# Can natural processes be used to strengthen coastal defence?

Han van Dobben
Pieter Slim

ALTERRA
WAGENINGEN UR

# Sea-level rise

- Sea-level rise since the end of the last ice-age (21 000 y BP): 120 m
  - = 6 mm/y
- Rapid rise after termination of ice-age, slow for the past 2000 years
  - 1.7 mm/y based on gauge measurements (since ~1850)
  - 3 mm/y based on satellite measurements (since 1995)
- Increase expected (but not yet observed!) due to climate change
  - rate ??

# Dune formation

- Dunes are a natural coastal defence
- Dunes are only formed in periods of transgression
- Incidental breaking of dune ridges causes sedimentation in hinterland!
  - and thereby closure of dune ridge
- Formation of dune-valley or salt-marsh behind dune ridges
  - high biological diversity

ALTERRA
WAGENINGEN UR

# Active coastal defence

- Since ~1200
  - Construction of dykes
  - Closing of gaps in dune ridges
- Results:
  - sedimentation => 0
  - soil subsidence starts
    - due to compaction of clay, oxidation of peat, and mining
- Consequence:
  - erosion / sedimentation cycle is disrupted
  - stronger defence needed!
  - loss of biological diversity

ALTERRA
WAGENINGEN UR

ALTERRA
WAGENINGEN UR

ALTERRA
WAGENINGEN UR

# Can this go on for ever?

- Increase of population density and economic investments => higher safety standards
- Expected increase of rate of sea-level rise
- Increase of soil subsidence due to mining
- Peat oxidation continues
- Increase of river discharge dynamics
- Increasing pressure to preserve biodiversity

# Commissie Veerman

- Find new ways for coastal defence!
- Intrinsically safe dykes
- Create areas for temporal water storage
- Use natural processes
- etc…

ALTERRA
WAGENINGEN UR

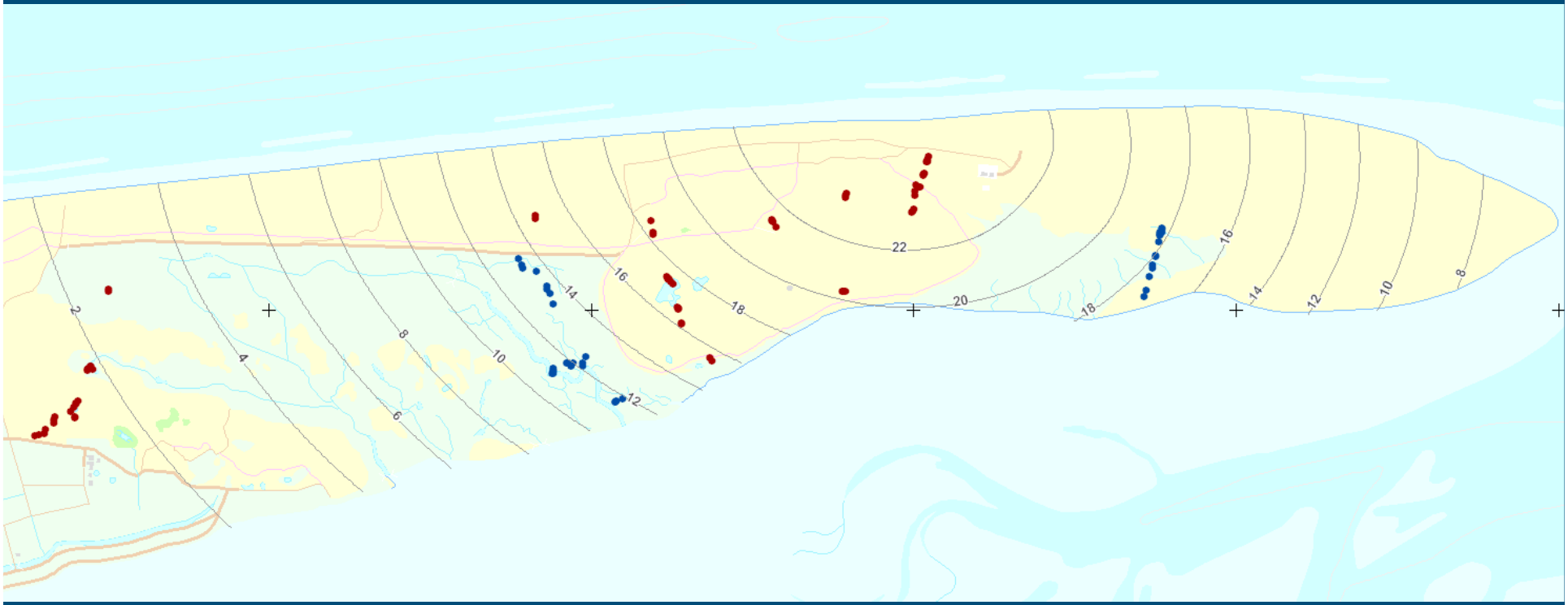
# Ameland: experimental test of natural processes

- Soil subsidence ca. 15 mm/y due to gas extraction
- No coastal defence
- Monitoring since start of extraction in 1986
  - sea level, precipitation, evaporation
  - erosion / sedimentation
  - soil properties
  - vegetation, birds

# Soil subsidence is simulated sea level rise!

- Present soil subsidence at Ameland: ~40 cm
- IPCC (2001): sea level rise ~44 cm in 2100
- Veerman (2008): sea level rise ~100 cm in 2100
- Main concerns at the start of the monitoring:
  - will natural areas be flooded, i.e. will their area decrease?
  - will there be a loss of biodiversity?

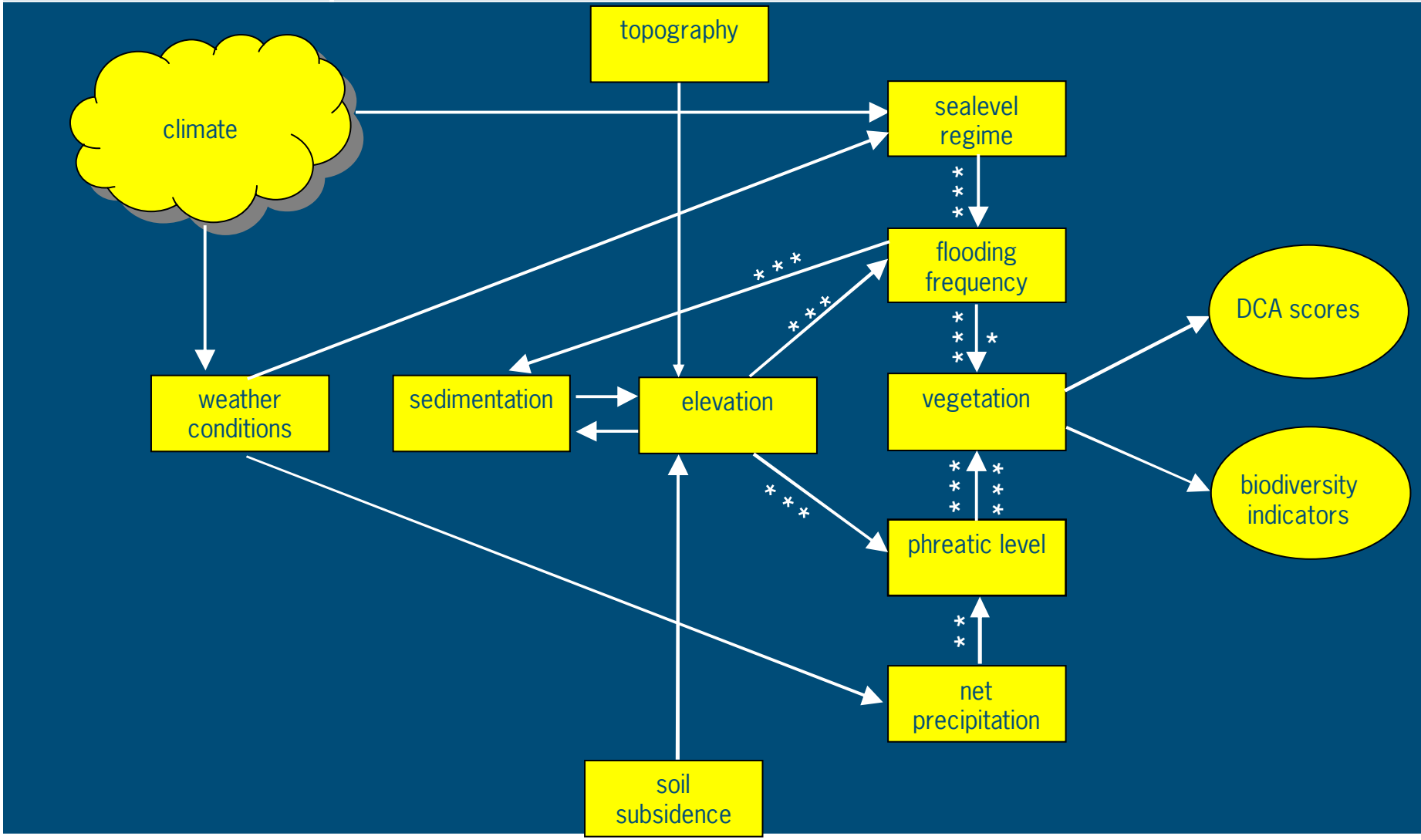
# Plots are arranged in transects




red = ‘dune’ , blue = ‘salt marsh’

ALTERRA
WAGENINGEN UR

# Our conceptual model...



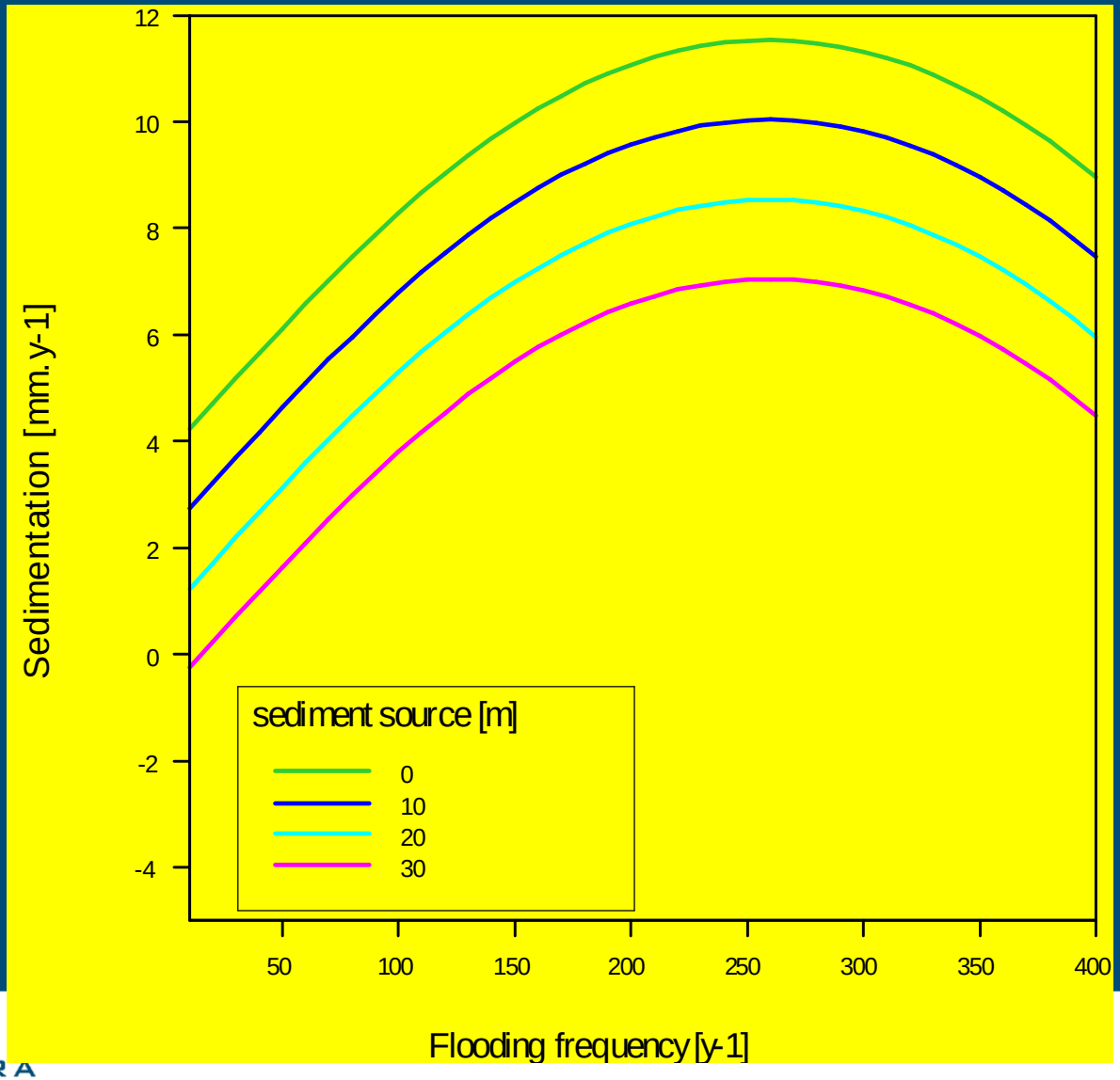
# Most important changes up to now

| zone | vegetation | soil |
|---|---|---|
| pioneer | little change | strong sedimentation, or cliff erosion |
| lower salt marsh | little change | sedimentation |
| upper salt marsh | succession, increase of Elymus athericus | some sedimentation |
| dune slack, incidentally flooded | increase of salt marsh species after flooding | very little sedimentation |
| wet dune slack (incl. freshwater pools) | increase of annuals in dry spring | no sedimentation (accumulation of organic matter may occur) |
| dry dunes | succession, eutrophication | sedimentation of wind-blown sand may occur |

# Extrapolation: what will happen if sea level rises?

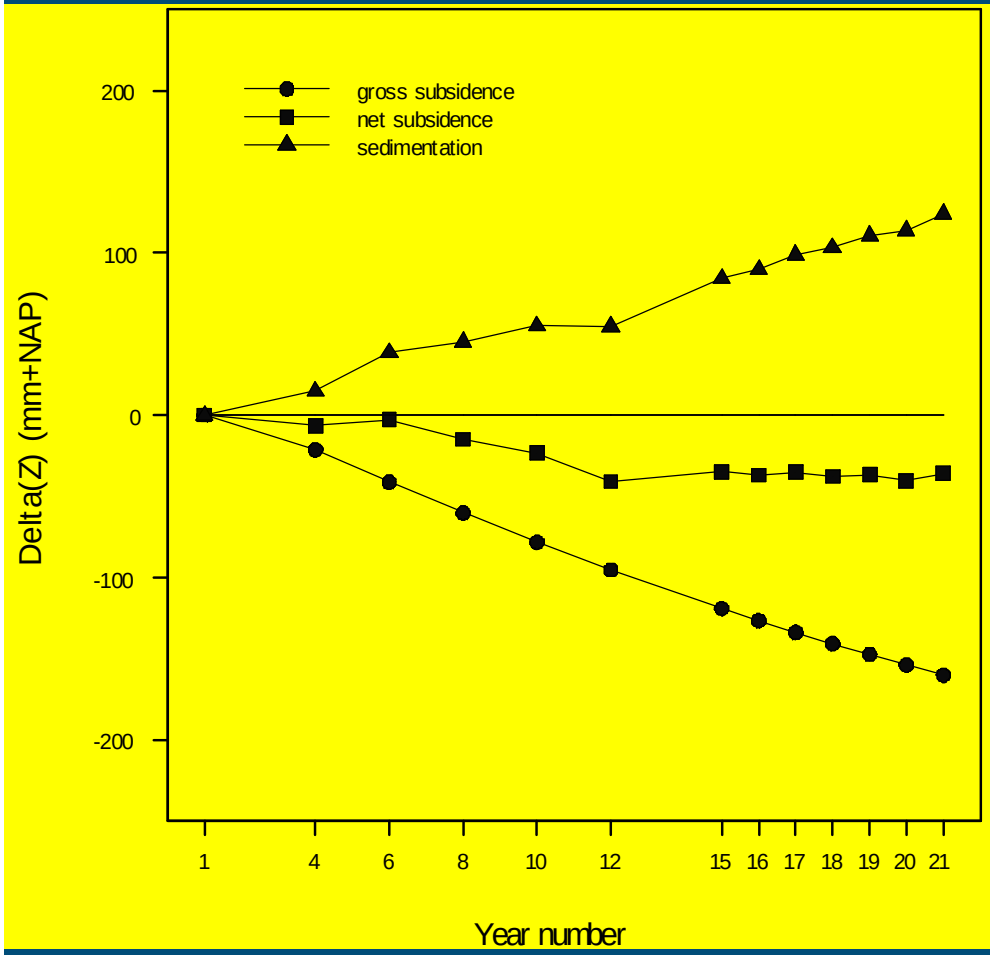
| zone | with climate change… |
|---|---|
| pioneer zone | cliff erosion may increase |
| lower salt marsh | sedimentation increases, little change in vegetation |
| upper salt marsh | sedimentation increases, little change in vegetation |
| dune slack, incidentally flooded | vegatation changes into salt marsh |
| wet dune slack (incl. freshwater pools) | waterlevel increases, 'drowning' of shrub vegetation may occur |
| dry dunes | no change |

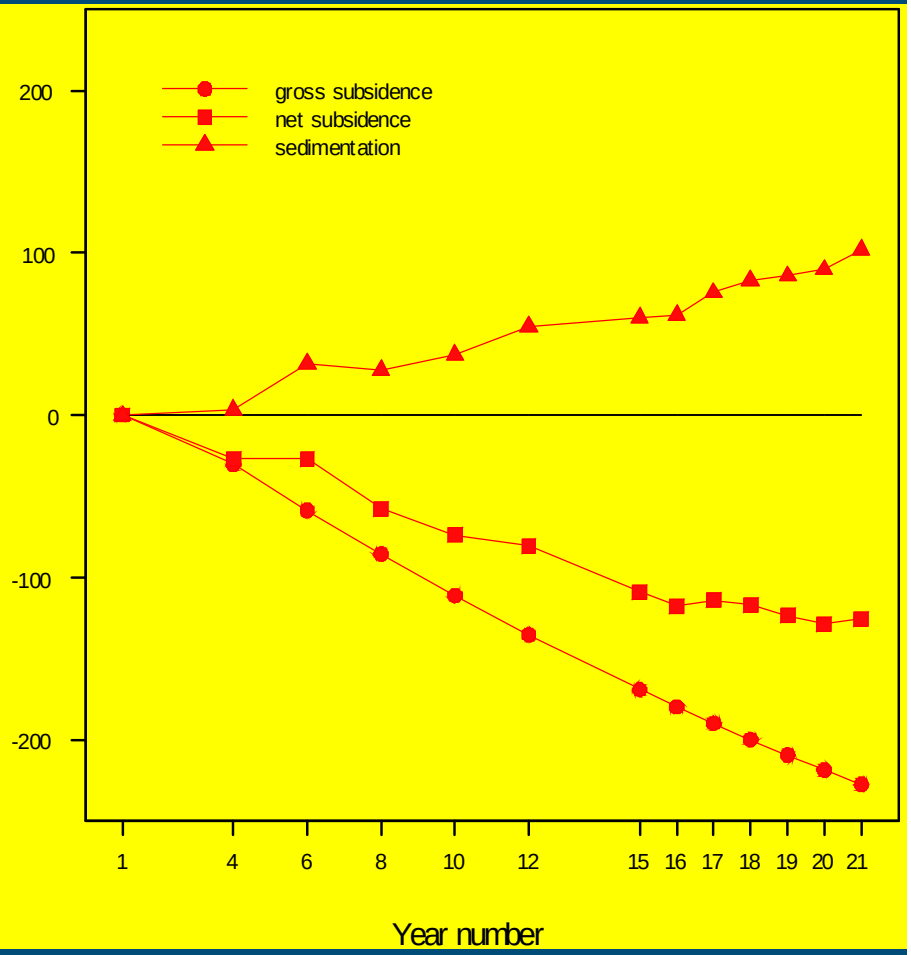
# Relation between flooding and sedimentation




ALTERRA
WAGENINGEN UR

# Subsidence is compensated by sedimentation




ALTERRA
WAGENINGEN UR

# Conclusions: sedimentation

- Total sedimentation over whole observation period:
  - Nieuwlandsreid 6.2 $\pm$ 9.0 mm.y$^{-1}$ (95% conf. interval)
  - Hon 5.1 $\pm$ 6.6 mm.y$^{-1}$ (95% conf. interval)
- Expected sea-level rise until 2100:
  - IPCC 4.4 $\pm$ 3.3 mm.y$^{-1}$ (range)
  - Veerman 8.8 $\pm$ 3.2 mm.y$^{-1}$ (range, excl. soil subsidence)

# Conclusions: sea-level rise

- In pioneer zone and lower salt marsh sea-level rise will be largely compensated by sedimentation
- Present sedimentation rate is large enough to keep pace with sea-level rise according to IPCC, but not according to Veerman
- However, sedimentation increases as flooding frequency increases
- Strongest effect of sea level rise expected in wet dune slack, where sedimentation is low

# Conclusions: vegetation

- Flooding-related vegetation gradient in salt marsh ('zonation') is extremely stable over time
  - this may partly explain the increase of sedimentation at higher flooding frequency
- But in dune slack, vegetation shifts along gradient as conditions change
  - with sea-level rise, this may lead to permanent changes
- Both in salt marsh, dune slack and dry dune, succession towards more eutrophic vegetation is the most prominent temporal trend

# Conclusions: biodiversity

- Loss of species number, and conservancy value is mainly related to succession (both in salt marsh and dune slack)
- Succession is an autonomous process that occurs in stable situations, but is accelerated by:
  - nitrogen deposition
  - lower cattle intensity
  - collapse of rabbit population
- Sea-level rise is expected to increase dynamics and thereby retard succession

# Conclusions: coastal defence

- Salt marsh and dunes are forms of natural coastal defence
- They have the ability to keep pace with a moderate rate of sea-level rise
- Therefore, the erosion / sedimentation cycle should not be disrupted
- Salt-marsh formation may be stimulated by accretion enhancement (kwelderwerken, rijshoutdammen)
- Dune formation may be stimulated by beach nourishment (suppletie)




ALTERRA
WAGENINGEN UR




ALTERRA
WAGENINGEN UR

ALTERRA
WAGENINGEN UR

ALTERRA
WAGENINGEN UR

# Monitoring will continue!



ALTERRA
WAGENINGEN UR