Wetland ecosystem services in agricultural landscapes: opportunities and risks

Jos T.A. Verhoeven

Universiteit Utrecht

[Faculty of Science
Biology]

Contents

- Introduction: wetland ecosystem services
- N retention and C storage:
  effect of loading?
- CO_2, CH_4 and N_2O: what is the GHG balance?
- Considerations for land use management and wetland restoration

Wetland ecosystem services

- Flood detention and water storage
- Nutrients and contaminant retention: better water quality
- Carbon fixation and storage
- Enhancement of offshore fisheries
- Feeding grounds for river fish
- Cultural heritage and ecotourism
- Biodiversity and gene pool

Wetlands in agricultural landscapes

- Wetlands are often present in depressions or riparian zones
- In many cases, the landscape as a whole contained large areas of wetland (i.e. floodplain, fen peatland)
- Drainage, fertilization and lifestock grazing affect wetlands hydrology and nutrient richness
- Wetlands often perform nutrient retention and carbon sequestration.

Wetland ecosystem services: this talk

- Flood detention and water storage
- Nutrients and contaminant retention: better water quality
- Carbon fixation and storage
- Enhancement of offshore fisheries
- Feeding grounds for river fish
- Cultural heritage and ecotourism
- Biodiversity and gene pool

N retention and C storage: positive or negative feedbacks?

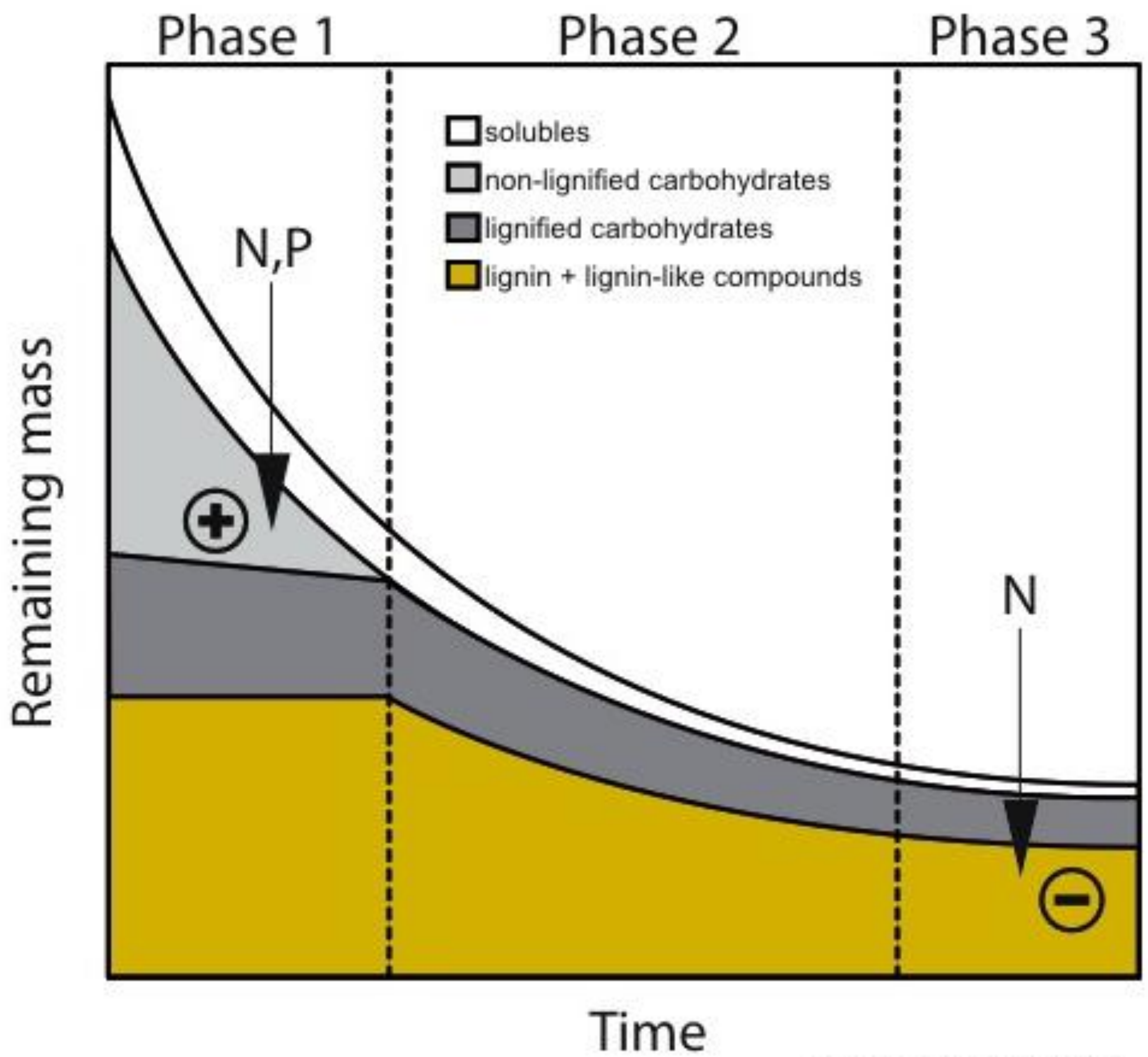
- Wetlands often accumulate organic matter
- This implies N as well as C retention
- Does higher N loading lead to
    - Higher production?
    - Faster N mineralization?
- Is CO_2 storage counterbalanced by CH_4 emission?
- Is N_2O emission enhanced by N loading?

N enrichment effects on wetlands

- Plant growth in many wetlands is either N- or P-limited
- Many ecosystems worldwide are being enriched with N
- This results in increase of plant production in N-limited wetlands
- Effect on decomposition?
- Decisive for carbon sequestration function

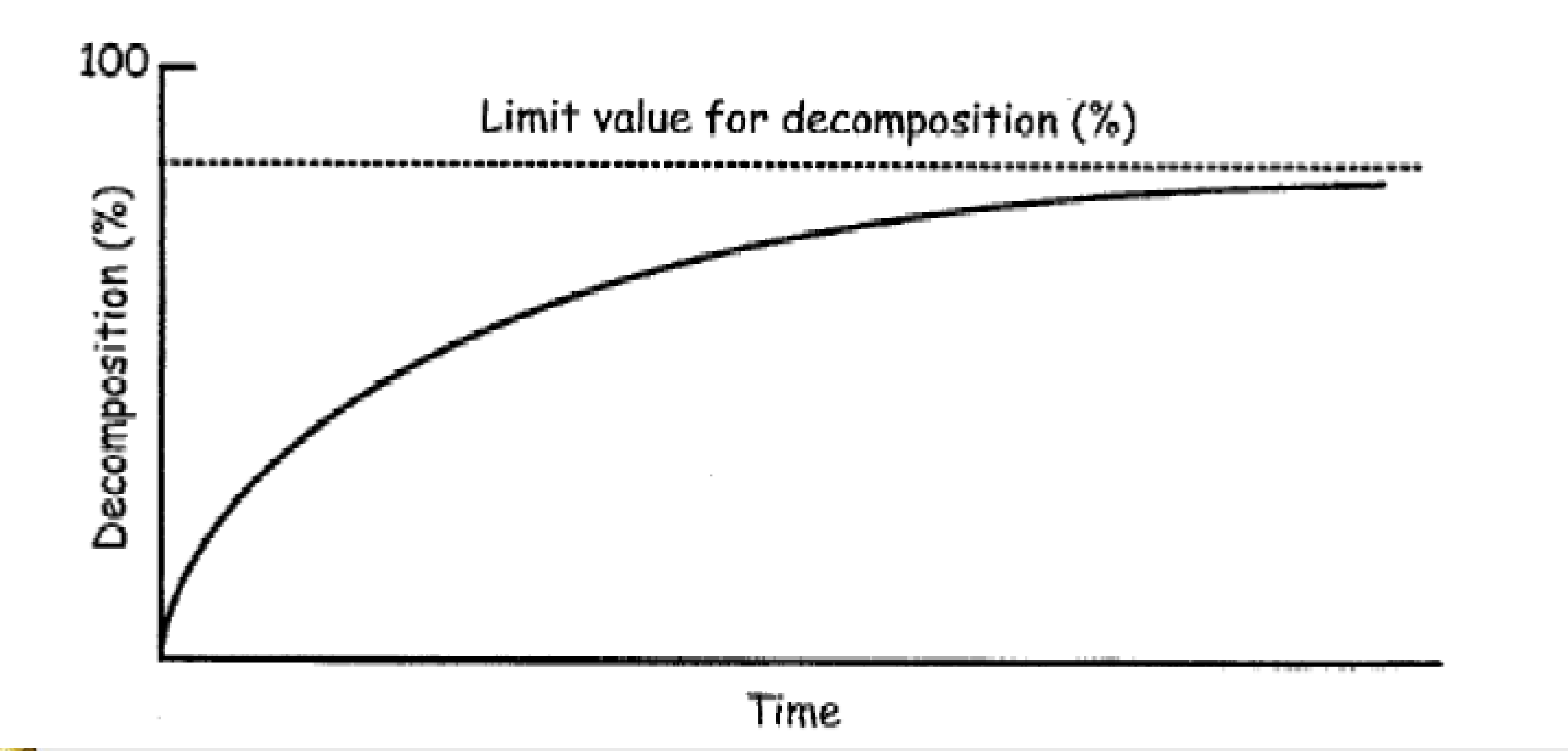
N addition effects on carbon balance in fens and mangroves

- Higher plant and litter production
- Effects of N addition on decomposition (Berg et al.):
  - Stimulating effect for easily degradable fraction of litter
  - Inhibiting effect on recalcitrant compounds (lignin, wax compounds)
- Overall effect may be higher or lower carbon sequestration



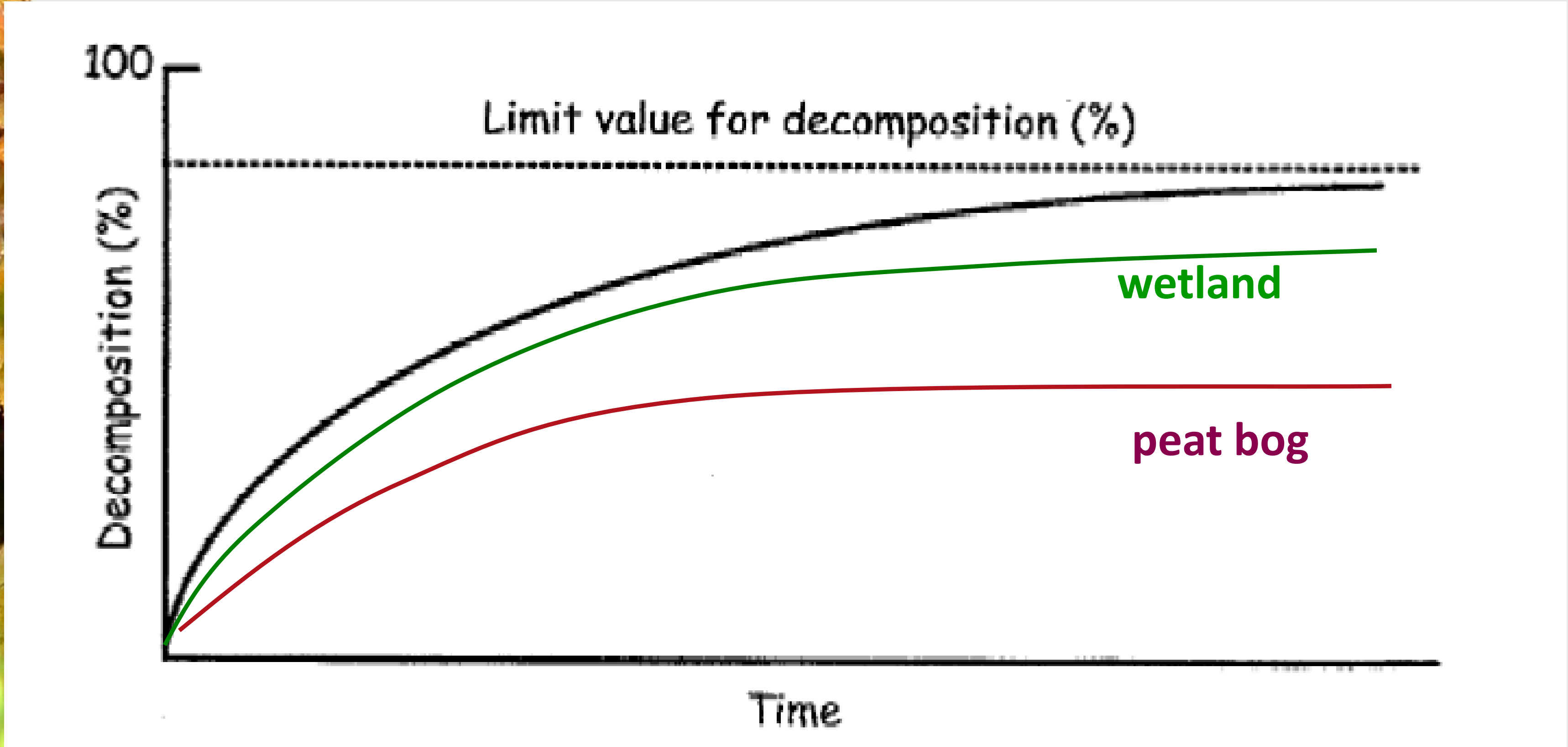
Berg & Laskowski 2006

Bjorn Berg's work on leaf litter decomposition: Limit value



Berg & Meentemeyer

Wetlands have low limit values; role of N?



Recent studies on N enrichment effects on decomposition

- Mesocosm study in grasslands (Manning et al. 2008) ↑
- Long-term N addition experiments:
  - North American forests (Pregitzer et al. 2008) ↓
  - North Canadian tundra (Mack et al. 2004) ↑
- Meta-analysis of studies in agricultural systems ↓ (Lu et al. 2011)
- Studies in wetlands (UU):
  - Leaf litter of fen plants (Van de Riet et al. 2012) ↓
  - Litter and SOM in naturally heated systems (Hefting et al.) ↓
  - SOM in mangroves (Keuskamp et al. 2012)

Carbon storage and N retention

- Carbon storage in wetlands will be enhanced by N addition due to:
  - Higher NPP
  - Inhibition of recalcitrant litter decomposition (mostly in oxic parts of the wetland)
- In agricultural landscapes, wetlands loaded with nitrate will perform a higher carbon storage service

Greenhouse Gas balance

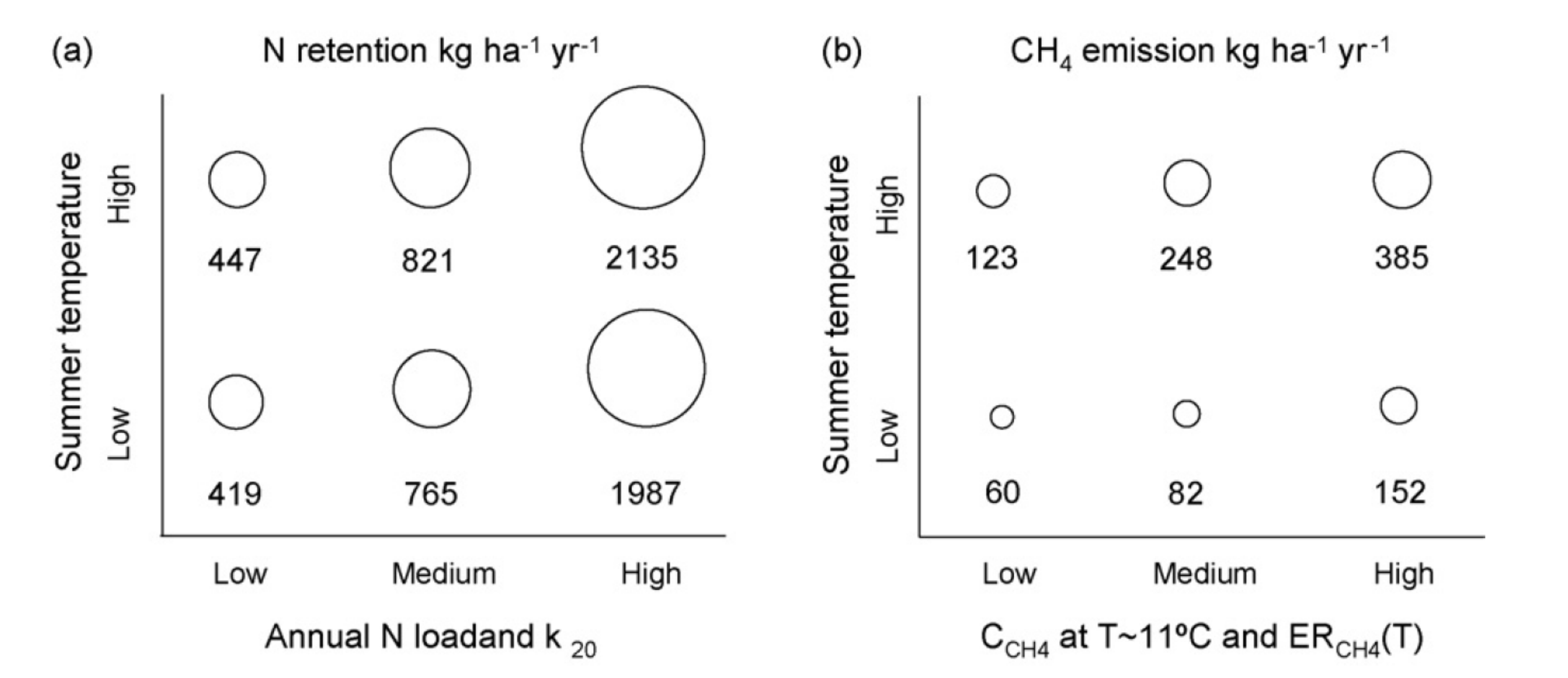
- Intact wetlands trap CO_2
- Intact wetlands produce CH_4 and N_2O
- Global Warming Potential (GWP):
  - CO_2 : 1
  - CH_4 : 72
  - N_2O : 289
- Restoring/ creating wetlands affects GHG balance

Methane emission in constructed wetlands

- Methane Global Warming Potential is 72
- Study in Swedish created wetlands
- Replicated fully instrumented wetlands were used for measuring year-round fluxes of N and CH_4
- Modelling predicted the two processes on the basis of (1) temperature; (2) loading rate
- N retention and methane emission for 3 'reference levels' (high, intermediate, low)

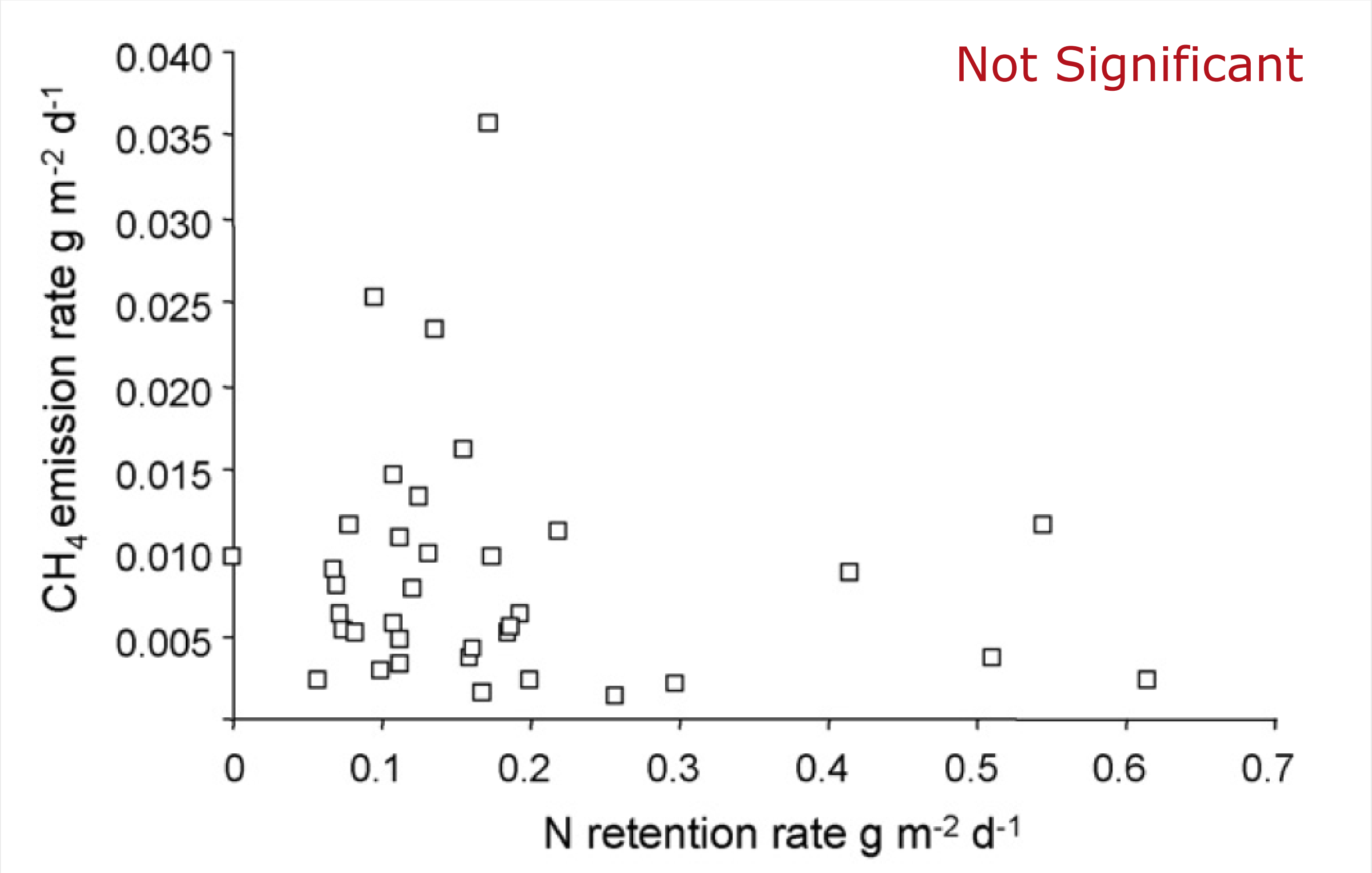
Thiere et al. 2009

Modelled potential N retention and CH_4 emission in Swedish wetlands



Thiere et al. 2009

CH_4 emission vs. N retention in Swedish wetlands

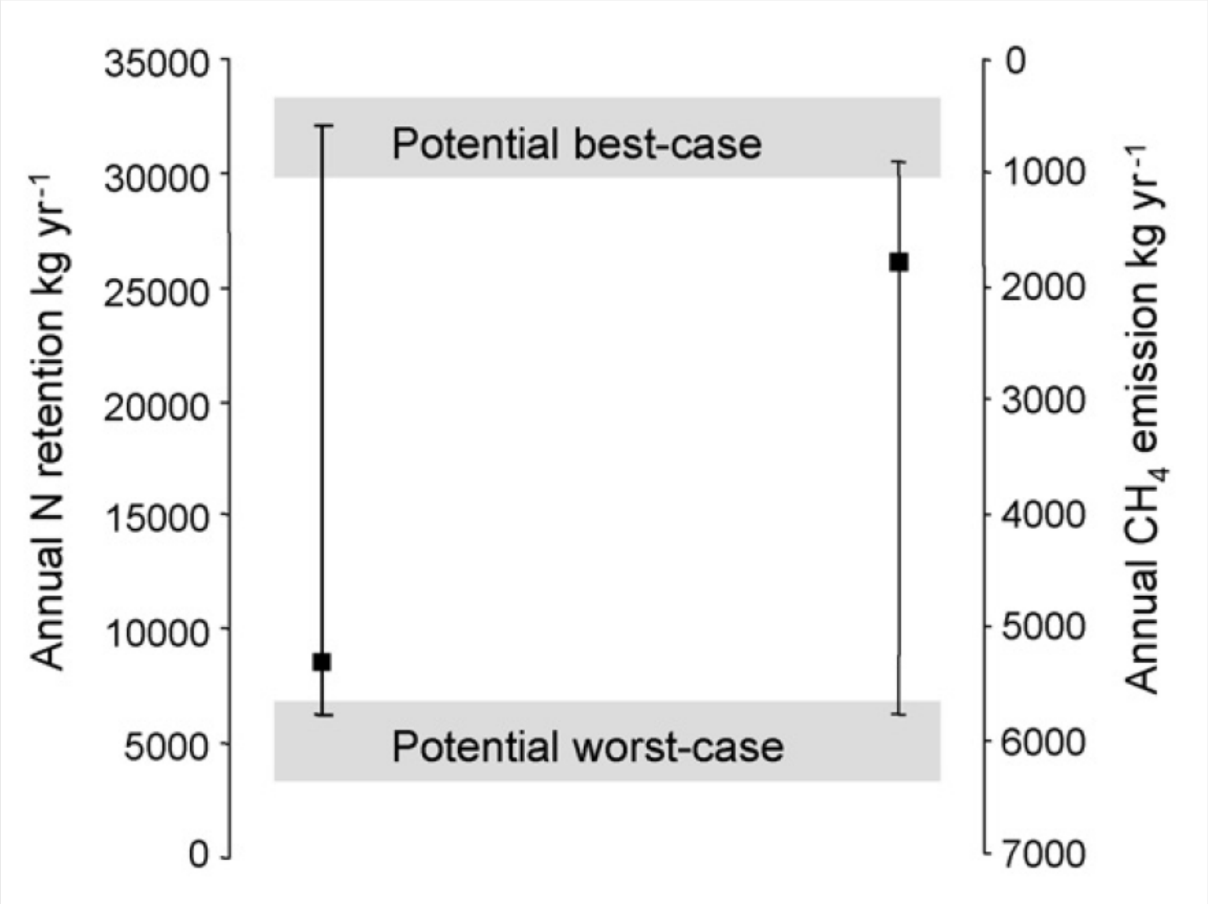


Universiteit Utrecht

Thiere et al. 2009

[Faculty of Science
Biology]

CH_4 emission vs. N retention in Swedish wetlands



36 sites

Total area
15 ha

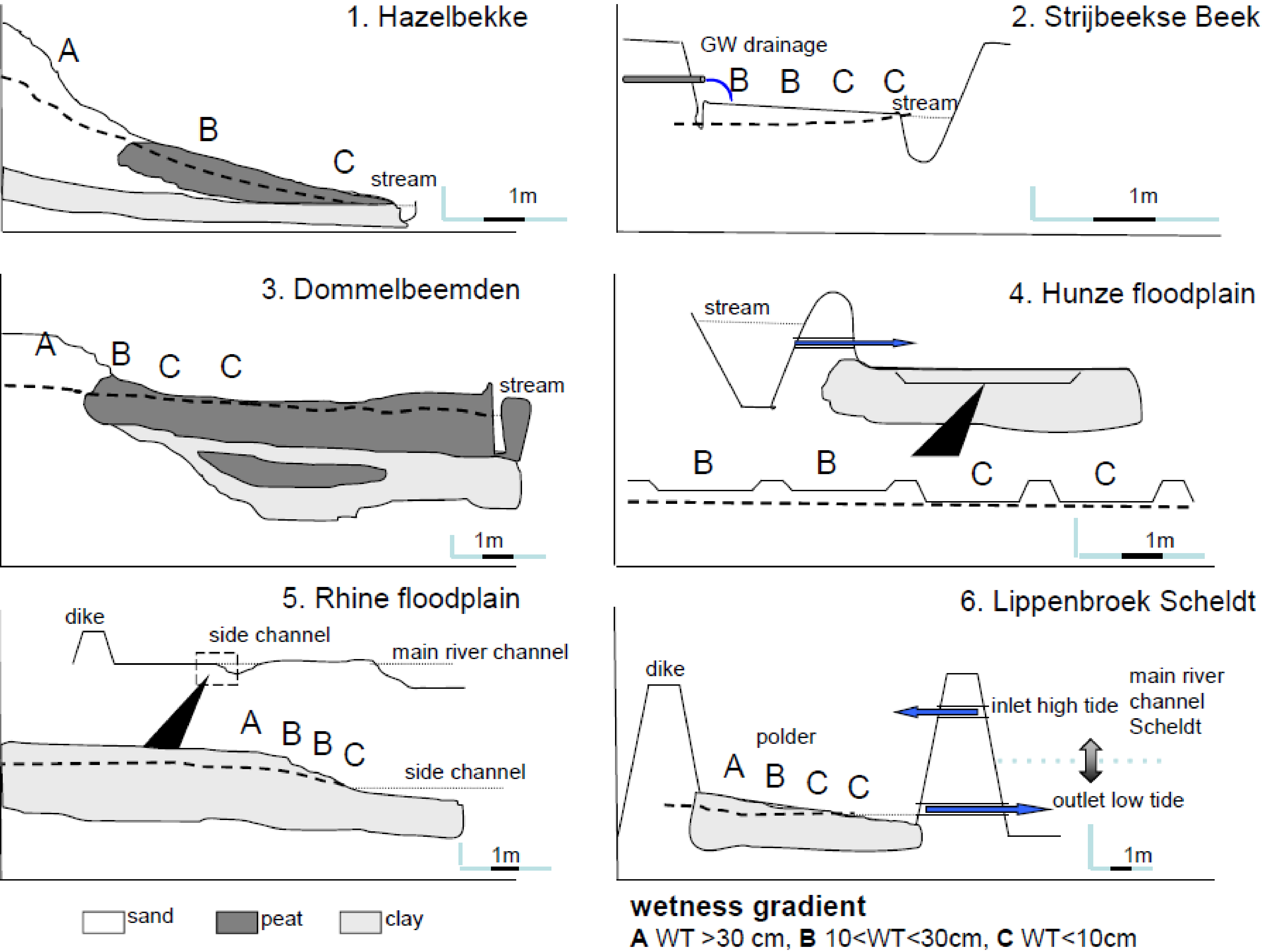
Thiere et al. 2009

Methane emission and N retention: some clues

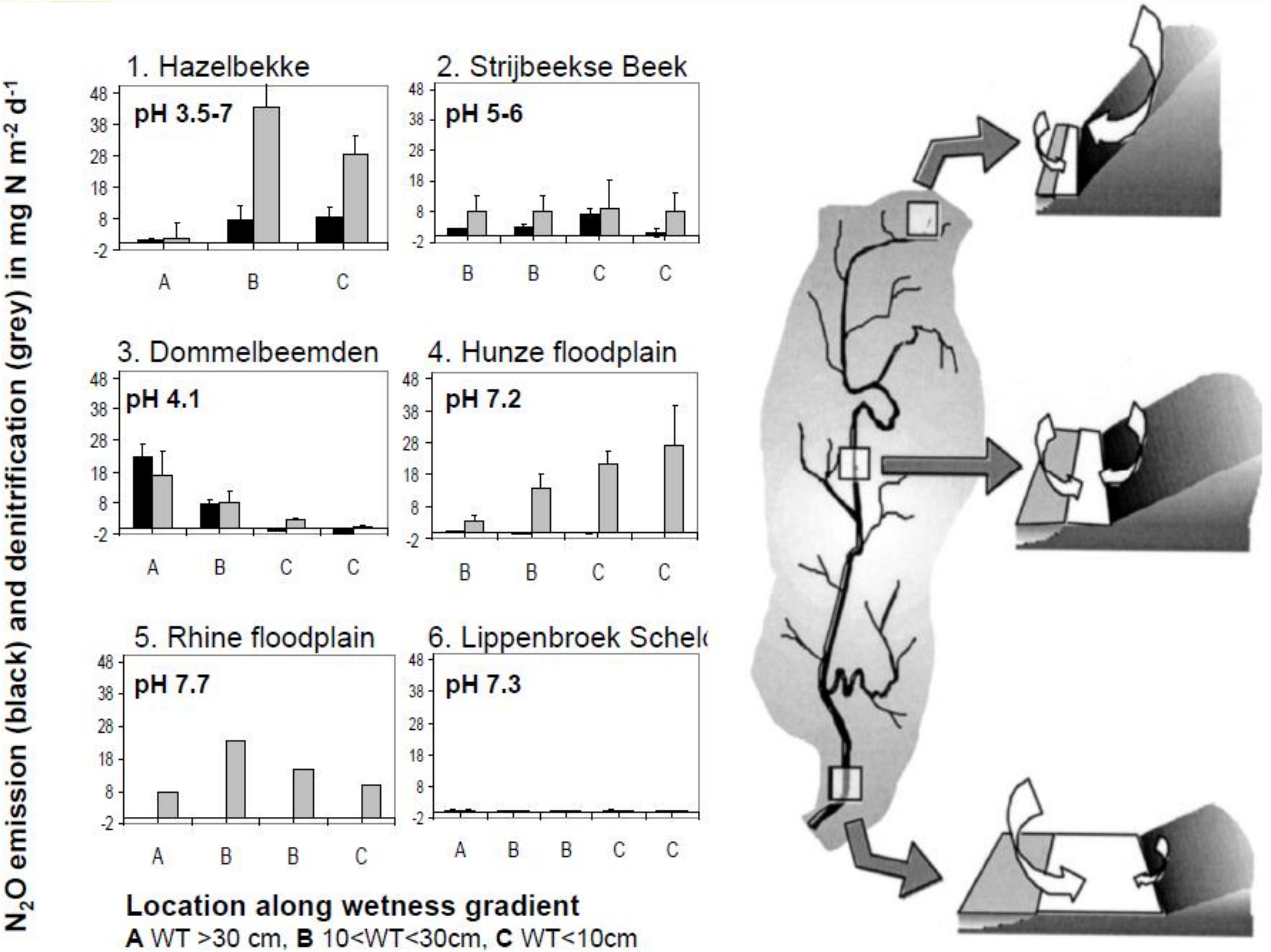
- N retention of the constructed wetlands is good but below maximum potential
- Methane emissions were mostly low. The two processes were not related
- Total planned wetland area will perform 27% of targeted N retention, and produce <0.04% GHG emissions in Sweden

Nitrous oxide emission and N retention

- Nitrous oxide is formed as intermediate compound in denitrification
- Global Warming Potential is 289
- Emissions are enhanced in conditions of high nitrate loading
- Study by Hefting et al. (2012) in Rhine/Scheldt catchment



1. Hazelbekke
A
B
C
stream
1m
2. Strijbeekse Beek
GW drainage
B B C C
stream
1m
3. Dommelbeemden
A B C C
stream
1m
4. Hunze floodplain
stream
B B C C
1m
5. Rhine floodplain
dike
side channel
main river channel
A B B C
side channel
1m
6. Lippenbroek Scheldt
dike
main river channel Scheldt
inlet high tide
polder
A B C C
outlet low tide
1m
sand
peat
clay
wetness gradient
A WT >30 cm, B 10<WT<30cm, C WT<10cm



N2O emission (black) and denitrification (grey) in mg N m-2 d-1
1. Hazelbekke
pH 3.5-7
2. Strijbeekse Beek
pH 5-6
3. Dommelbeemden
pH 4.1
4. Hunze floodplain
pH 7.2
5. Rhine floodplain
pH 7.7
6. Lippenbroek Schel
pH 7.3
Location along wetness gradient
A WT >30 cm, B 10<WT<30cm, C WT<10cm

Nitrous oxide emission risk: some clues

- Nitrous oxide emissions are locally enhanced in nitrate-loaded riparian wetlands
- Emissions tend to be peaking in specific conditions (e.g. low soil pH, low redox conditions) which may show spatial patterns in the catchment
- Low-order sandy streams in the Rhine catchment showed low pH and high emissions

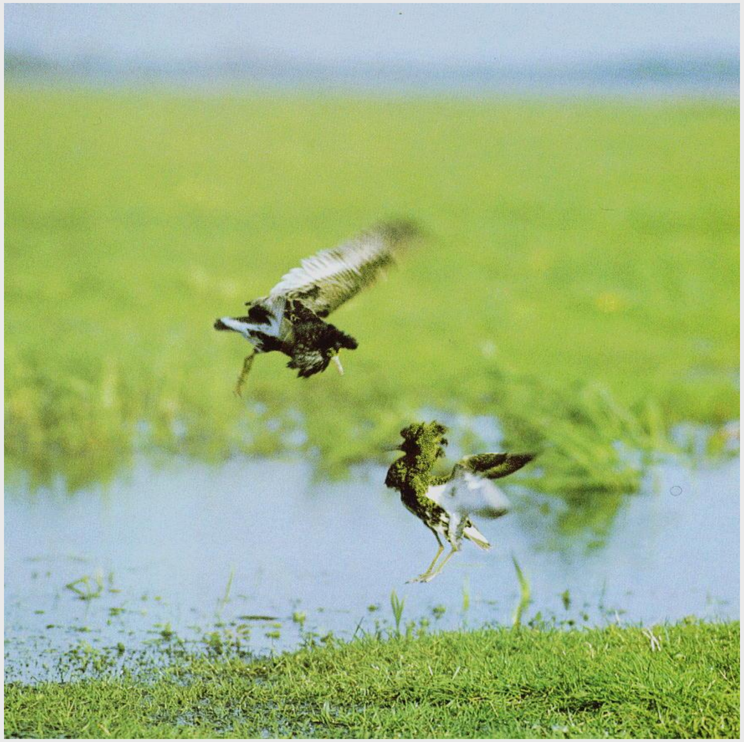
Adding it all up:
peat meadows in The Netherlands

- Peat meadows in drained peatlands have been in agricultural use for centuries
- Peat oxidation has created long-term soil subsidence
- Intensive land use with deep drainage and heavy fertilizer use threatens environmental health
- Biodiversity of seminatural reserves is declining
- Water quality has deteriorated
- Comparison of GHG balance in three polders (area 100-500 ha) by Schier et al. (2010)

Aerial view of peat meadows

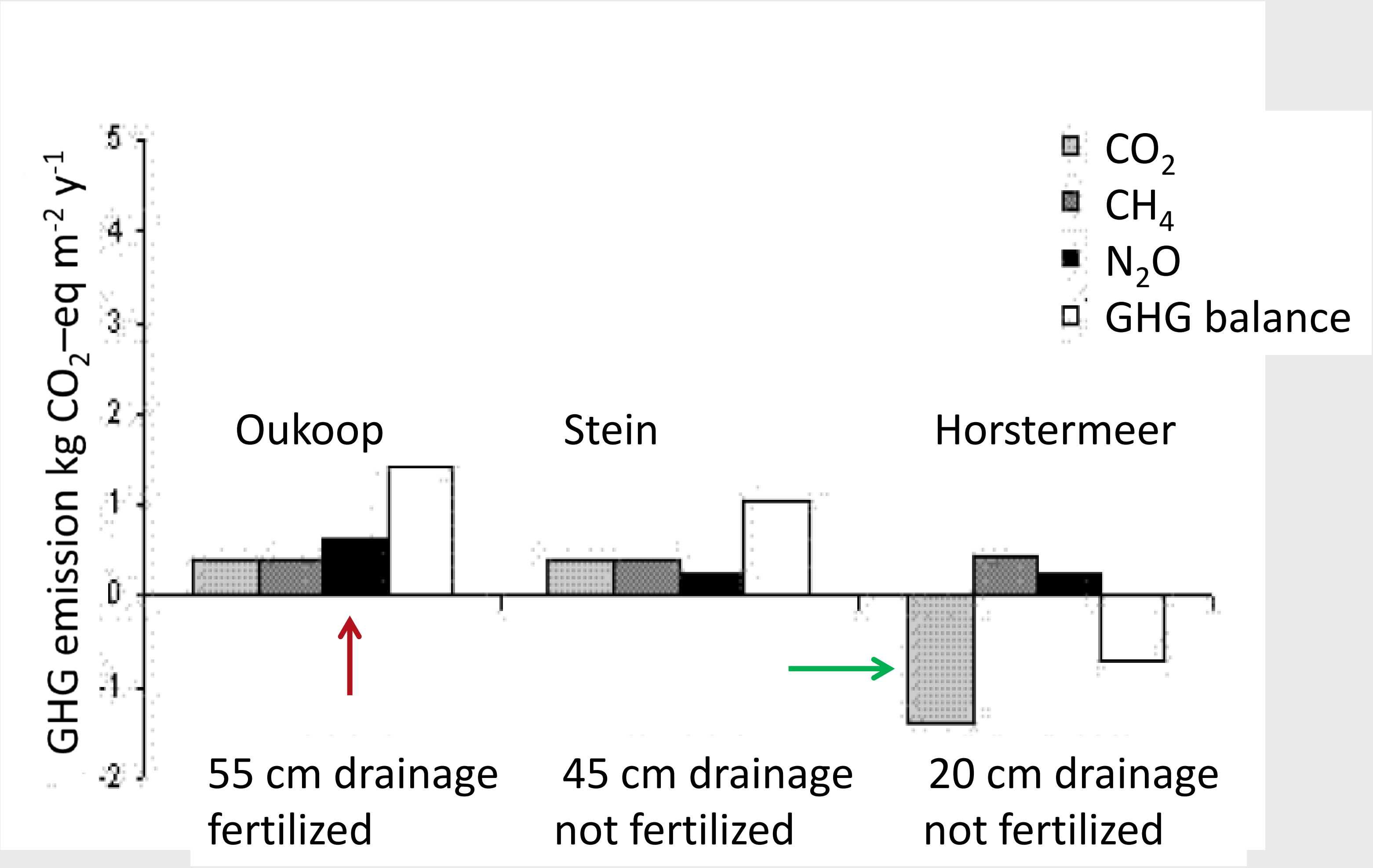
Rich bird life in these wet meadows

Black-tailed godwit



Ruff

GHG balances of peat meadow polders



Schier-Uyl 2010

Nutrient retention, carbon sequestration and GHG balance

- Nutrient loading is expected to not interfere with carbon sequestration (perhaps even positive effect)
- Creation or restoration of wetlands does not have negative effects on the GHG balance:
  - Methane emission may increase after wetland creation, but the nutrient retention effect still outweighs this disservice
  - Overall GHG balance of rewetted peat meadows is strongly positive, regardless of fertilizer use.

Thank you