

BIO-PHYSICAL INTERACTIONS IN TIDAL MARSHES & THEIR ROLE IN NATURE-BASED COASTAL DEFENSE

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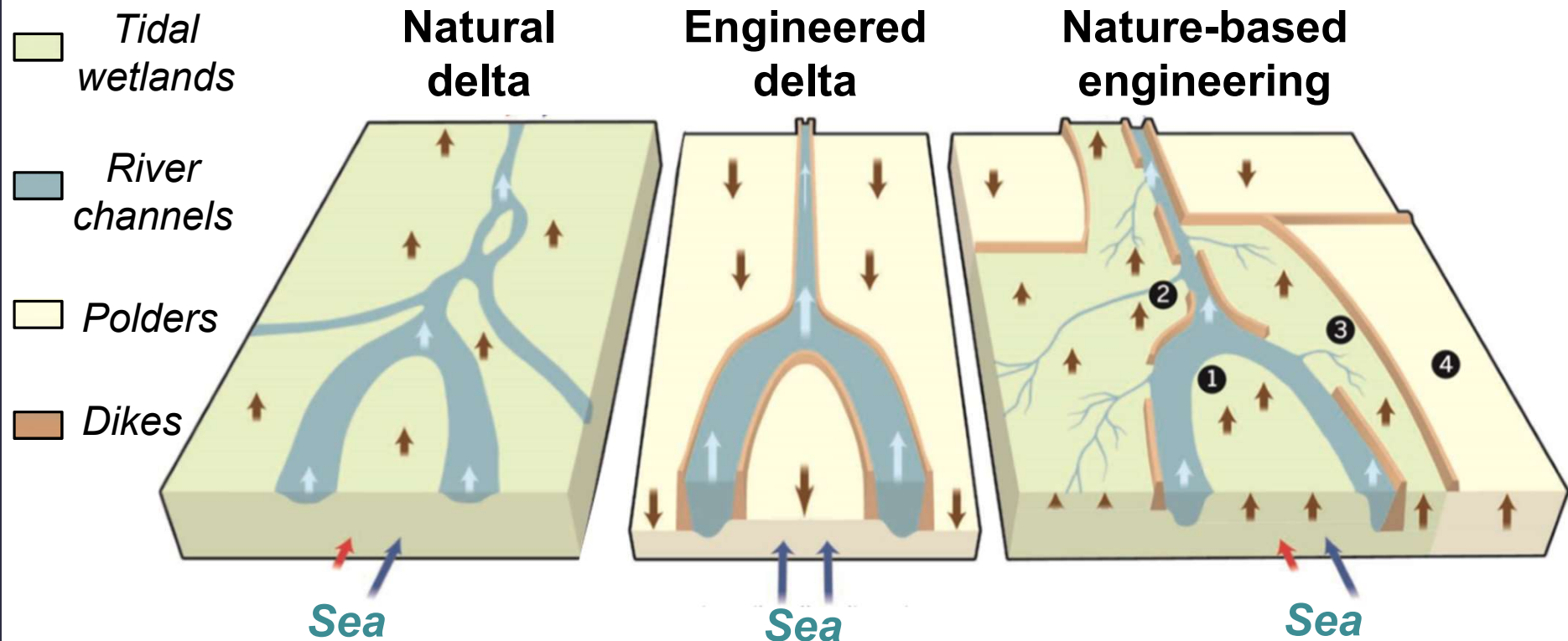


Research Group
Ecosystem Management
University of Antwerp



Towards more sustainable coastal defense by Nature-based risk reduction & Engineering

Natural ecosystems reduce waves, storm surges, erosion, build up land with rising sea & additional benefits



E.g. Temmerman & Kirwan (2015) Science

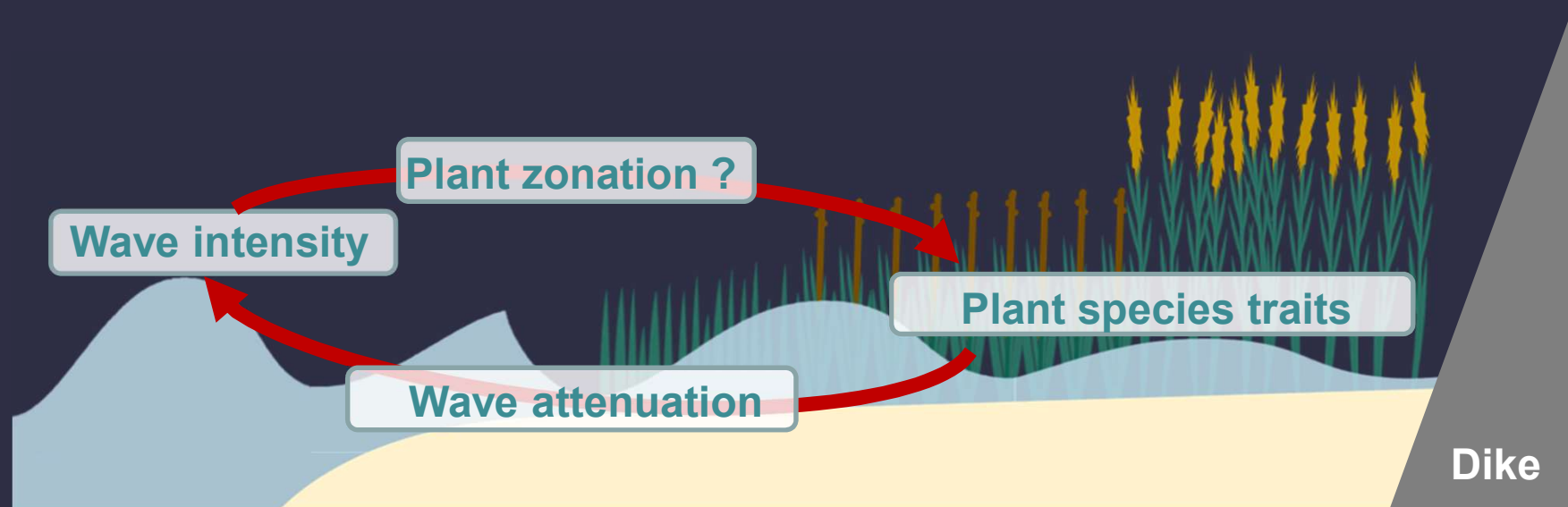
1) How effective is WAVE ATTENUATION by marshes ?

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How plants affect waves?... much studies
How waves affect where plants can grow? ... much less known

MUTUAL FEEDBACKS ??



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MUTUAL FEEDBACKS ??

PhD work of:



Alexandra
Silinski



Maike
Heuner

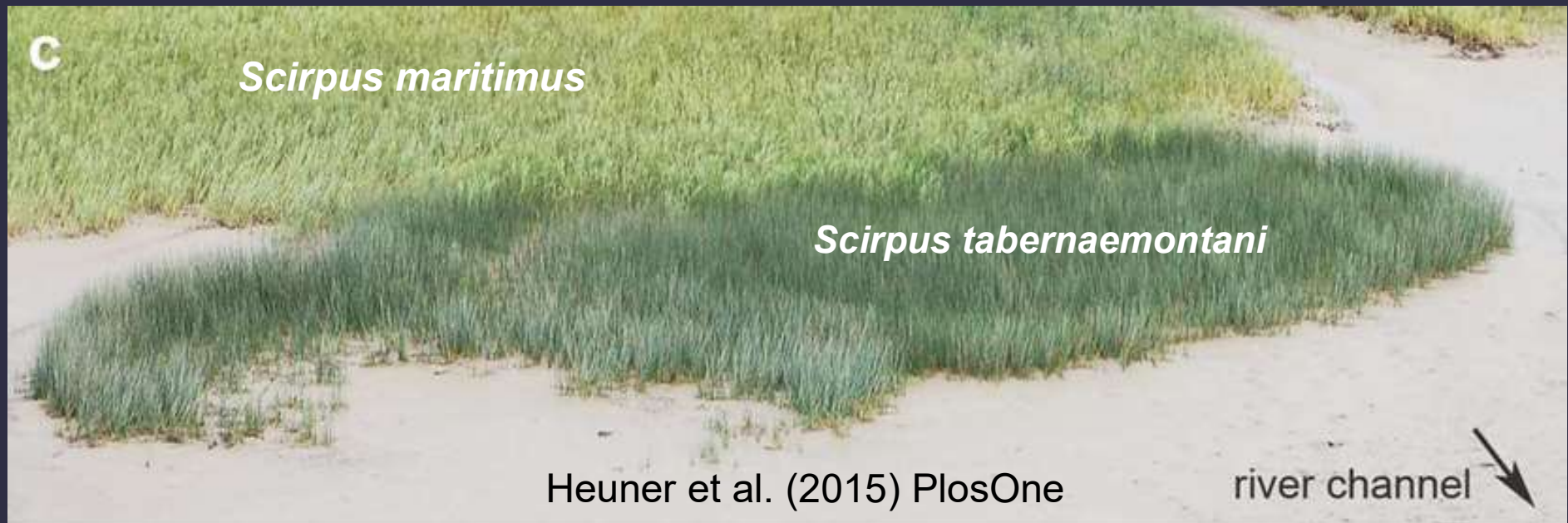


Ken
Schoutens

1) How effective is WAVE ATTENUATION by marshes ?



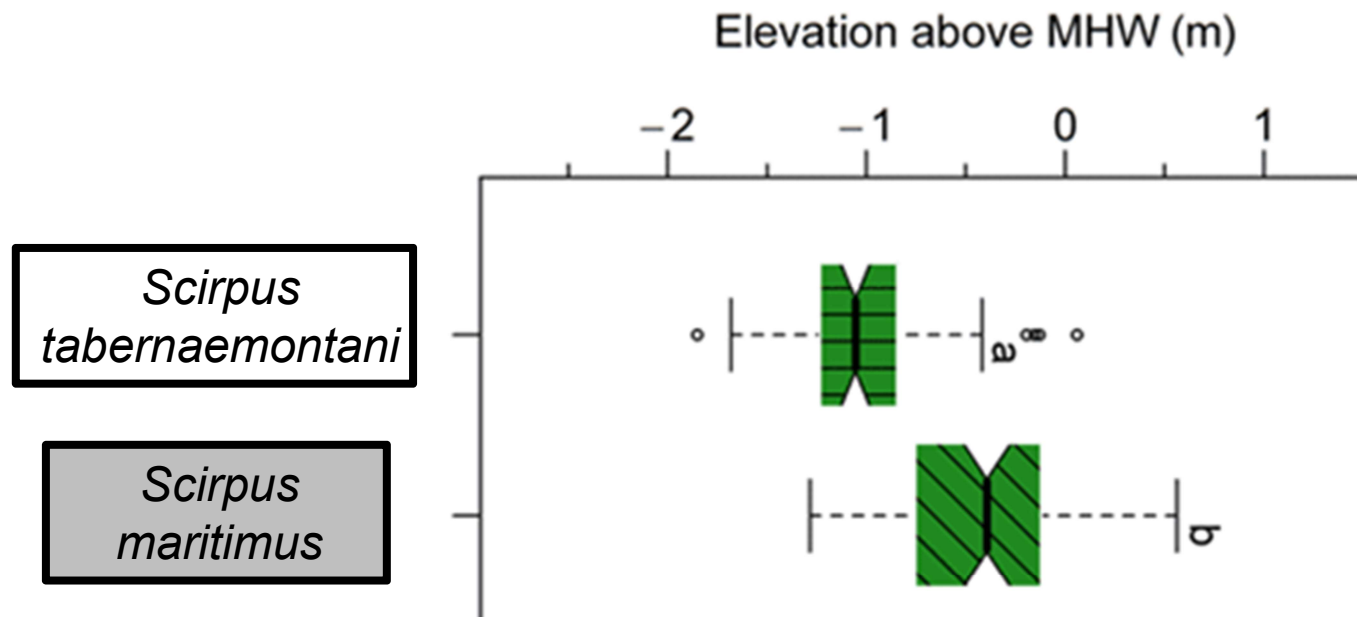
Study on 2 species dominant at marsh front
in NW European brackish estuaries (Elbe, Weser)
Showing typical species zonation



1) How effective is WAVE ATTENUATION by marshes ?



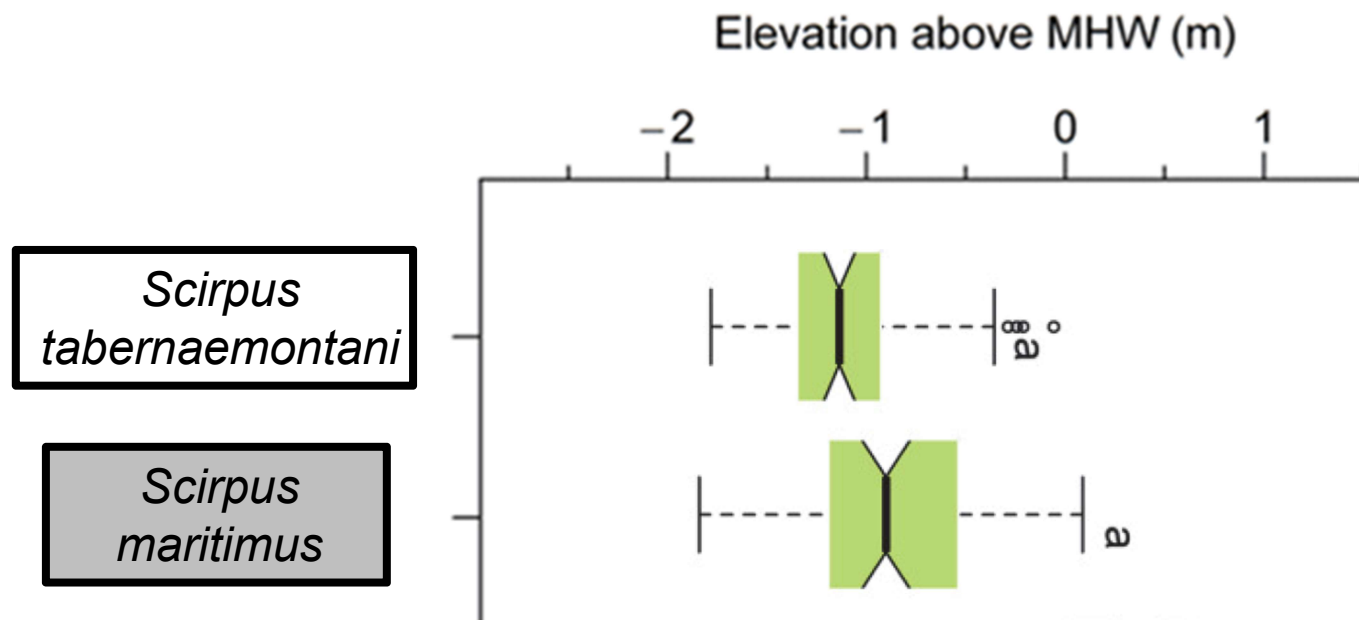
Clear species zonation in main channels of Elbe & Weser
(wave-exposed, fetch lengths ~several km)



1) How effective is WAVE ATTENUATION by marshes ?



Species zones overlap in anabranches of Elbe & Weser
(wave-sheltered, fetch lengths ~few 100s of m)

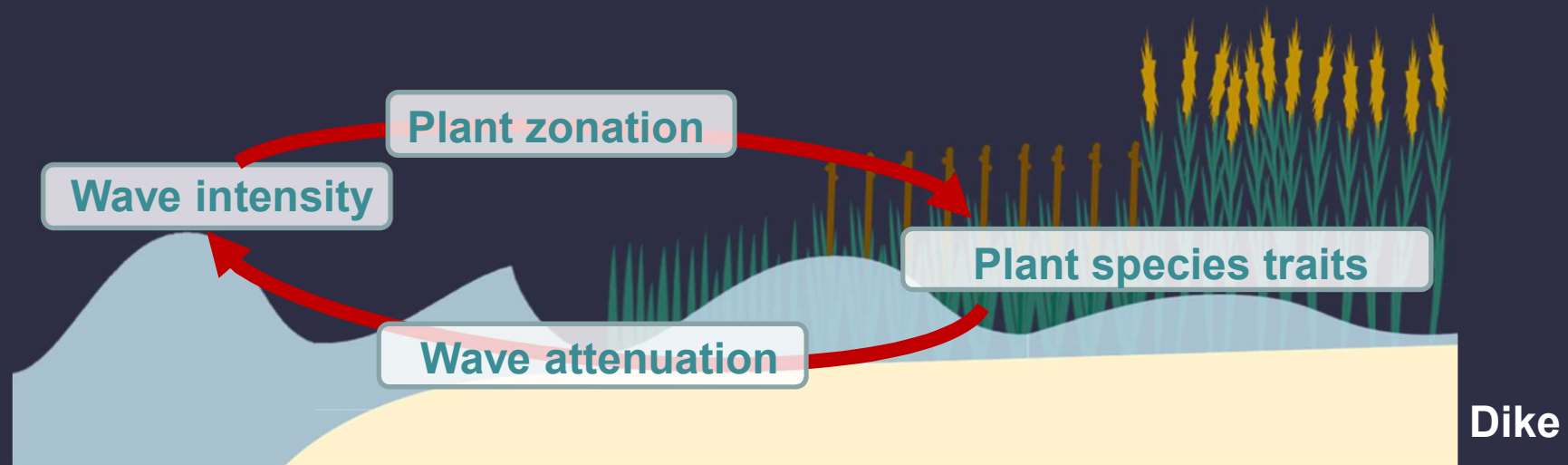


1) How effective is WAVE ATTENUATION by marshes ?



Questions: (1) to which extent is species zonation a result of species-dependent plant tolerance to waves ?

(2) What is feedback on species-dependent wave attenuation?



1) How effective is WAVE ATTENUATION by marshes ?

Effects of different plant traits?

PLANTS



WAVES



Plant surface area

-

+

Plant stiffness

-

+

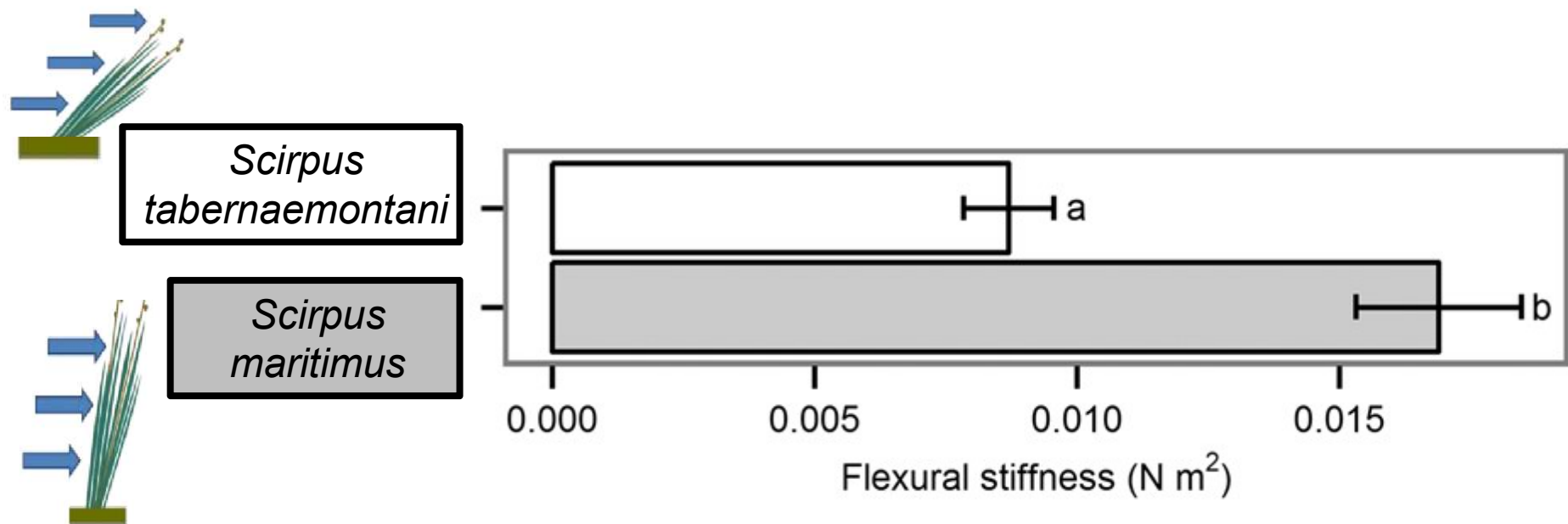


1) How effective is WAVE ATTENUATION by marshes ?

Effects of different plant traits?



Differences in plant stiffness



Heuner et al. (2015) PlosOne

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Effects of different plant traits?



Flume experiments: exposing plants to waves & erosion



Heuner et al. (2015) PlosOne; Silinski et al. (2015) PlosOne; (2016) Geomorph.

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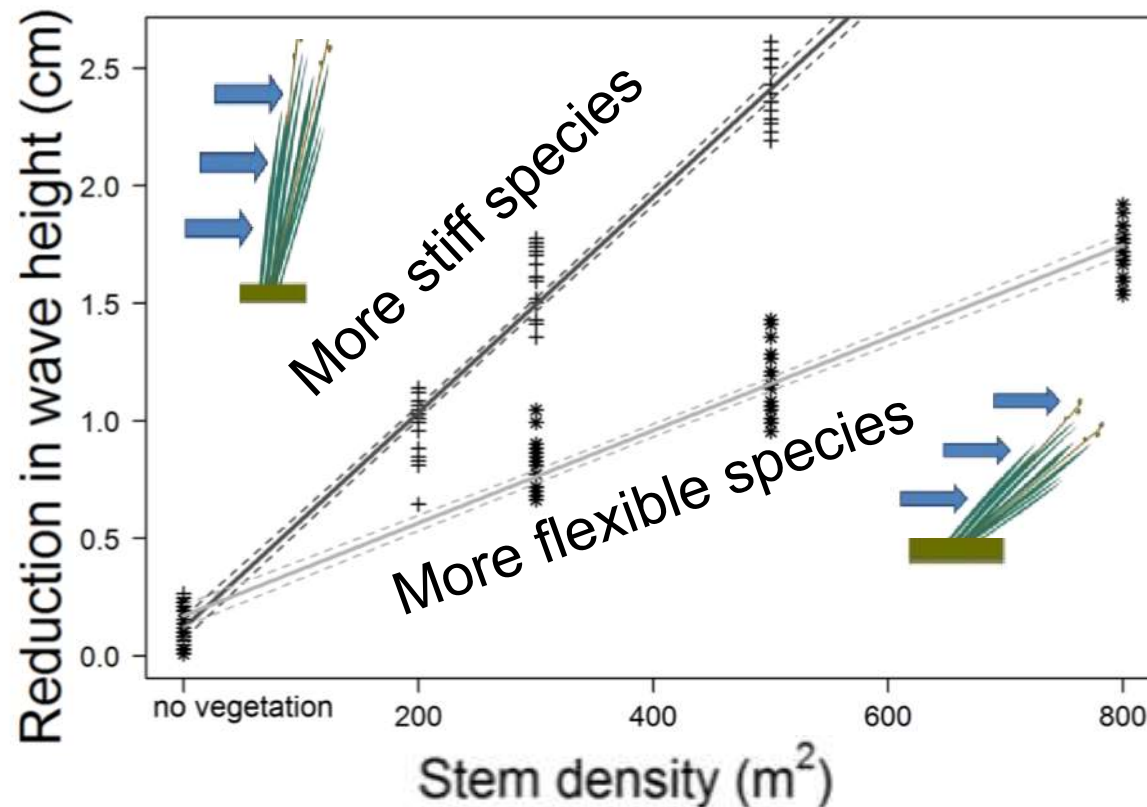
Effects of different plant traits?

PLANTS



WAVES

The **MORE STIFF** species provides **MORE WAVE ATTENUATION**



In the lab

Measured over 1,6 m distance

Heuner et al. (2015)
PlosOne

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Effects of different plant traits?

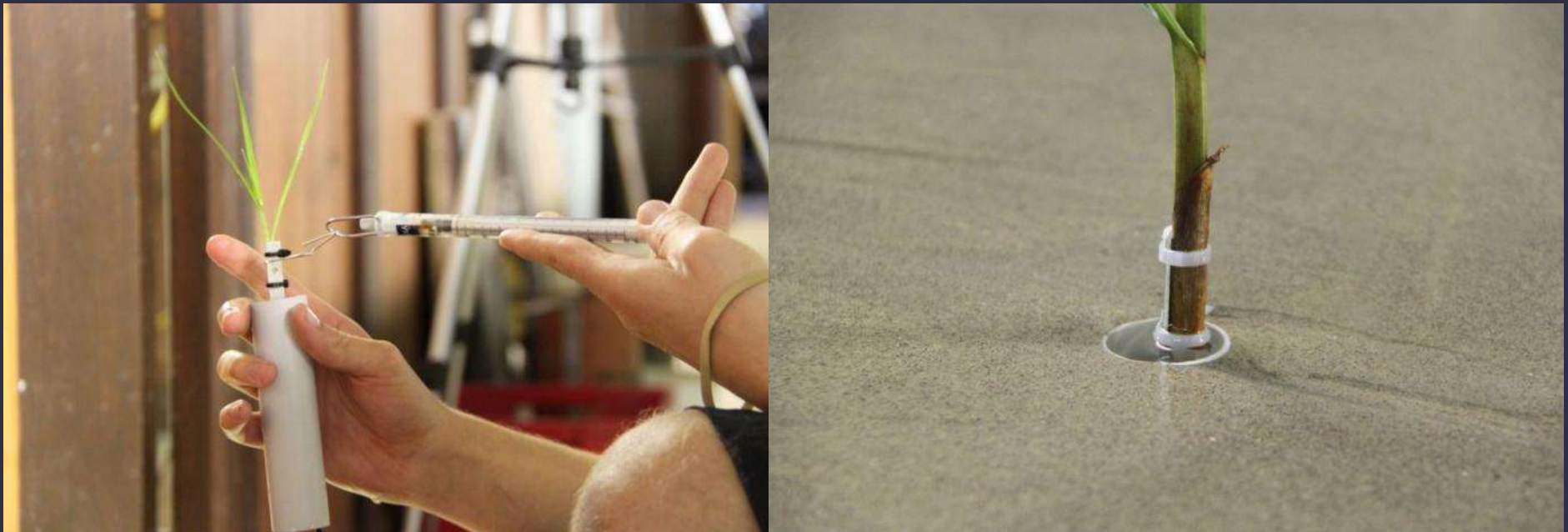


1) How effective is **WAVE ATTENUATION** by marshes ?

Effects of different plant traits?



Flume experiments: measuring drag forces (pulling on plants)



Heuner et al. (2015) PlosOne; Silinski et al. (2015) PlosOne; (2016) Geomorph.

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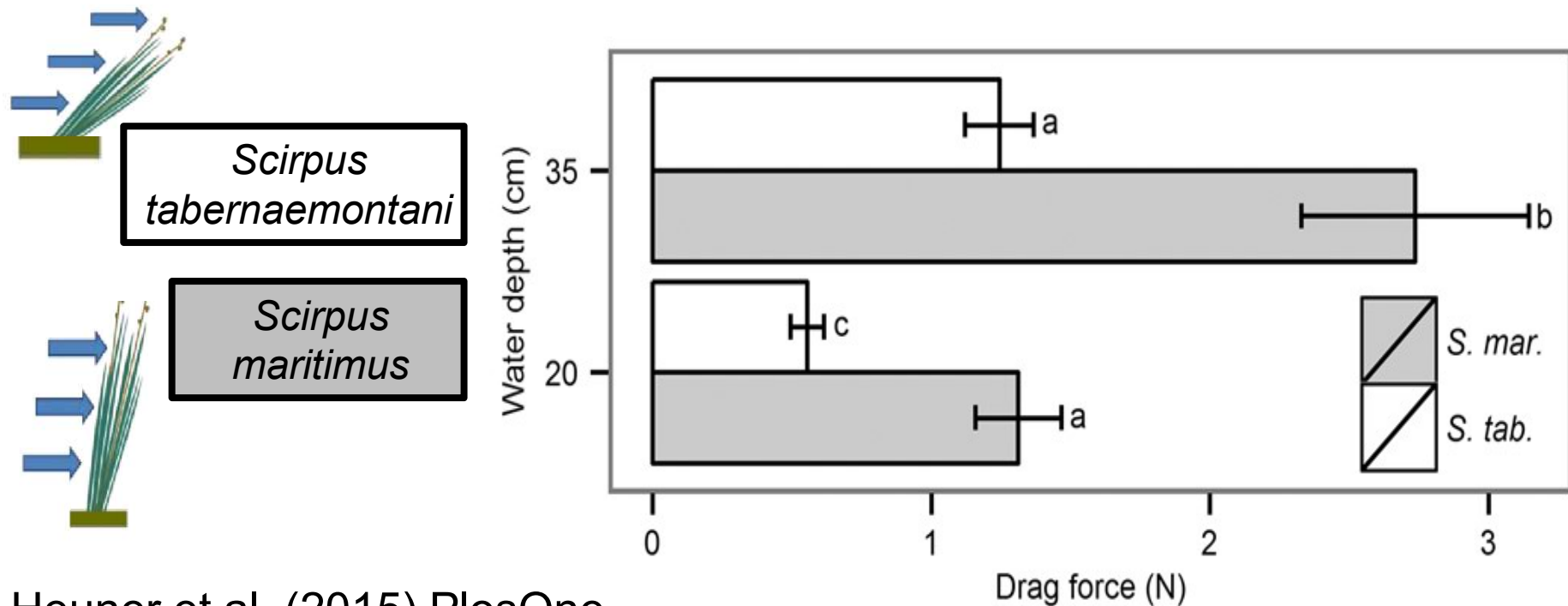
Effects of different plant traits?

PLANTS



WAVES

The **MORE FLEXIBLE** species feels **LESS DRAG** from waves



Heuner et al. (2015) PlosOne

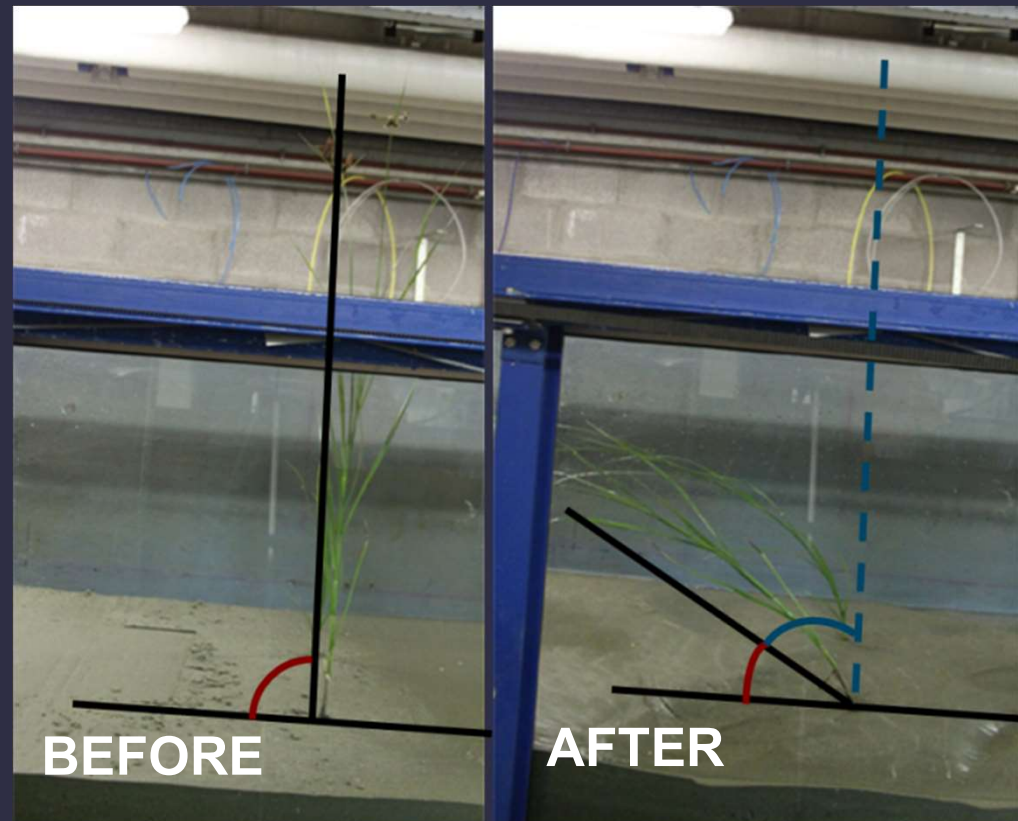
1) How effective is WAVE ATTENUATION by marshes ?

Effects of different plant traits?



Flume experiments:

measuring stem bending
before & after 200 waves



Heuner et al. (2015) PlosOne; Silinski et al. (2015) PlosOne; (2016) Geomorph.

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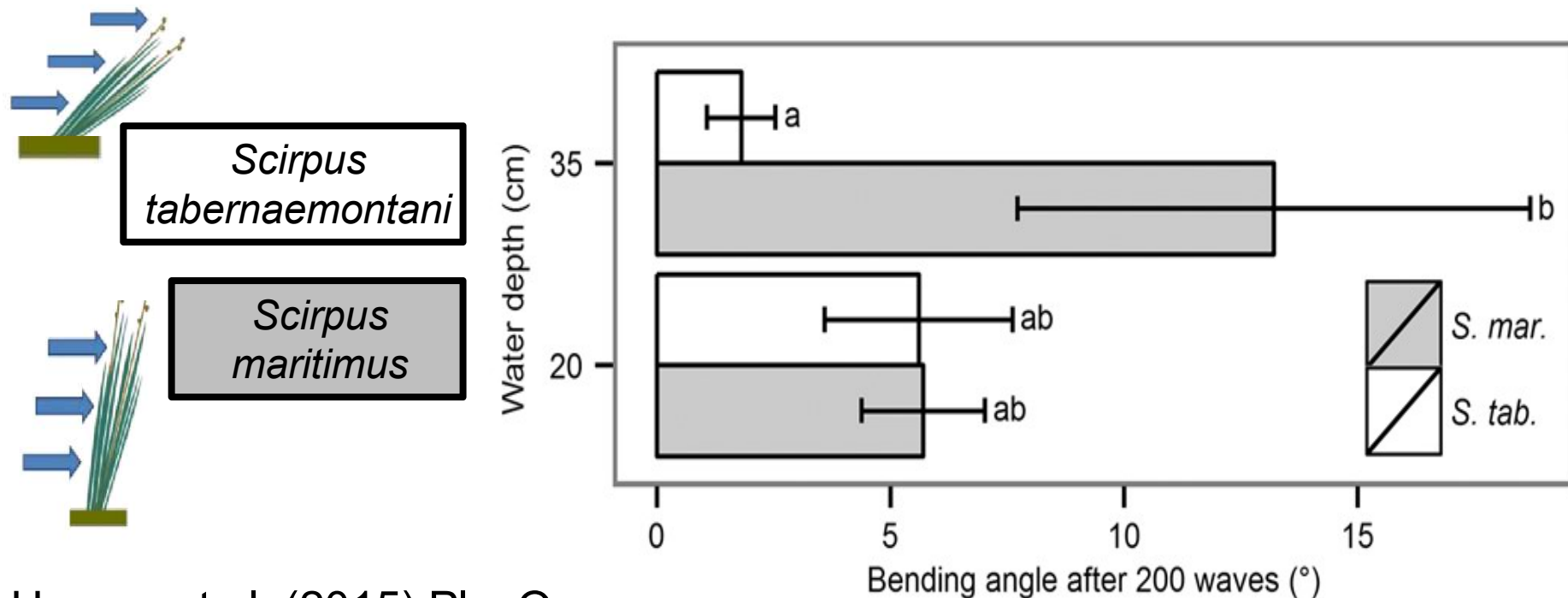
Effects of different plant traits?

PLANTS



WAVES

The **MORE FLEXIBLE** species is **LESS BENDED** after waves



Heuner et al. (2015) PlosOne

1) How effective is WAVE ATTENUATION by marshes ?

The **MORE FLEXIBLE** species **COPE BETTER** with waves & therefore can grow in **MORE WAVE-EXPOSED** locations ??



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Transplantation experiments with manipulation of wave regime
Elbe estuary, winter 2018 – winter 2020



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Elbe estuary, winter 2018 – winter 2020



3 species

X 20 replicas

X 3 elevations

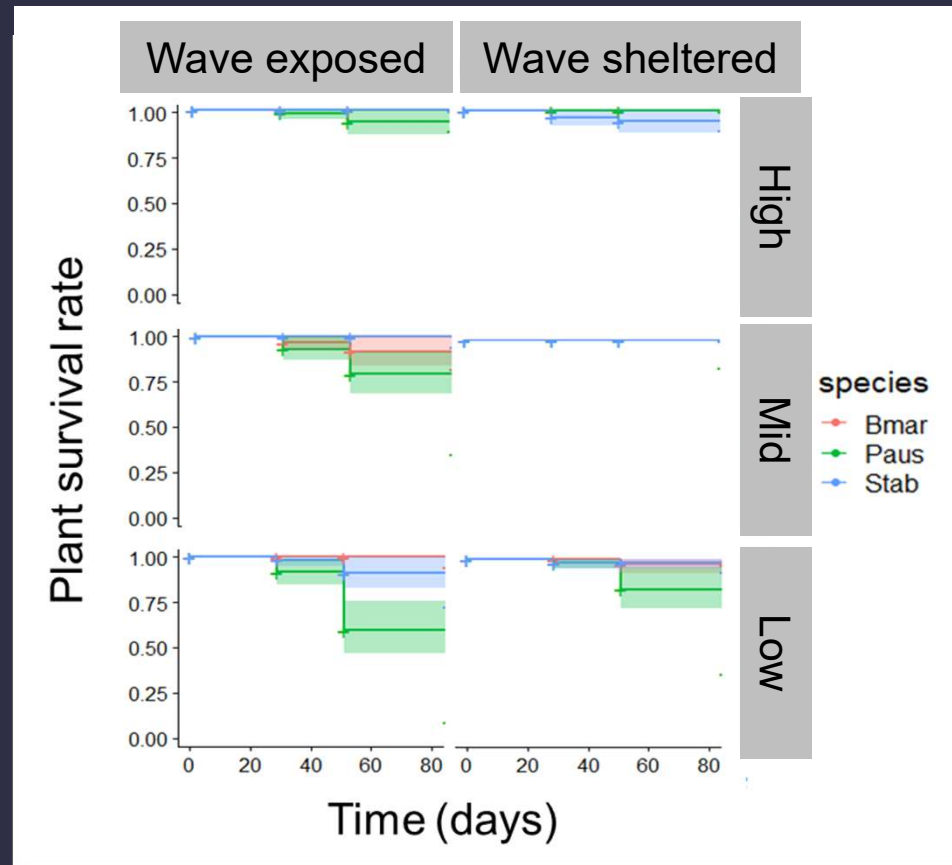
X 2 wave regimes

2-yr monitoring of
waves, currents,
sedimentation-erosion,
sediment & plant
properties...

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Transplantation experiments with manipulation of wave regime
Elbe estuary, winter 2018 – winter 2020



Very preliminary
results

Kaplan-Meier
survival analysis

1) How effective is WAVE ATTENUATION by marshes ?

Summarizing....



Intensity of interaction depends on

DRAG

Plant stiffness, surface area, density, biomass...



LESS EFFECTIVE to grow in
WAVE-EXPOSED locations (?)

MORE EFFECTIVE in
WAVE ATTENUATION

TRADE-OFFS

2) Predicting long-term, landscape-scale marsh dynamics?

Nature restoration in Hedwige- & Prosperpolder (HPP), Schelde



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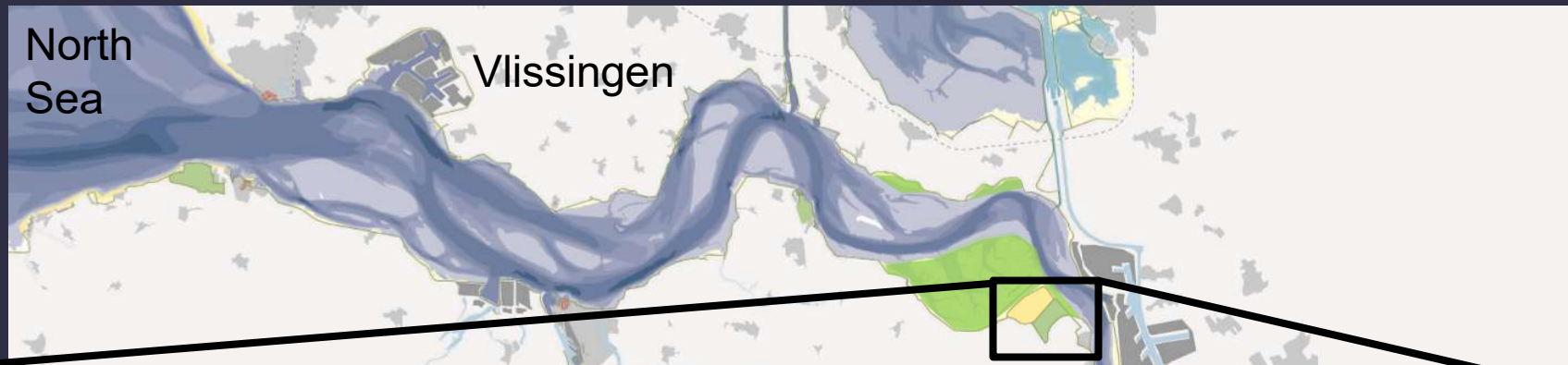
+4,65 km² new marsh **under construction & realized by ~2022**



Artist impression

2) Predicting long-term, landscape-scale marsh dynamics?

Nature restoration in Hedwige- & Prosperpolder (HPP), Schelde



+4,65 km² new marsh under construction & realized by ~2022

Reasons:

- Dutch-Flemish agreement “Schelde-verdrag 2005”
- Restoration of historically lost mudflats & marshes; to meet EU Natura 2000
- Water storage to mitigate storm surges & flood risks (Flemish Sigmaphan + 40 km² new floodplains)
- Not compensation for dredging & port access

2) Predicting long-term, landscape-scale marsh dynamics?

How successful is marsh restoration in a former polder area?

Will it stay 'a big box of mud' for ever?

Will it evolve quickly to a 'boring' climax vegetation of reeds?

Can you steer the development?

(options: breach width & number, digging channels,...)



Artist impression

2) Predicting long-term, landscape-scale marsh dynamics?

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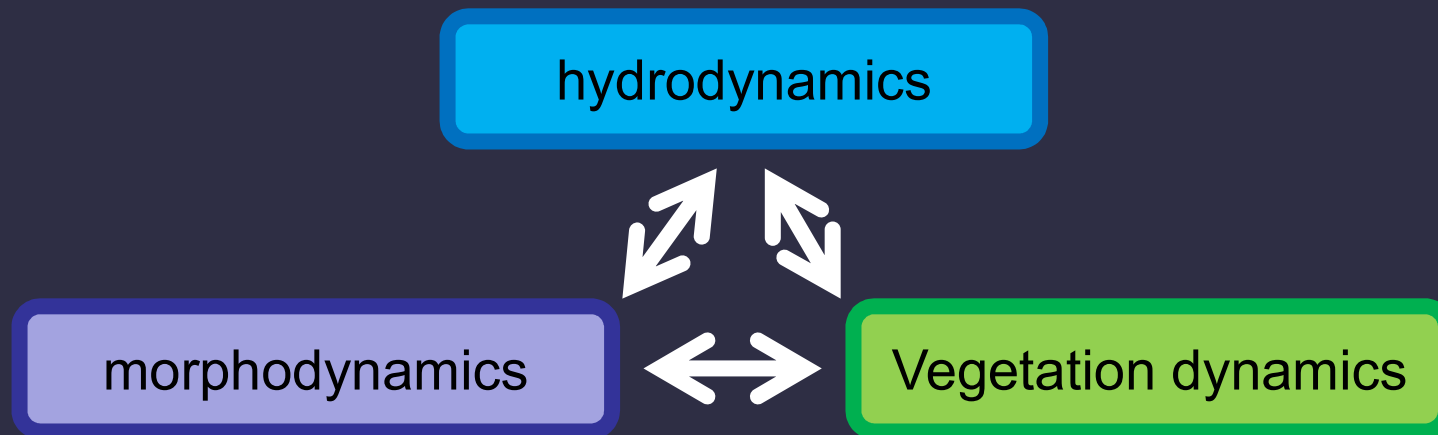
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2) Predicting long-term, landscape-scale marsh dynamics?

A new bio-geomorphic model



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A new bio-geomorphic model
Based on extensive new field & flume data



morphodynamics

hydrodynamics

Vegetation dynamics



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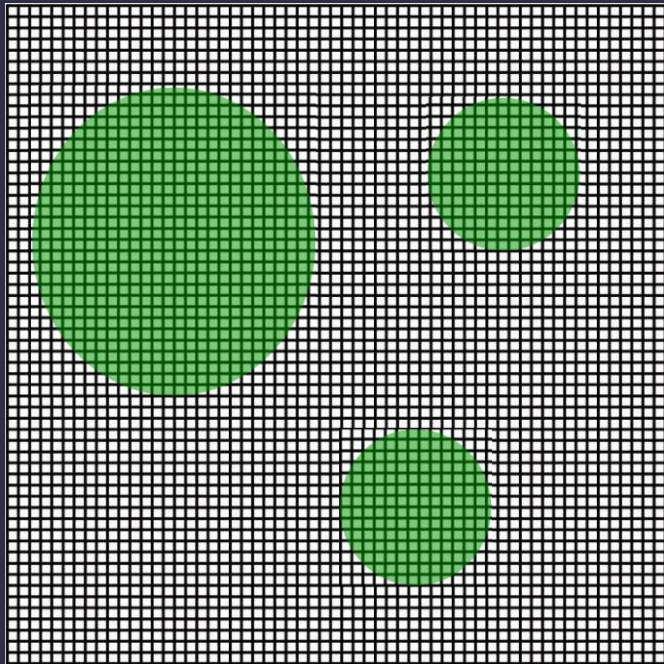
hydrodynamics

Vegetation dynamics



2) Predicting long-term, landscape-scale marsh dynamics?

A new bio-geomorphic model
New techniques for coupling of multi-scale interactions

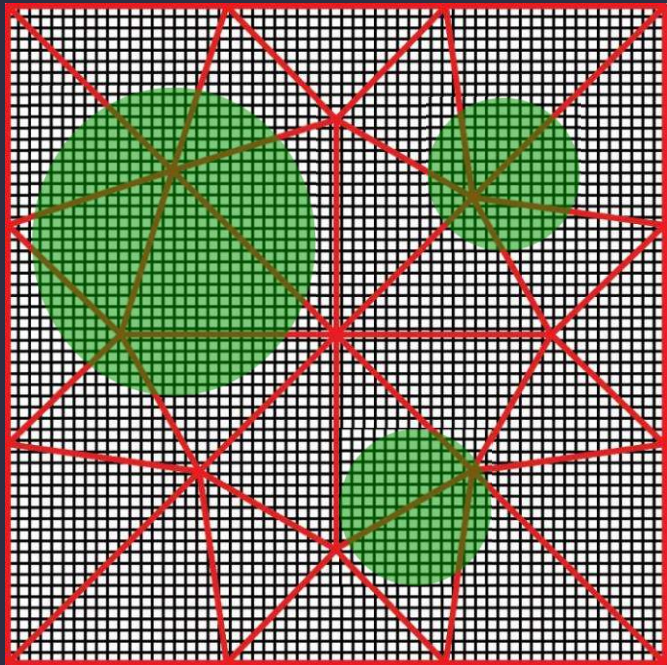


Vegetation model
0.25 m resolution



2) Predicting long-term, landscape-scale marsh dynamics?

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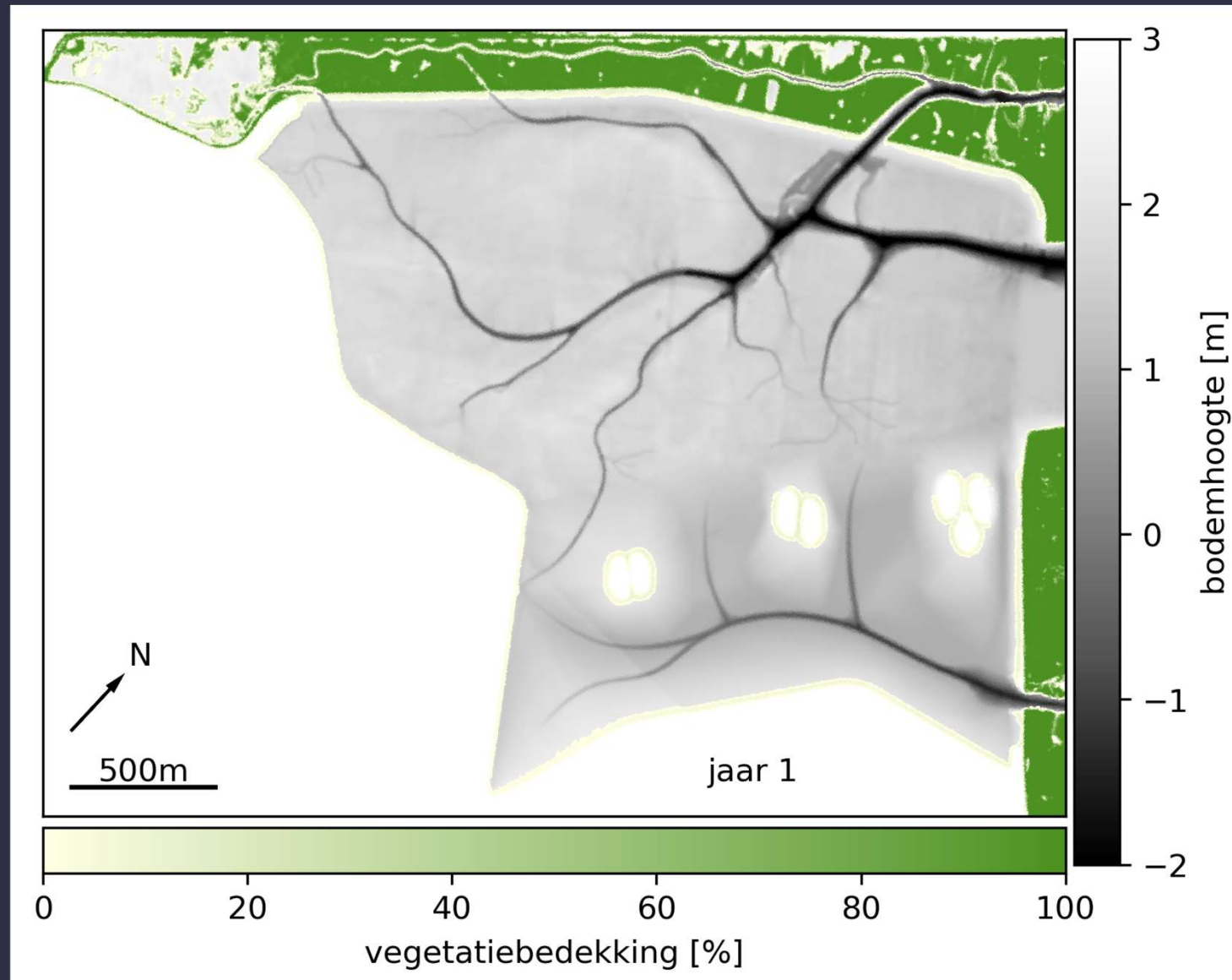


Vegetation model
0.25 m resolution

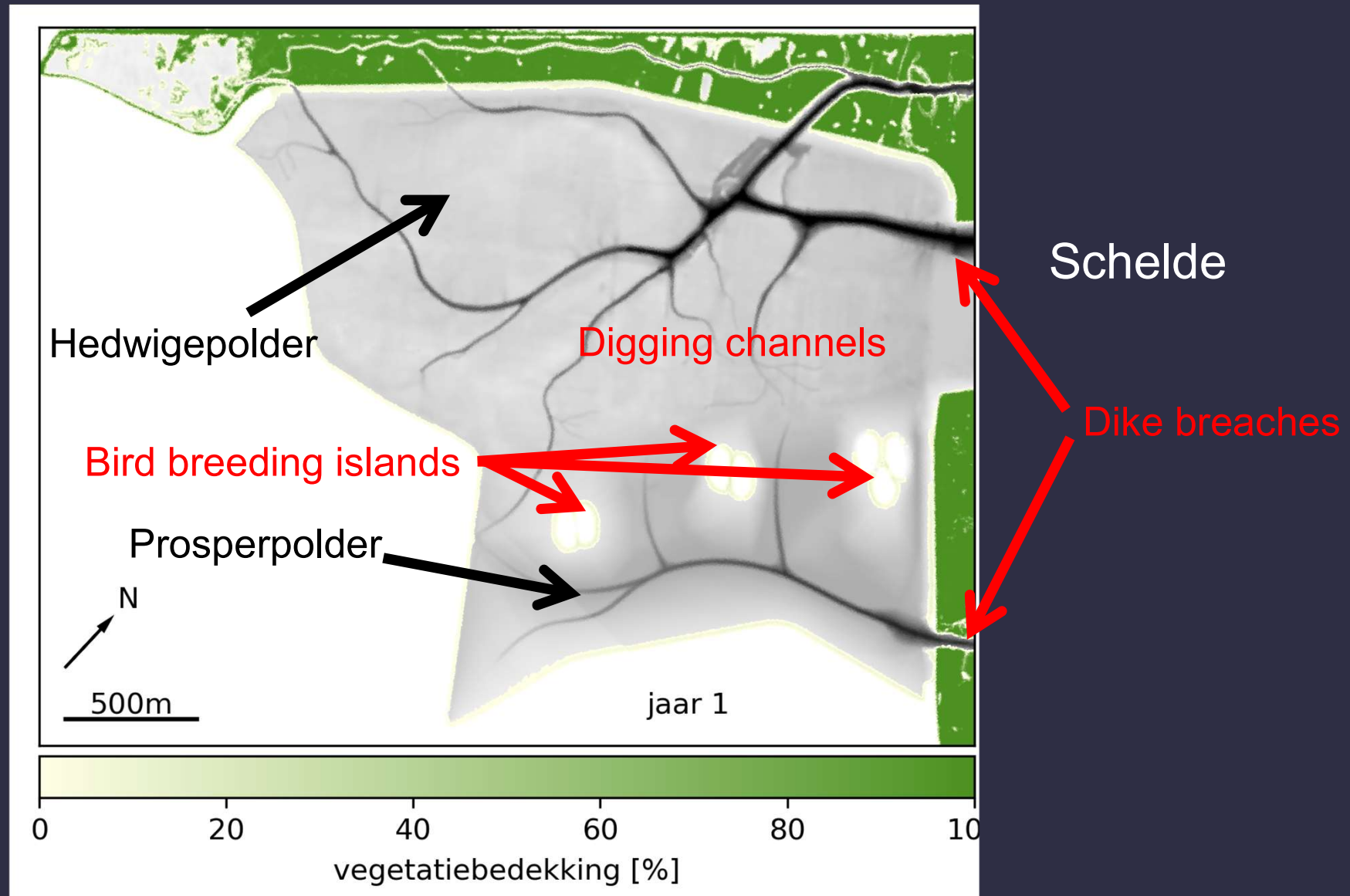


**Hydro- & morphodynamic model
coarser resolution & TIN**

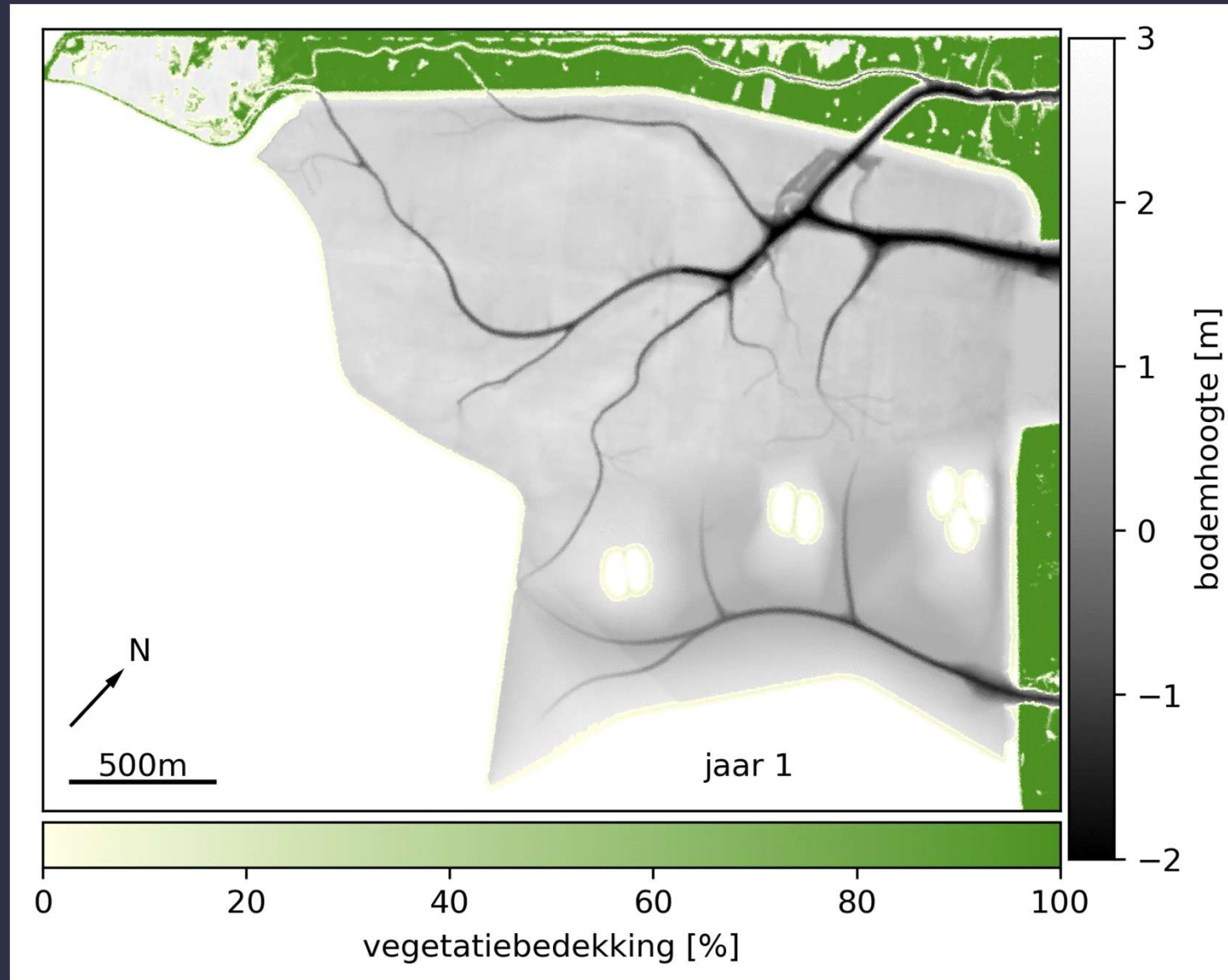
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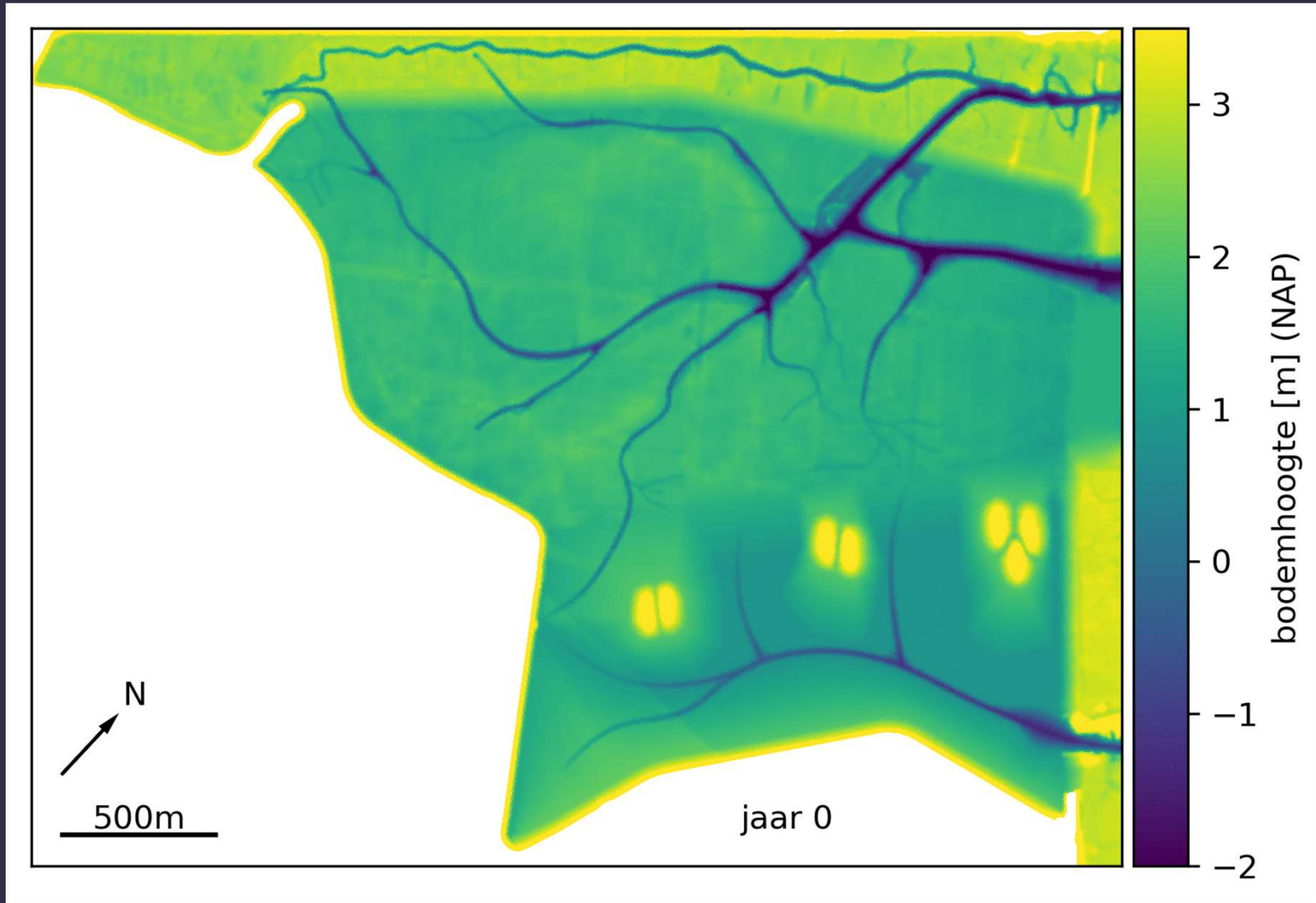


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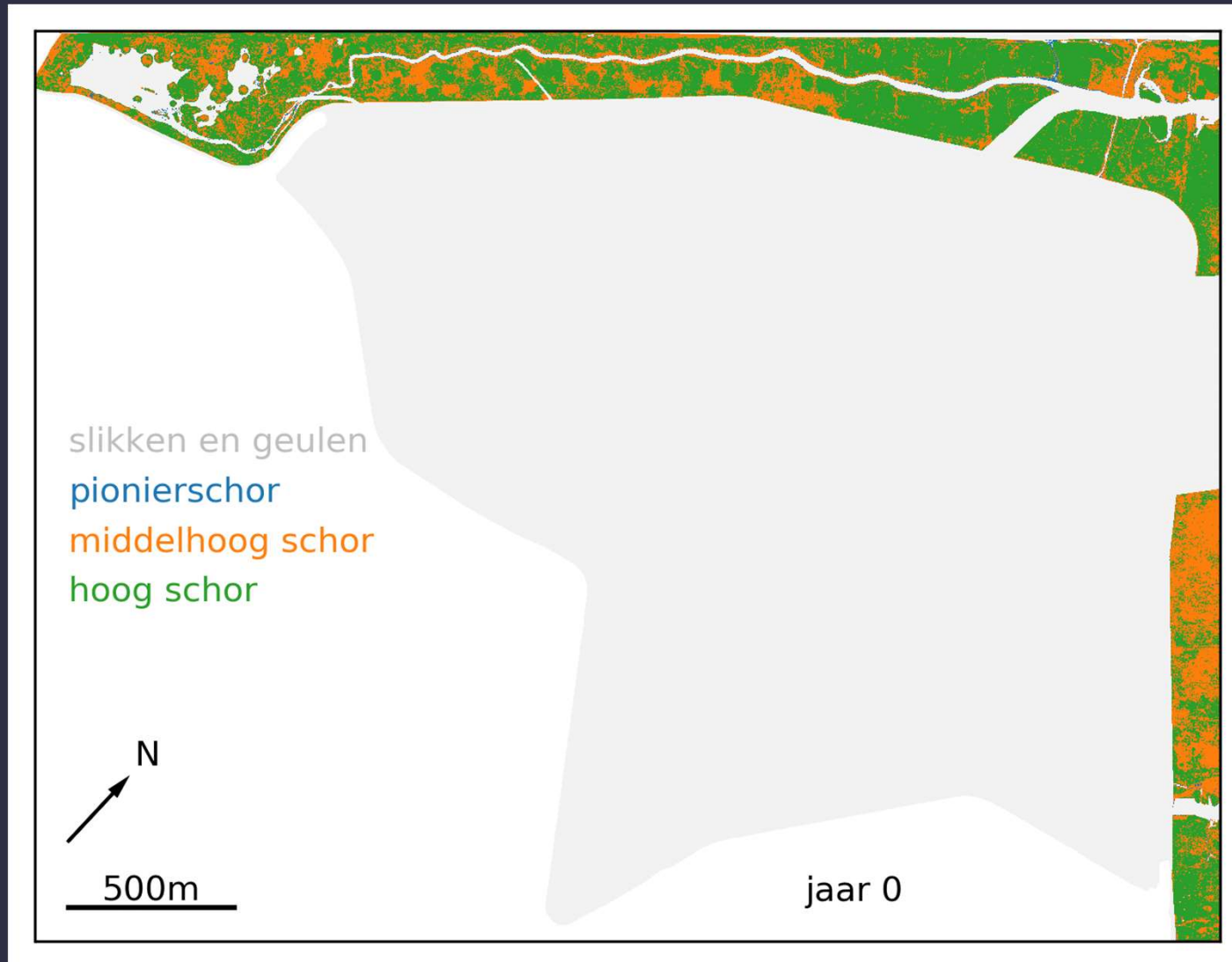
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Topographical development



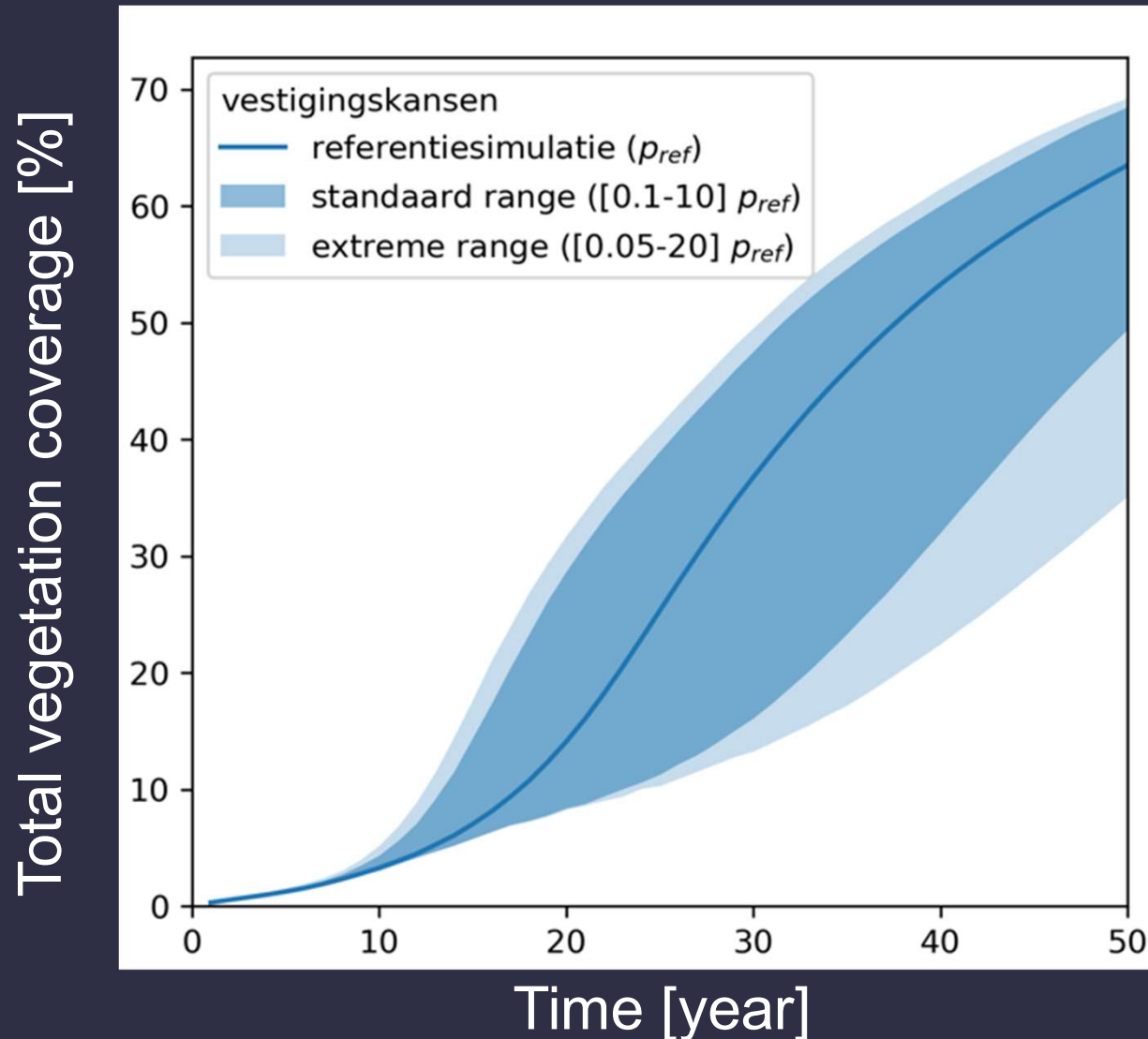
2) Predicting long-term, landscape-scale marsh dynamics?

Development of main vegetation types



2) Predicting long-term, landscape-scale marsh dynamics?

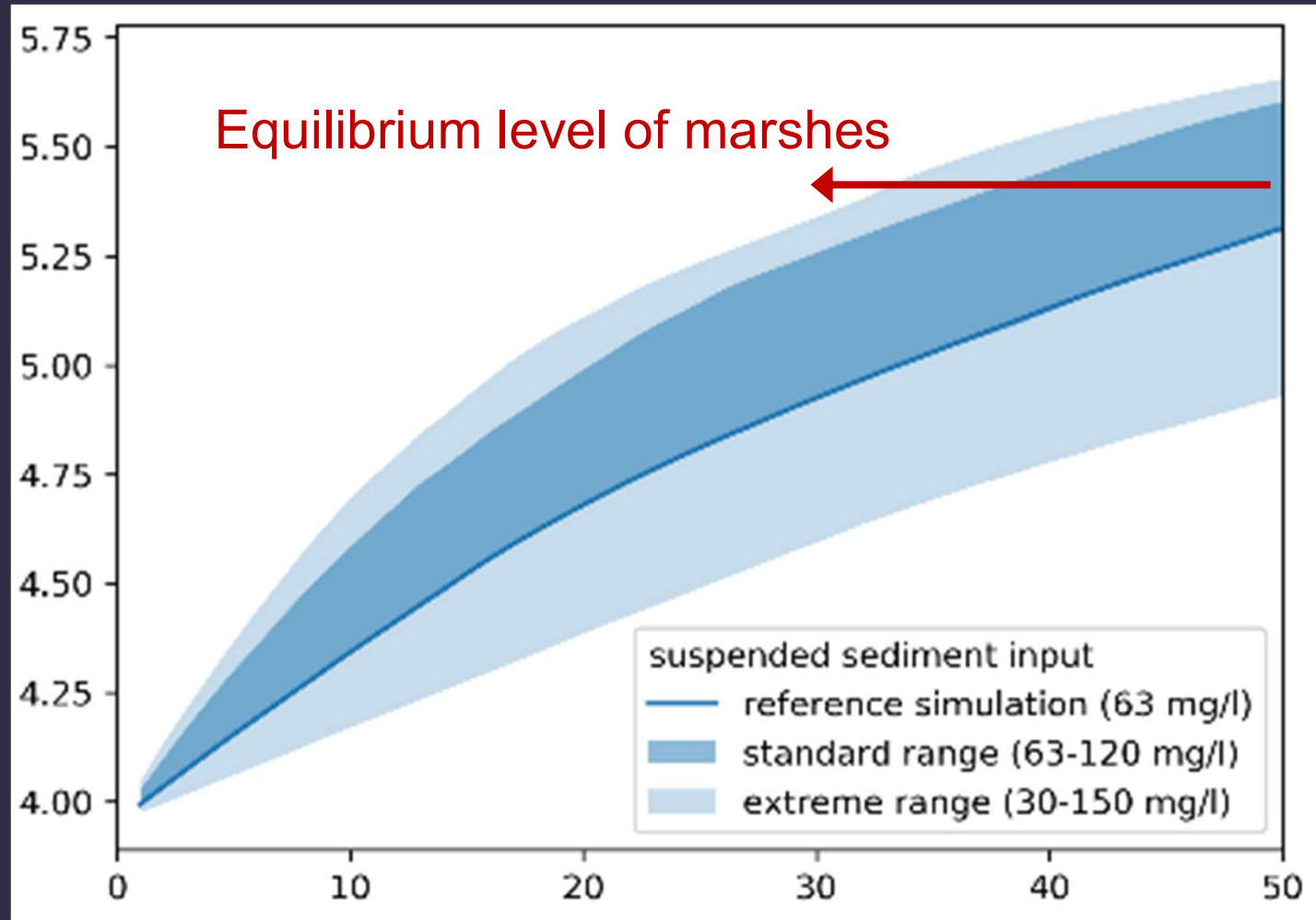
Slow development; uncertainty due to stochasticity etc....



2) Predicting long-term, landscape-scale marsh dynamics?

Slow development; uncertainty due to stochasticity etc....

Area-averaged soil elevation
[m TAW]

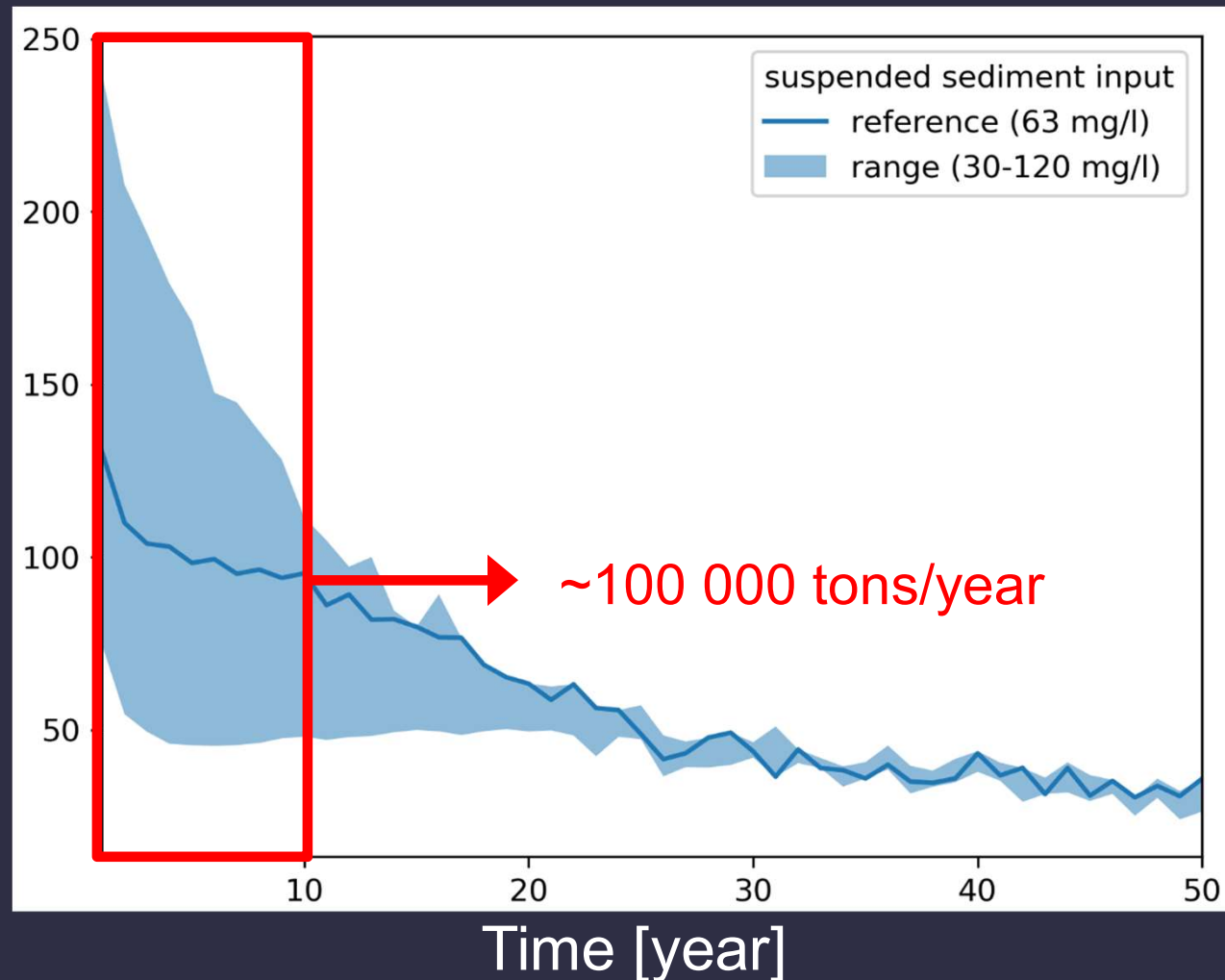


Time [year]

2) Predicting long-term, landscape-scale marsh dynamics?

Calculation of delivery of ecosystem services: **sediment removal**

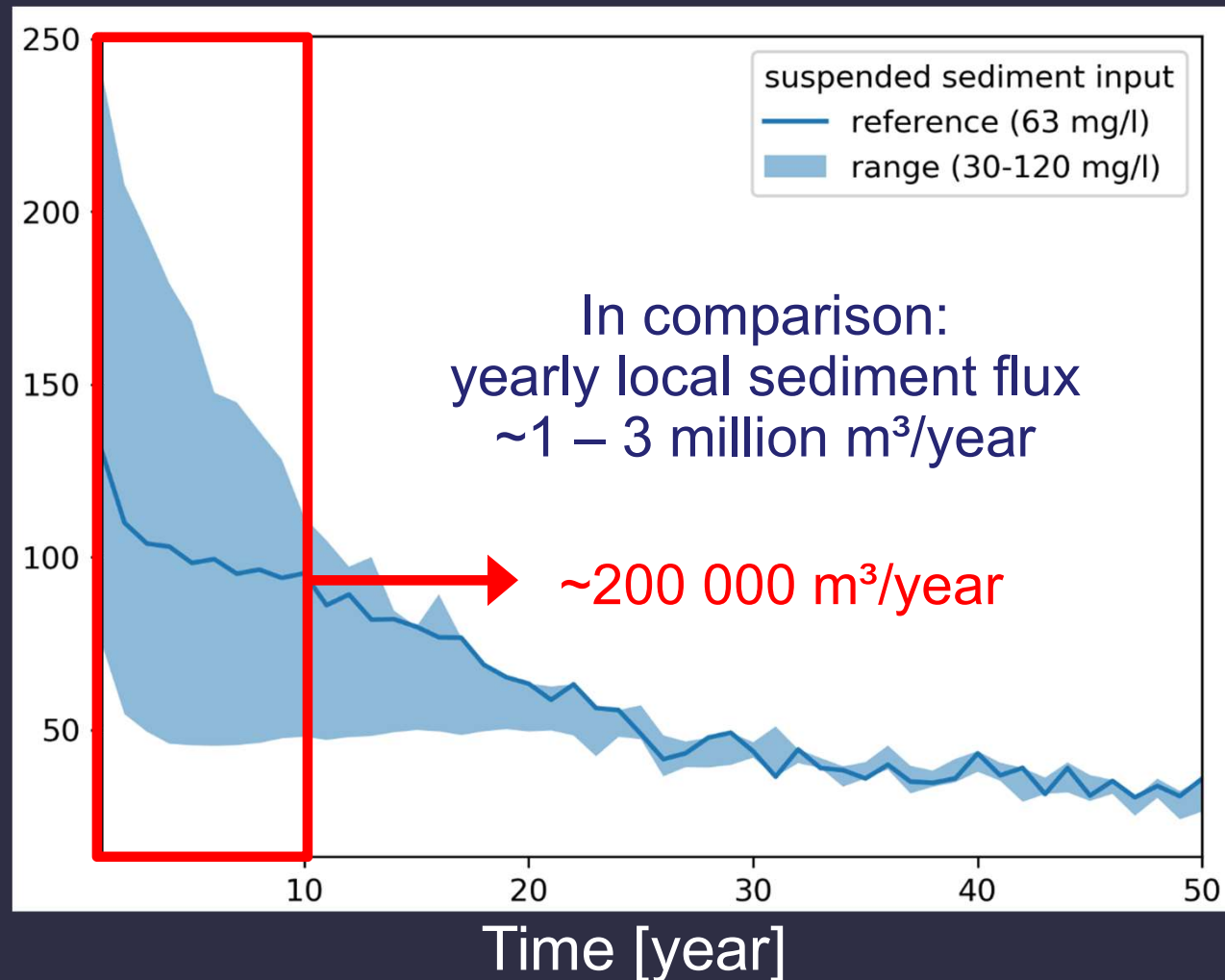
Total sedimentation rate
[10³ tons/year]



2) Predicting long-term, landscape-scale marsh dynamics?

Calculation of delivery of ecosystem services: **sediment removal**

Total sedimentation rate
[10³ tons/year]



2) Predicting long-term, landscape-scale marsh dynamics?

Calculation of delivery of ecosystem services: **carbon removal**

~6 000 ton C/year

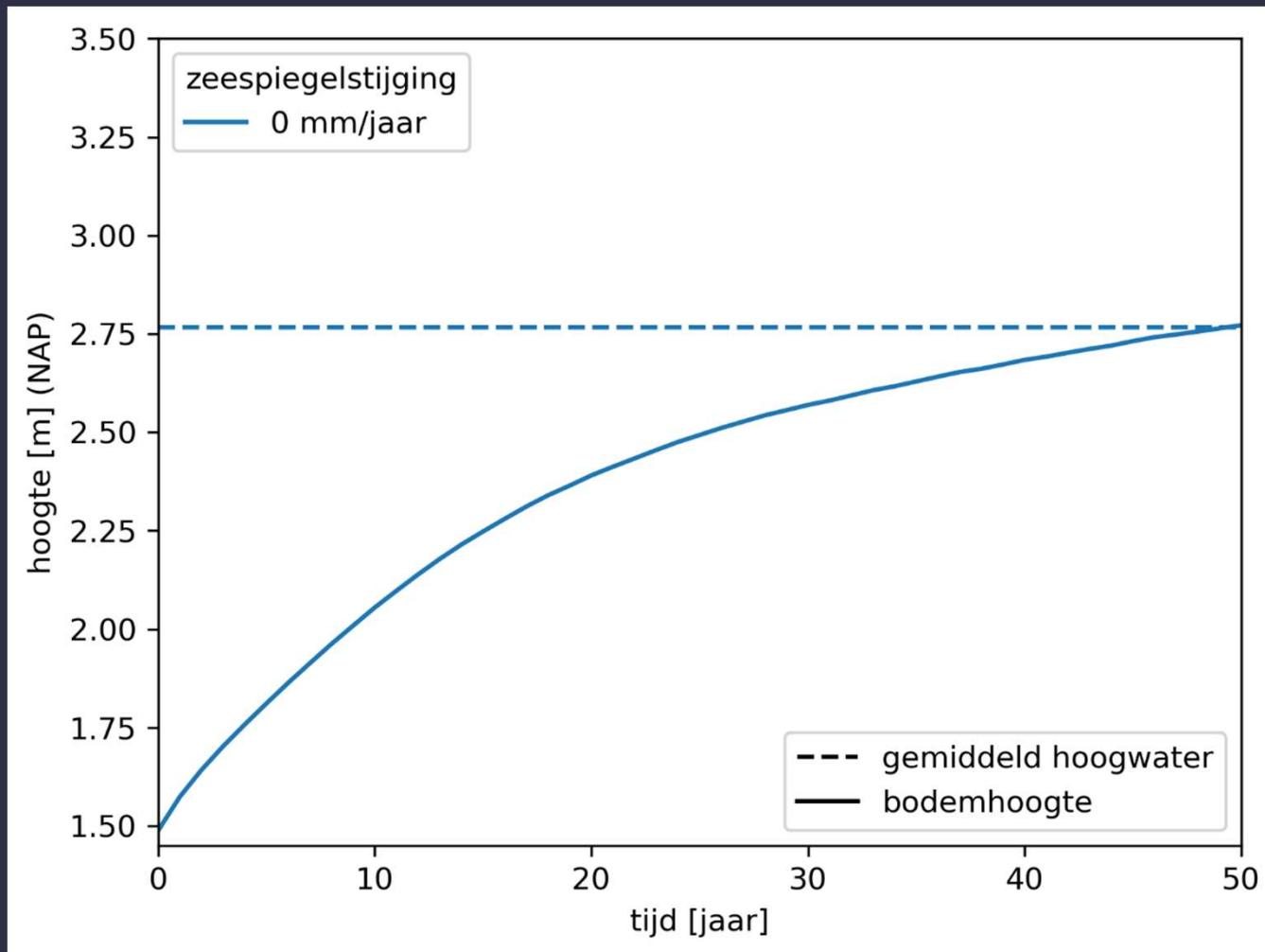
~Yearly emission of ~9000 cars



x 9000 / year

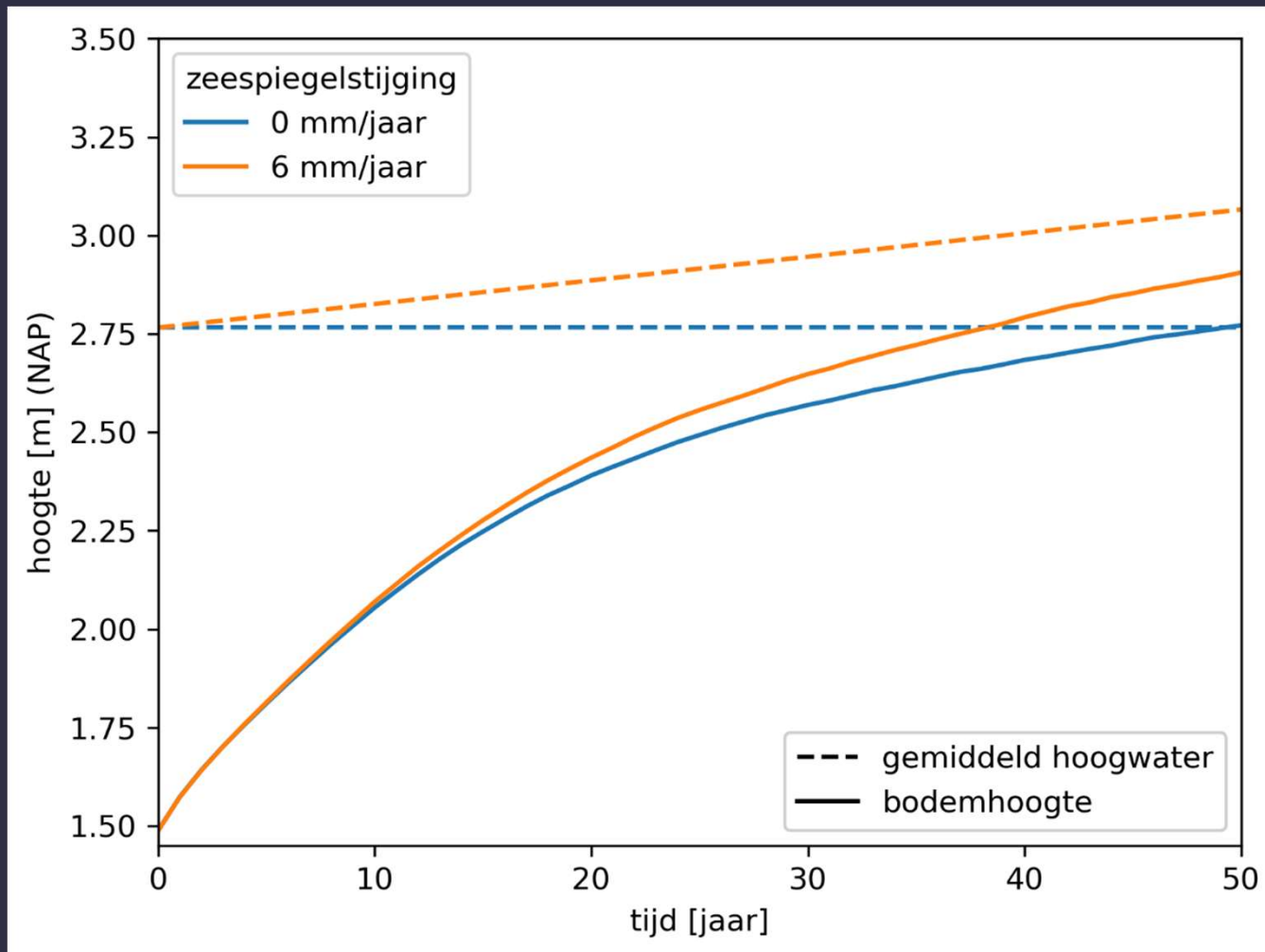
2) Predicting long-term, landscape-scale marsh dynamics?

Temporal 'de-poldering' as a measure to build up land elevation with sea level rise



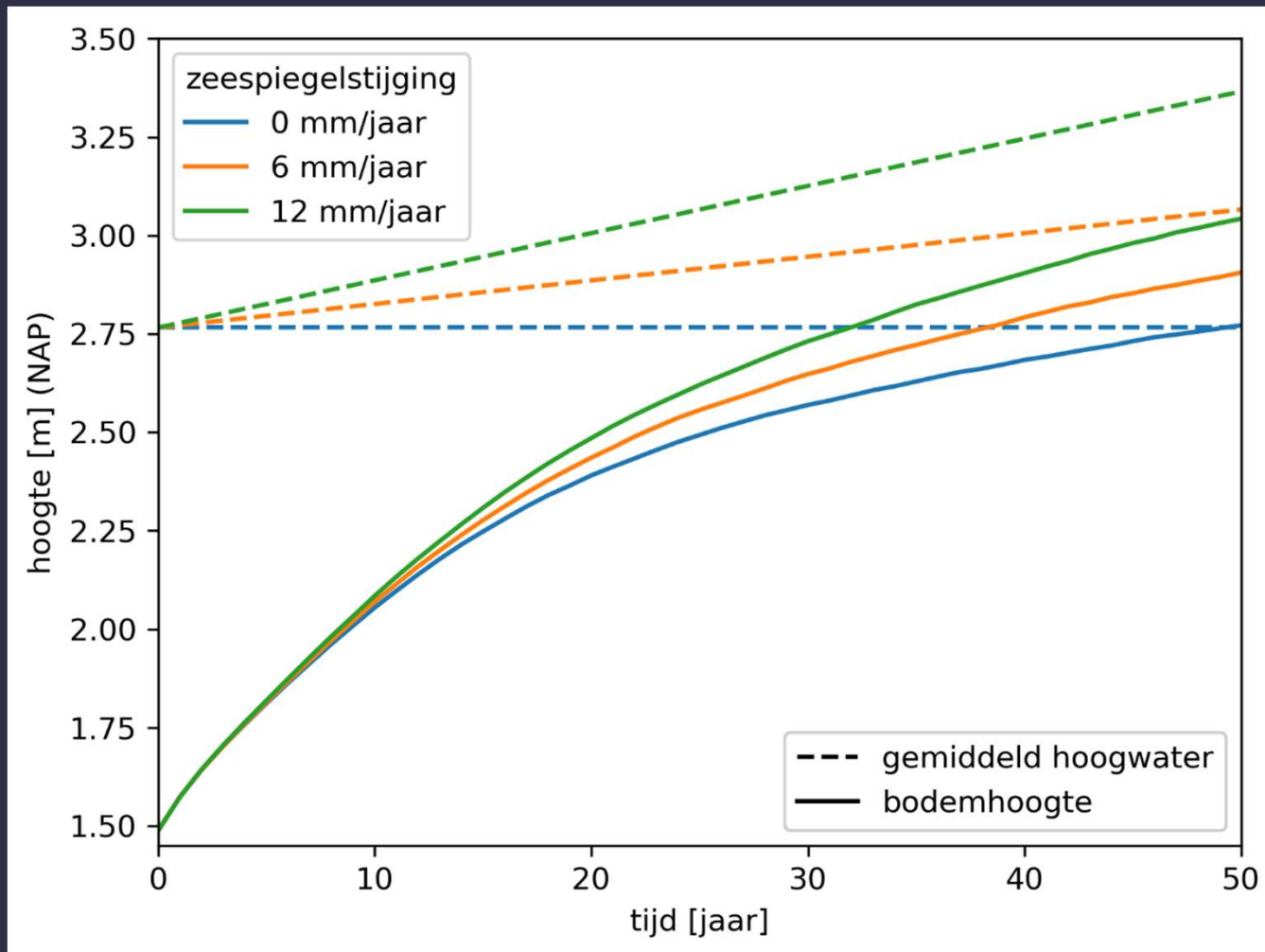
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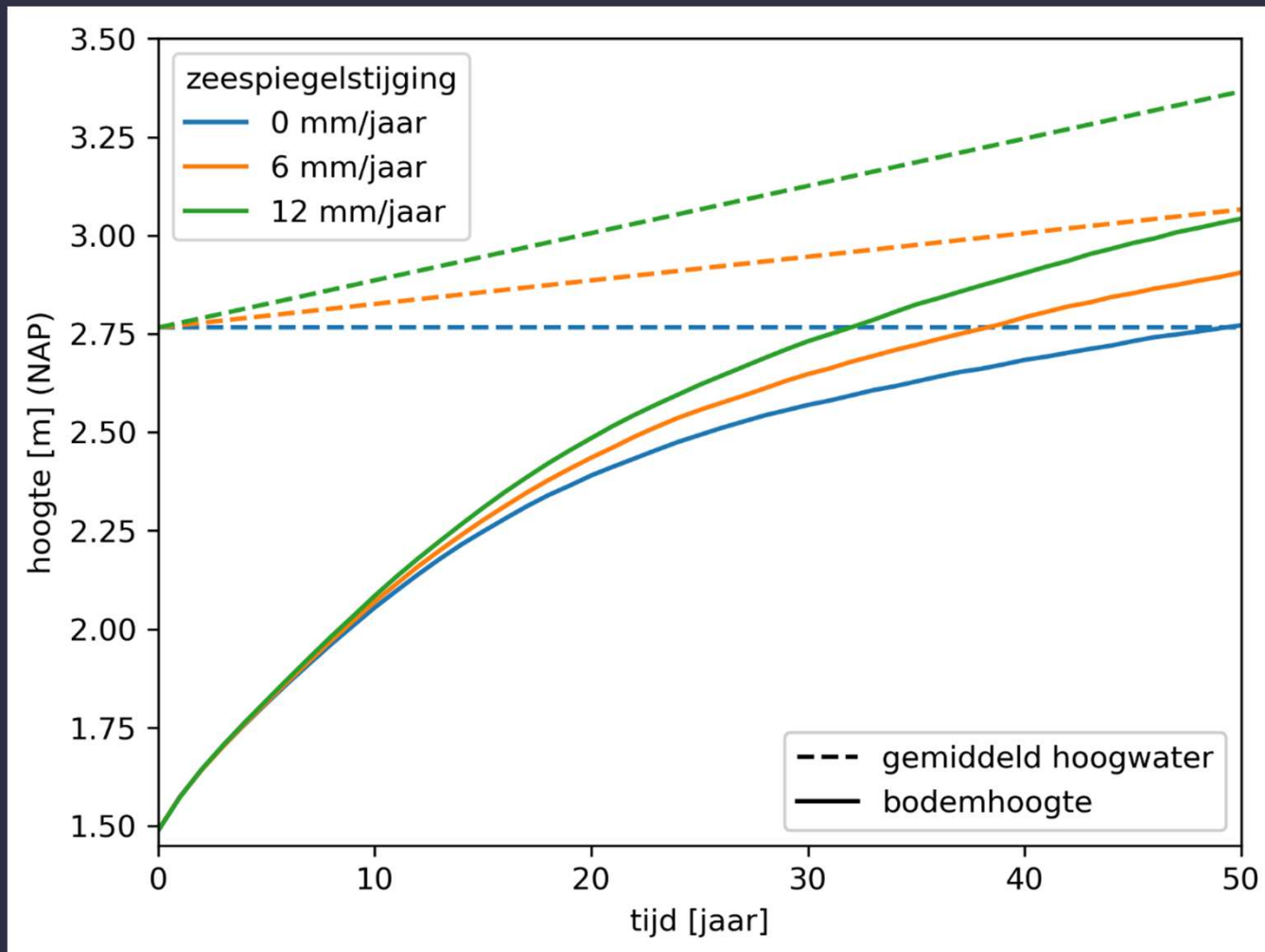
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2) Predicting long-term, landscape-scale marsh dynamics?

Rate of sedimentation & vegetation development:
can be steered by dike breach design

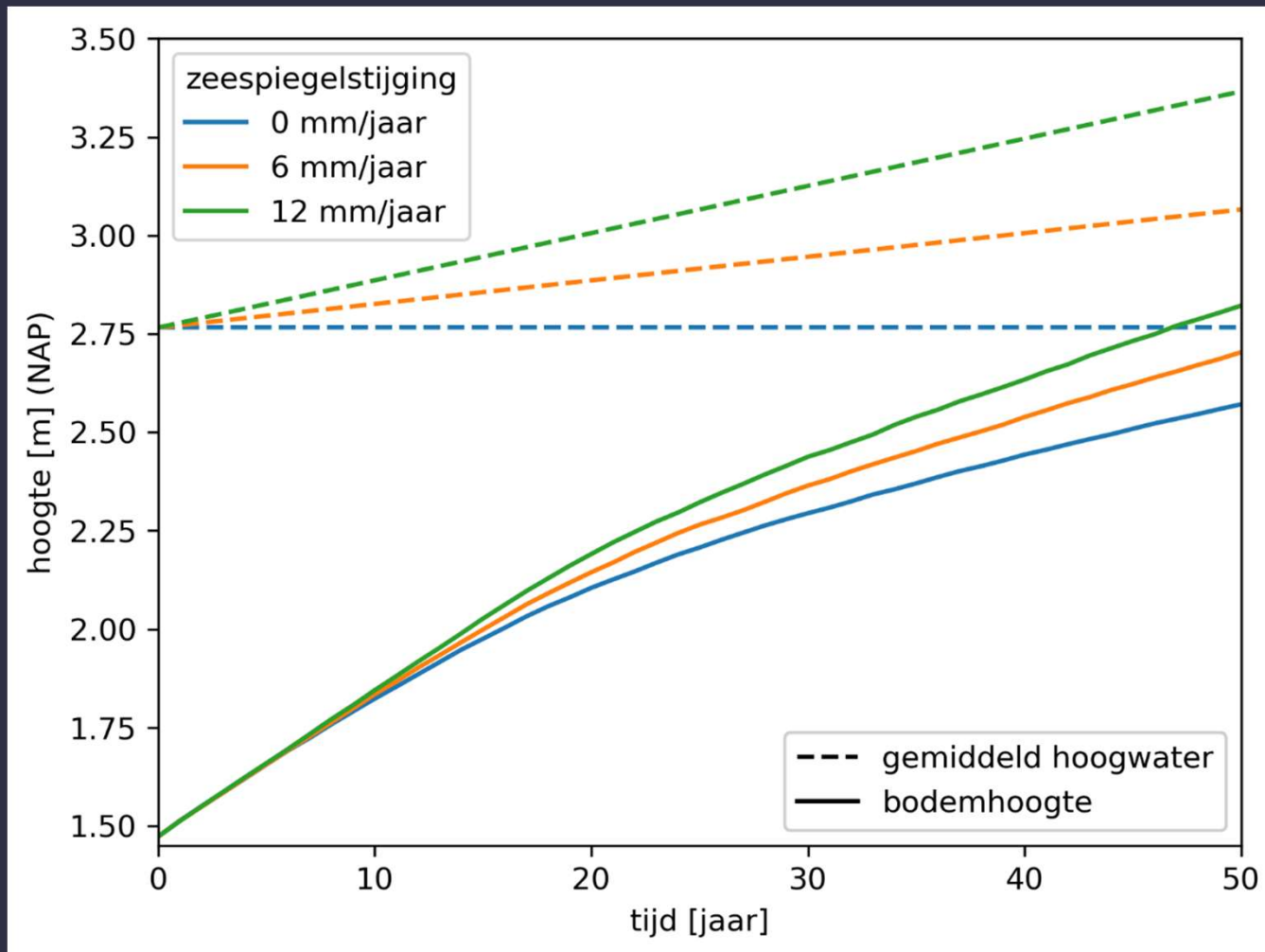
Prosper-
polder
**Small
dike
breach
(50 m)**



2) Predicting long-term, landscape-scale marsh dynamics?

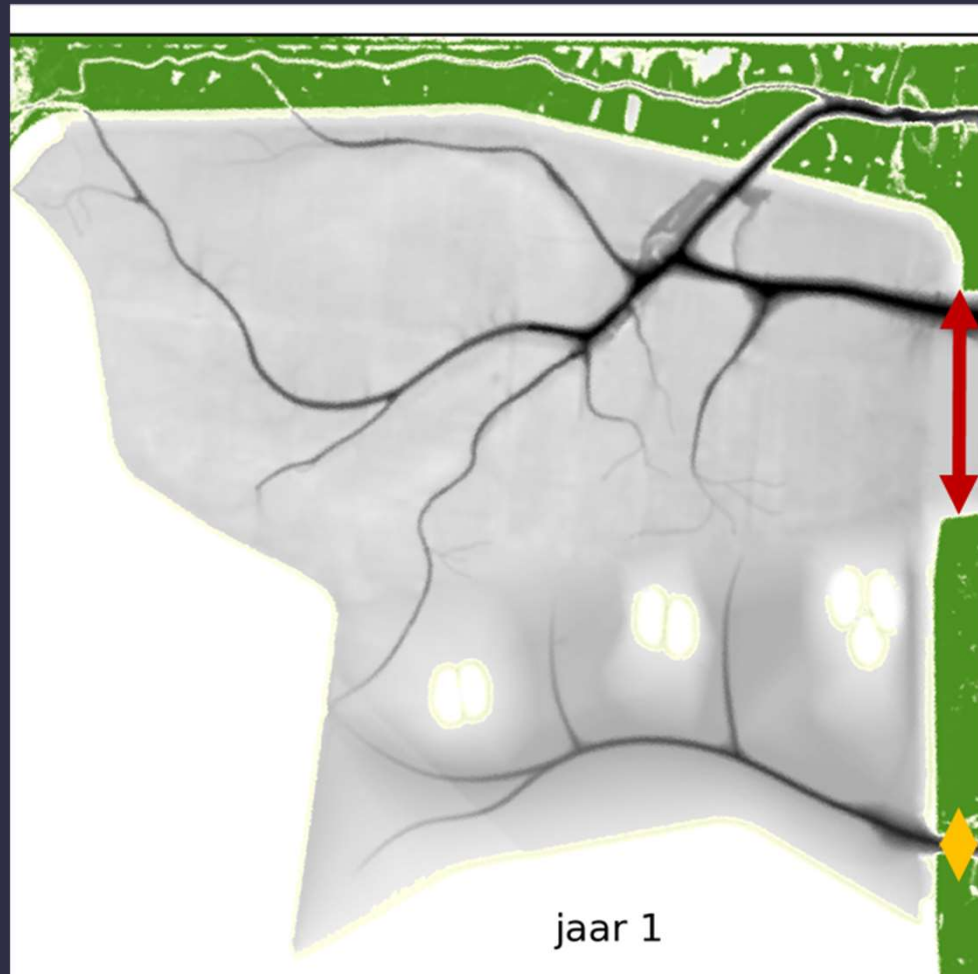
Rate of sedimentation & vegetation development:
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Hedwige-
polder
**Wide
dike
breach
(600 m)**



2) Predicting long-term, landscape-scale marsh dynamics?

Rate of sedimentation & vegetation development:
can be steered by dike breach design



Hedwige-polder

Wide dike breach (600 m)

Slower sedimentation

Prosper-polder

Small dike breach (50 m)

Faster sedimentation

2) Predicting long-term, landscape-scale marsh dynamics?

Summarizing...

- HPP does not develop into 'mud box' or 'boring reed marsh'
 - Instead slow development, diversity of habitat types

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- Uncertainties due to stochasticity, sea level rise, sediment supply, biotic top-down controls,...

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 - Instead slow development, diversity of habitat types
- Uncertainties due to stochasticity, sea level rise, sediment supply, biotic top-down controls,...
- Estimation of ecosystem service delivery: multi-benefits
- Rate of land rise & vegetation development can be steered by landscape design (breach dimensions, channels...)