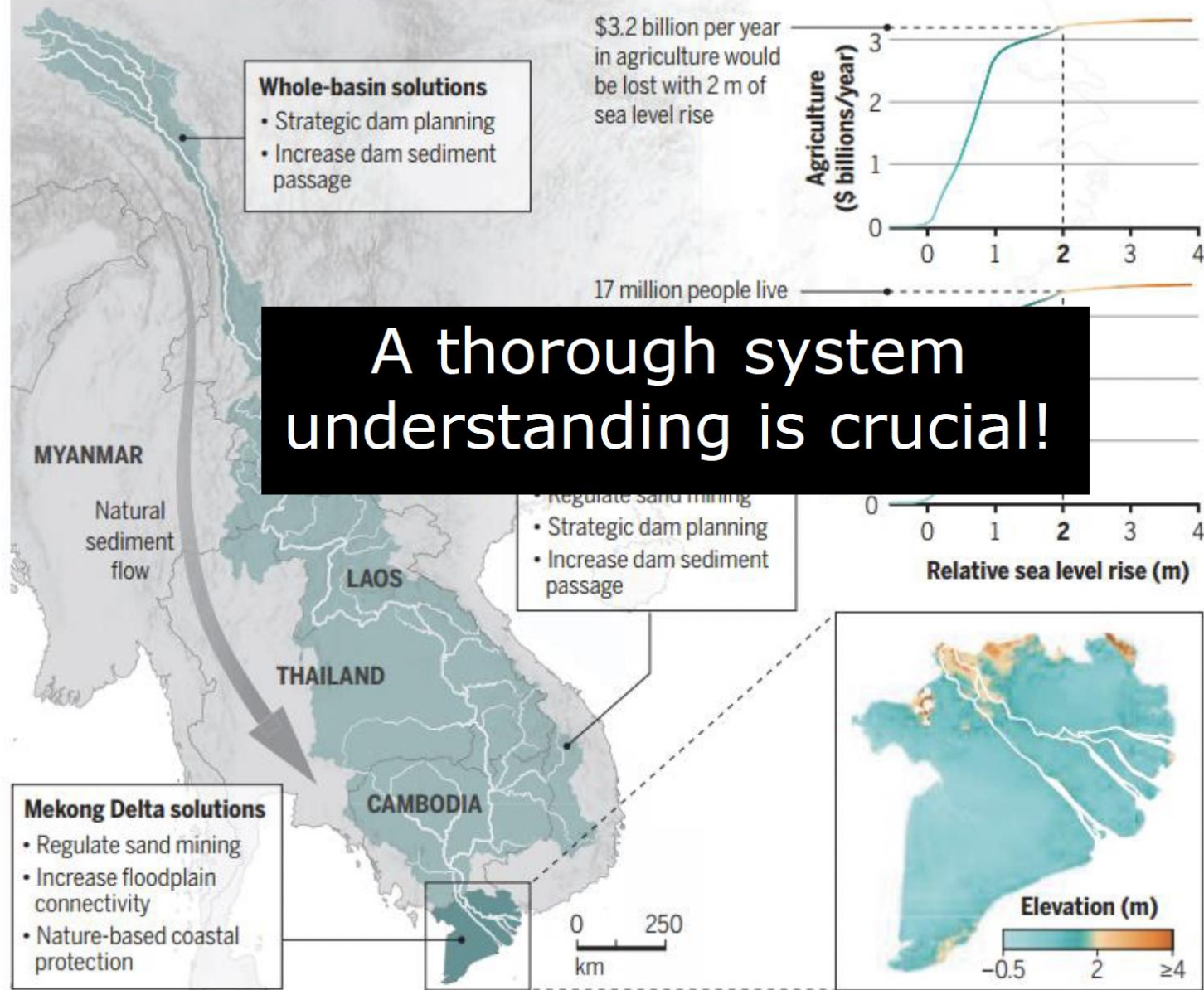
Groundwater extraction scenarios Mekong Delta



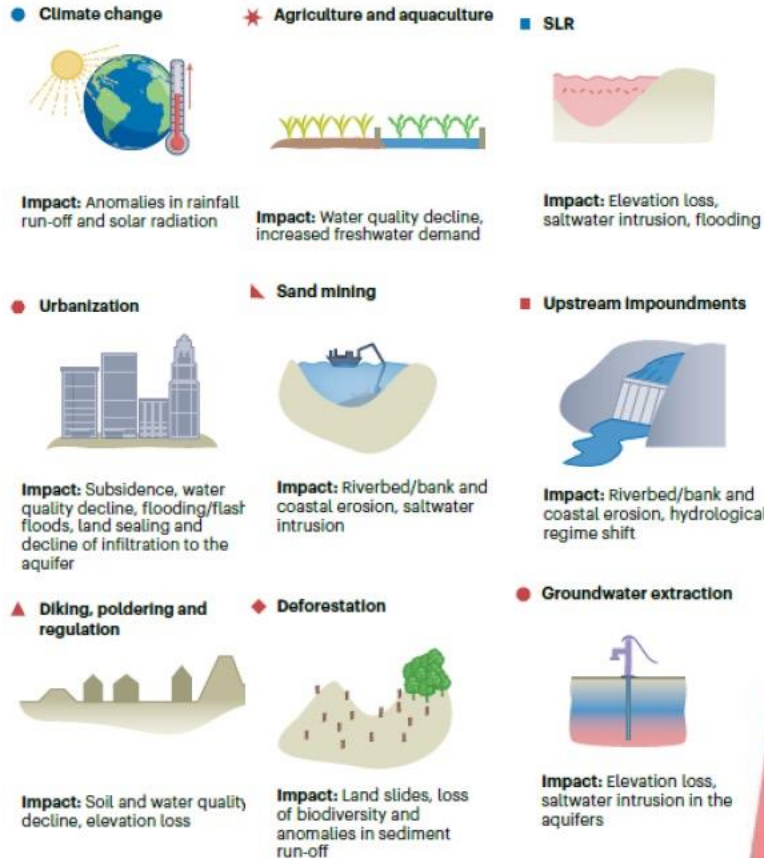
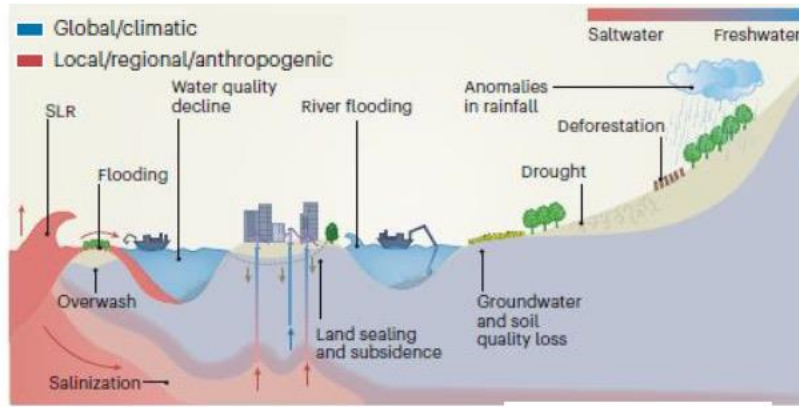
Minderhoud et al. (2020)

Save the Mekong Delta from drowning

Policy must address drivers, not just symptoms, of subsidence

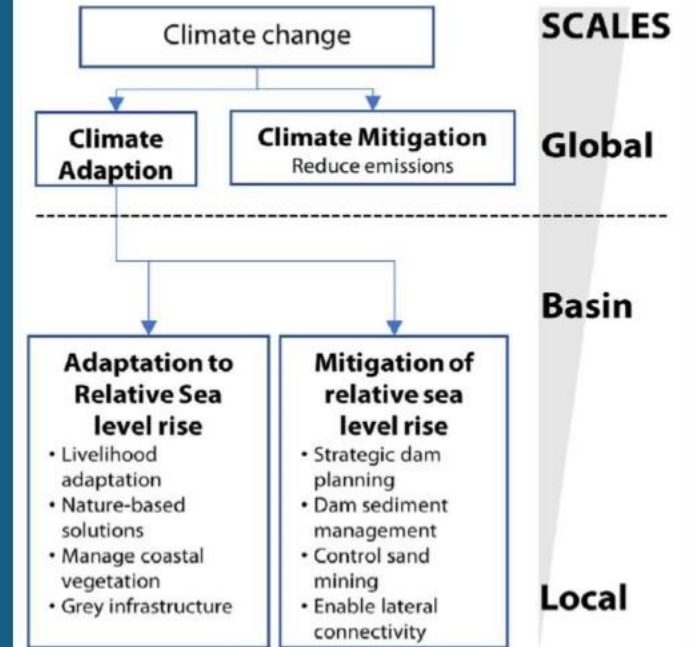


Processes and drivers across scales



System perspective to reach integrated solutions

Responses across scales



Local drives can have local solutions

Opportunities for local-led adaptation & mitigation!

Crucial for successful NBS implementation

The value of groundwater

- Groundwater carries delta land
- Groundwater is not a free resource
- When overexploited, you pay with elevation
- Protecting your groundwater is protecting your elevation

GROUNDWATER Making the invisible visible



Thank you for your attention!

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