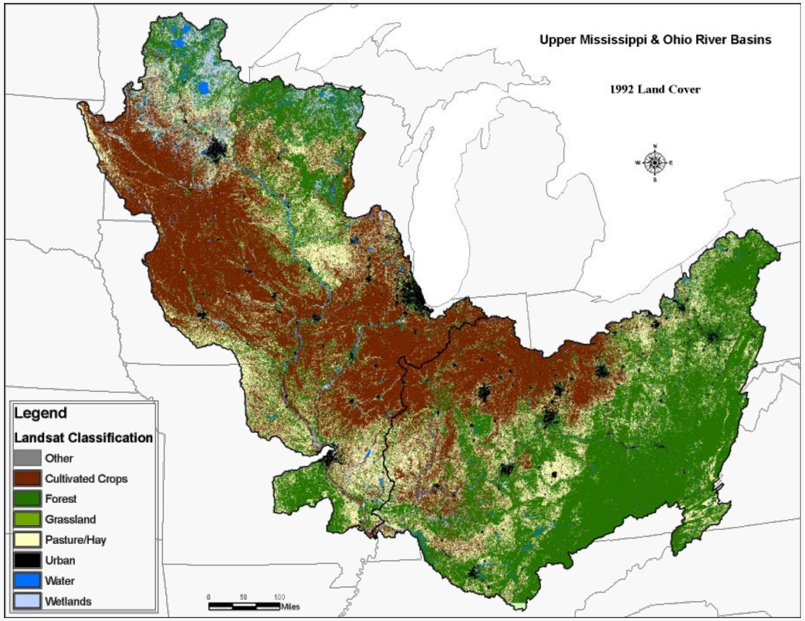
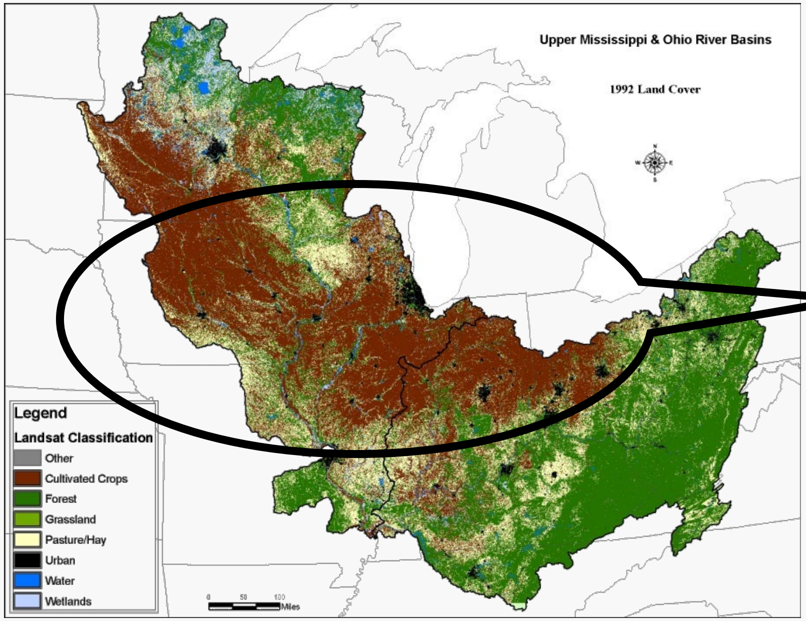
N_2O Production and Emission in Wetlands Receiving Elevated, Agricultural Nitrate Loads

W. Crumpton, G. Stenback, D. Green, and J. Norton. Iowa State University

Professor William G. Crumpton
Department of Ecology, Evolution, and Organismal Biology
Iowa State University, Ames, Iowa USA

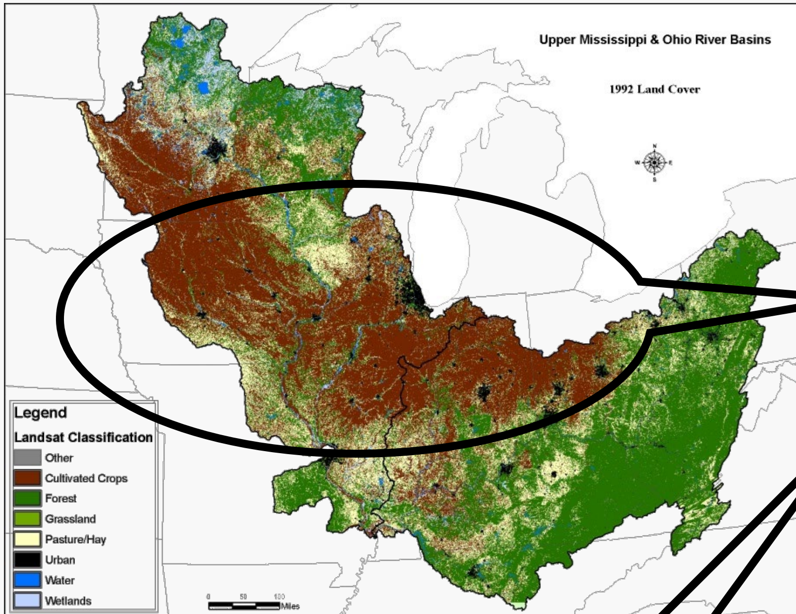


Upper Mississippi Basin is characterized by:



Upper Mississippi Basin is characterized by:

- extensive cultivated cropland



Upper Mississippi Basin is characterized by:

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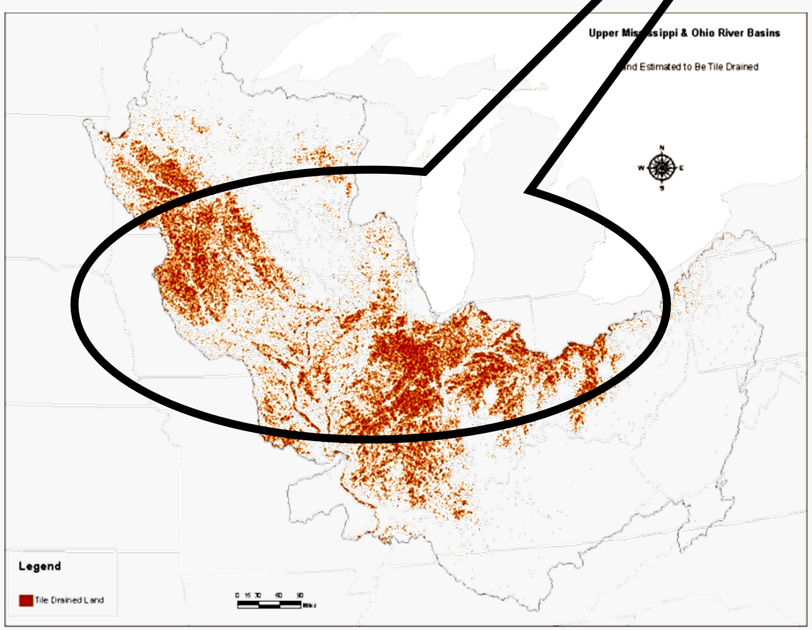
- extensive agricultural drainage



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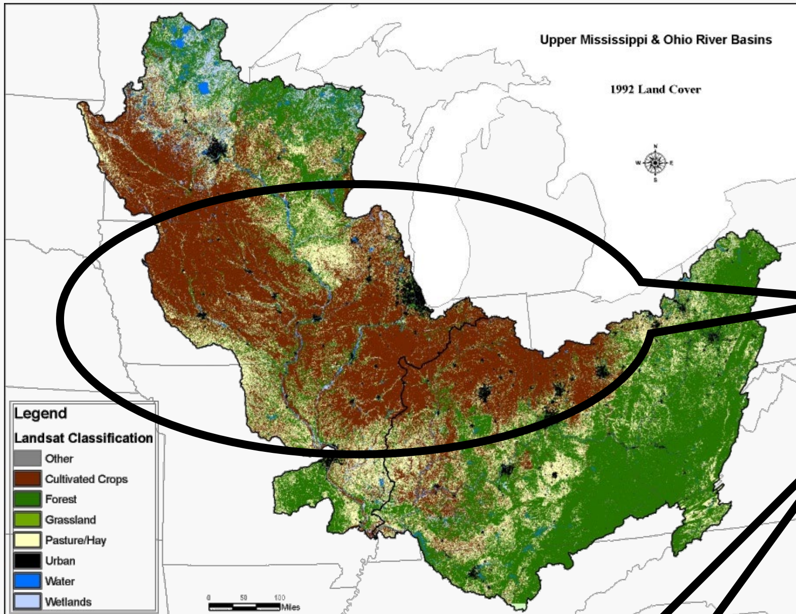
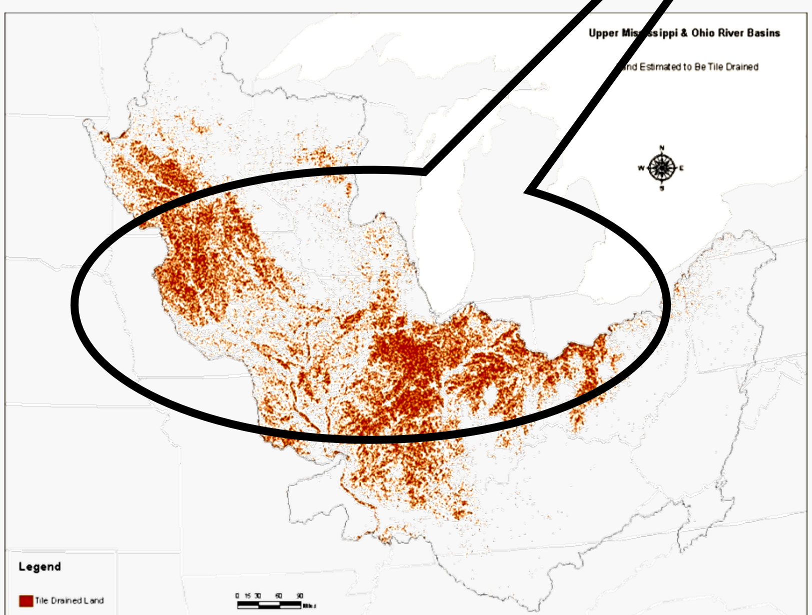
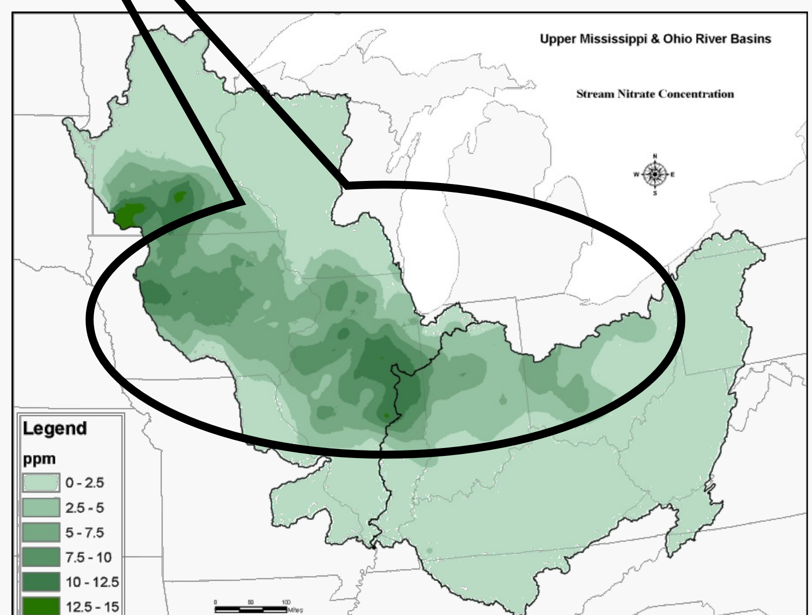
Upper Mississippi Basin is characterized by:

- extensive cultivated cropland
- extensive agricultural drainage
- elevated nitrate concentrations in surface waters







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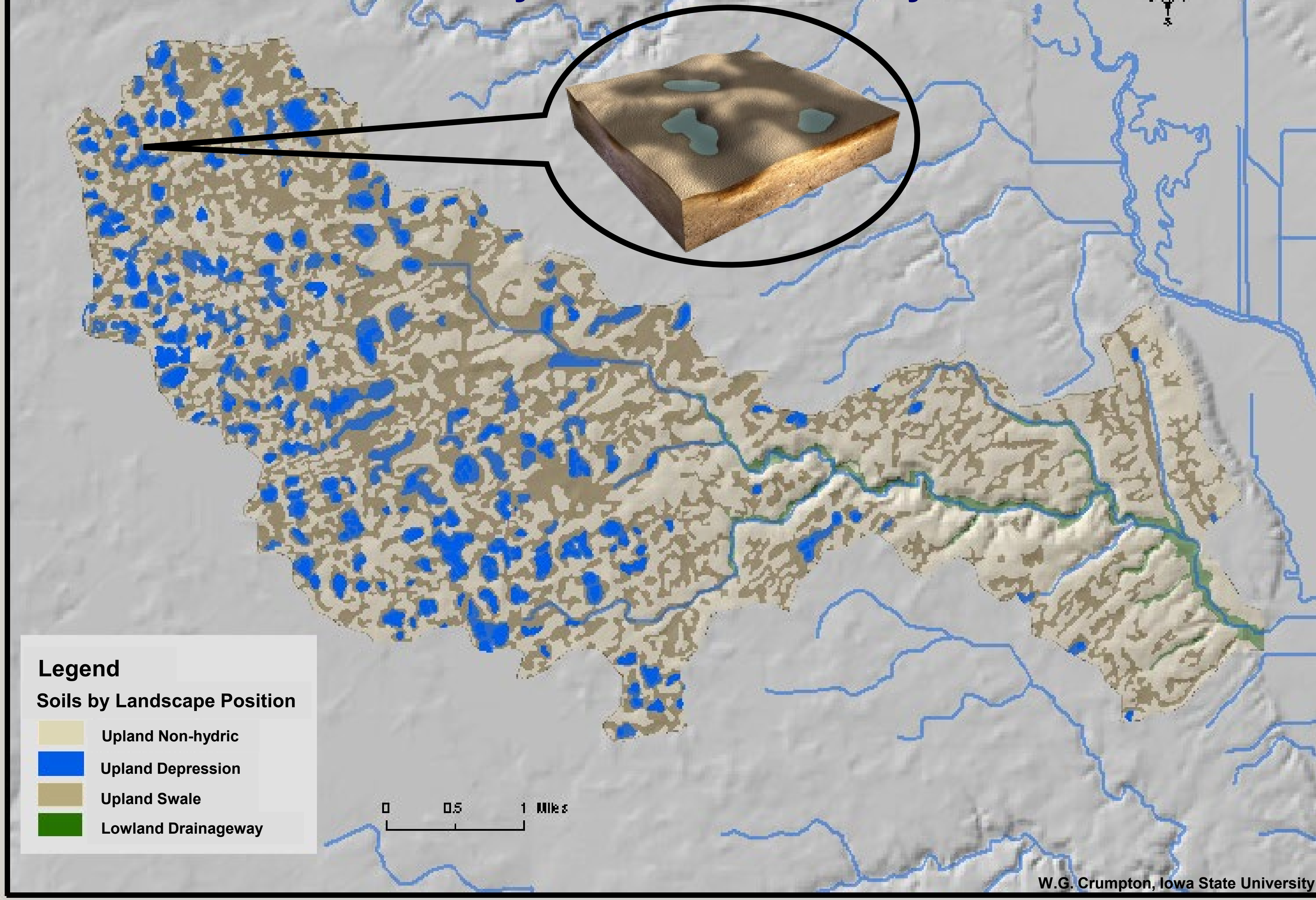
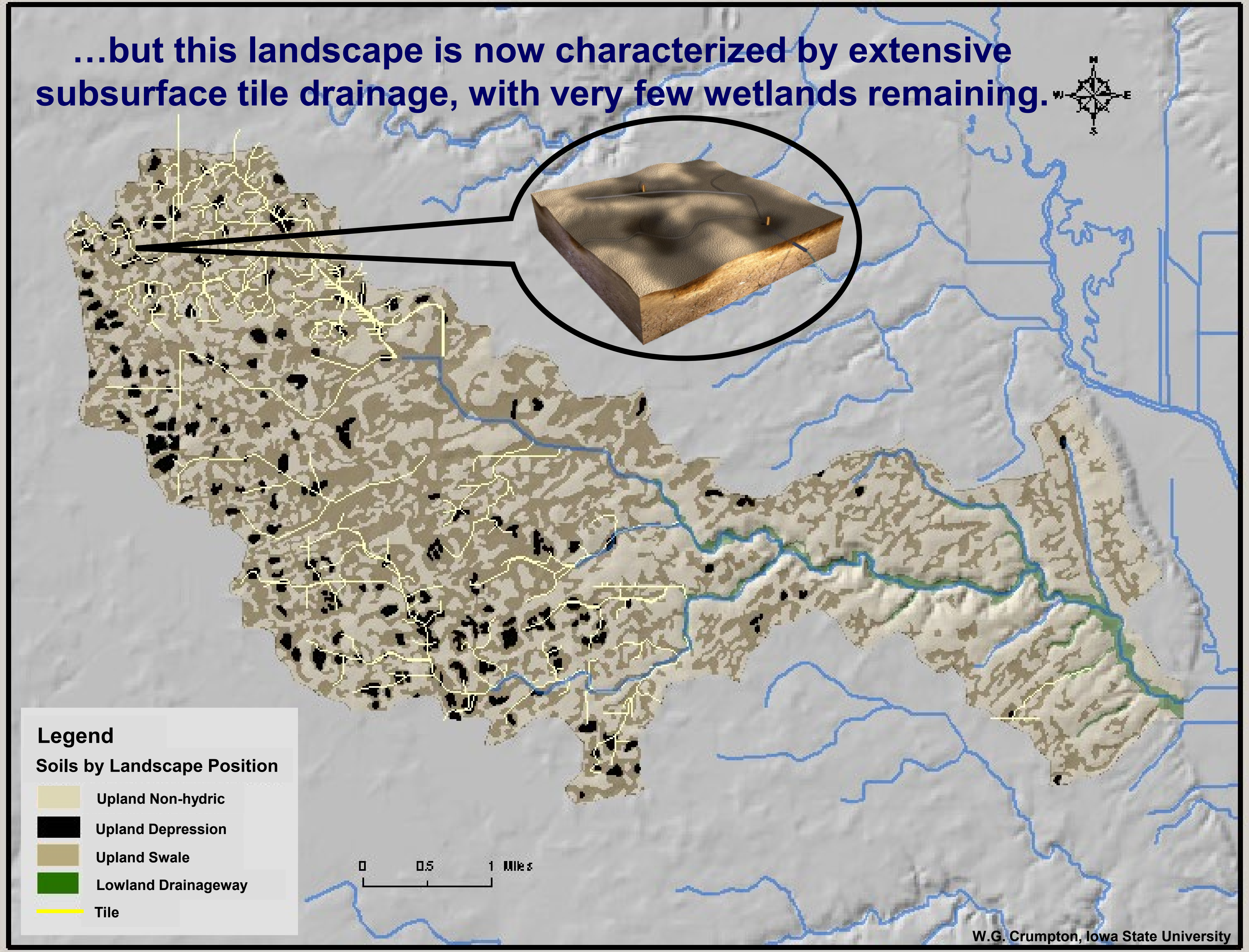
Prior to European settlement, much of Iowa's landscape was characterized by extensive wetland systems



…but this landscape is now characterized by extensive subsurface tile drainage, with very few wetlands remaining.

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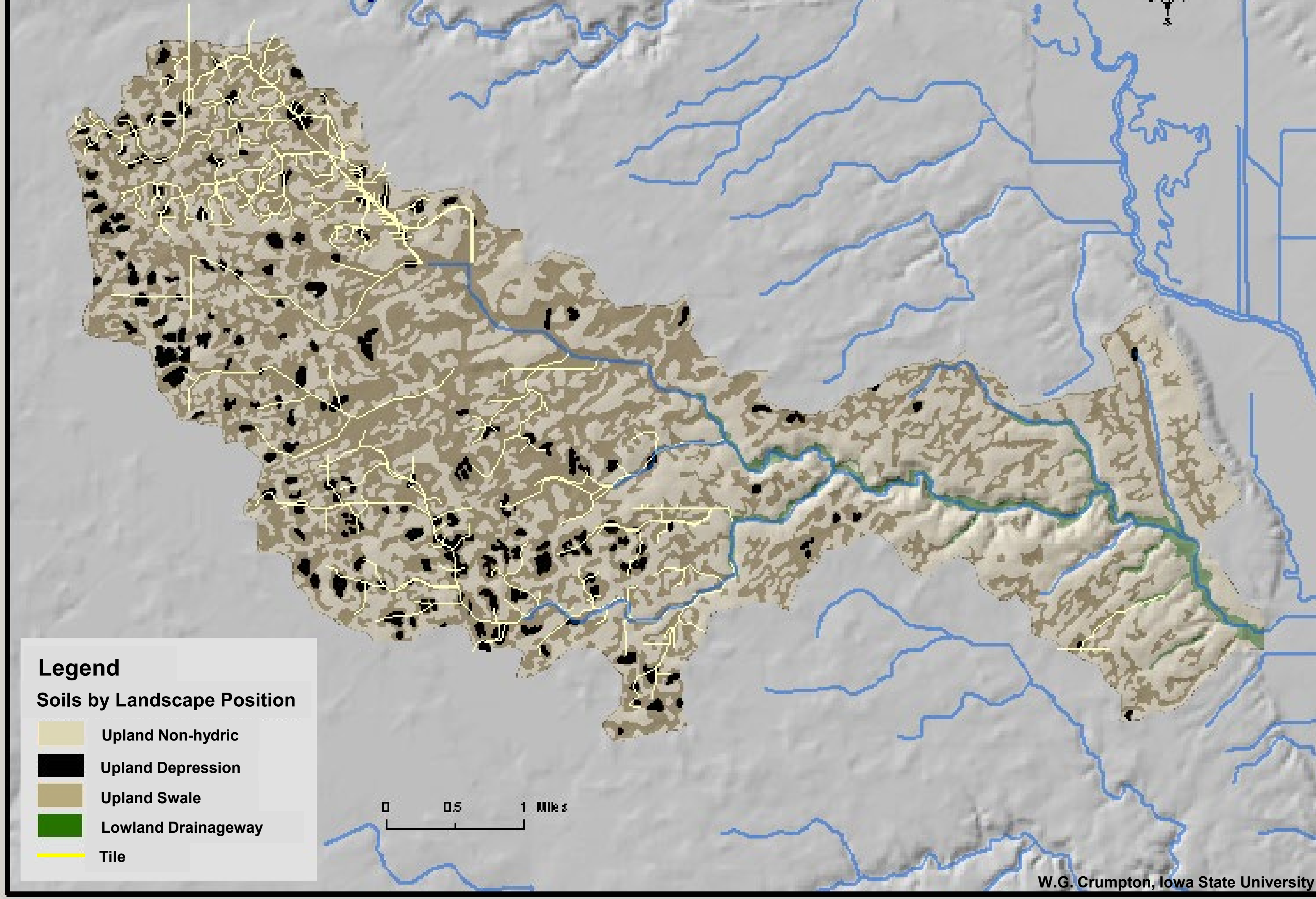
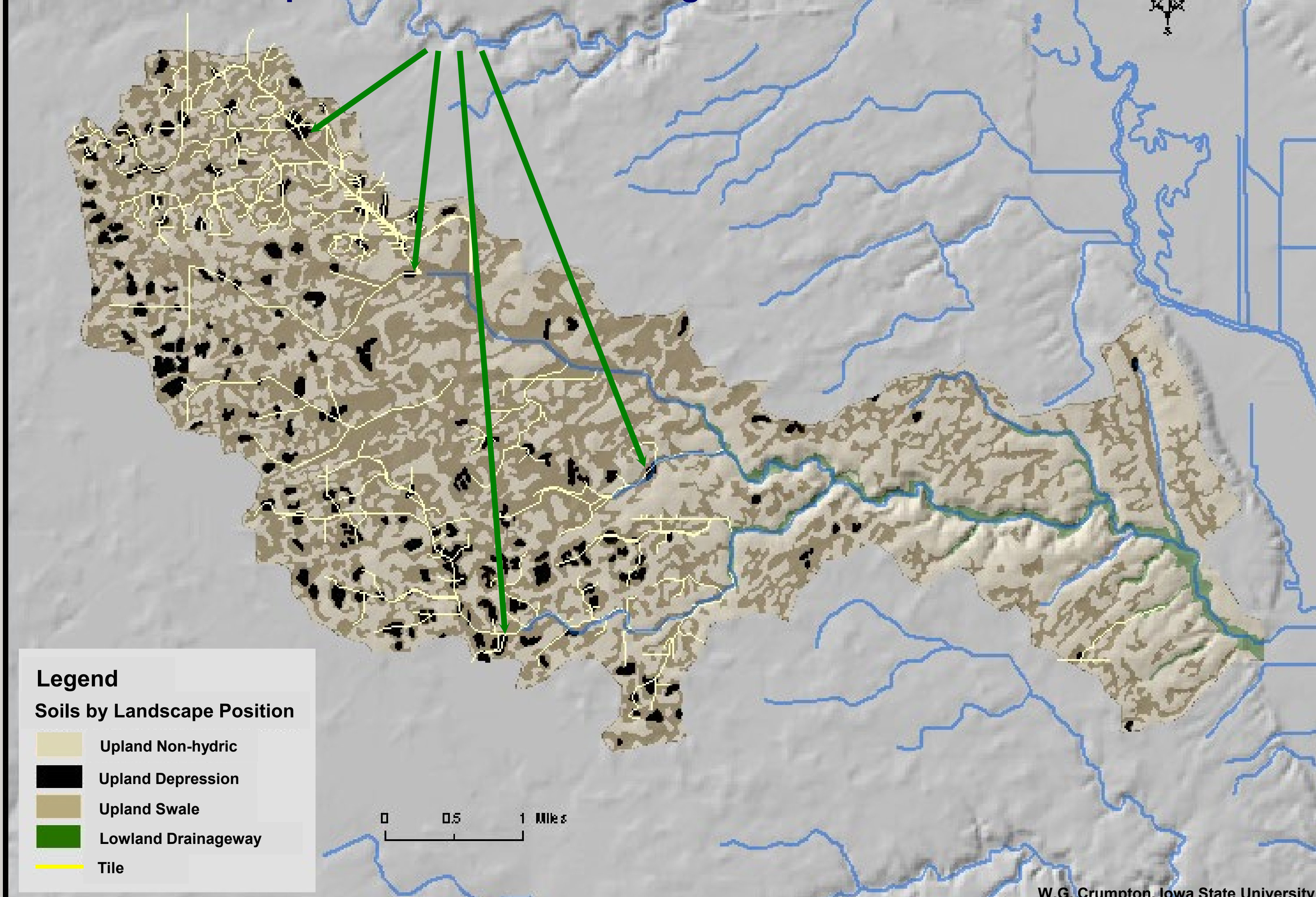
These drainage networks are the primary pathway for nitrate transport to surface waters in Iowa,



...but also provide unique opportunities for targeting wetland restorations to intercept and reduce NPS nitrogen loads.

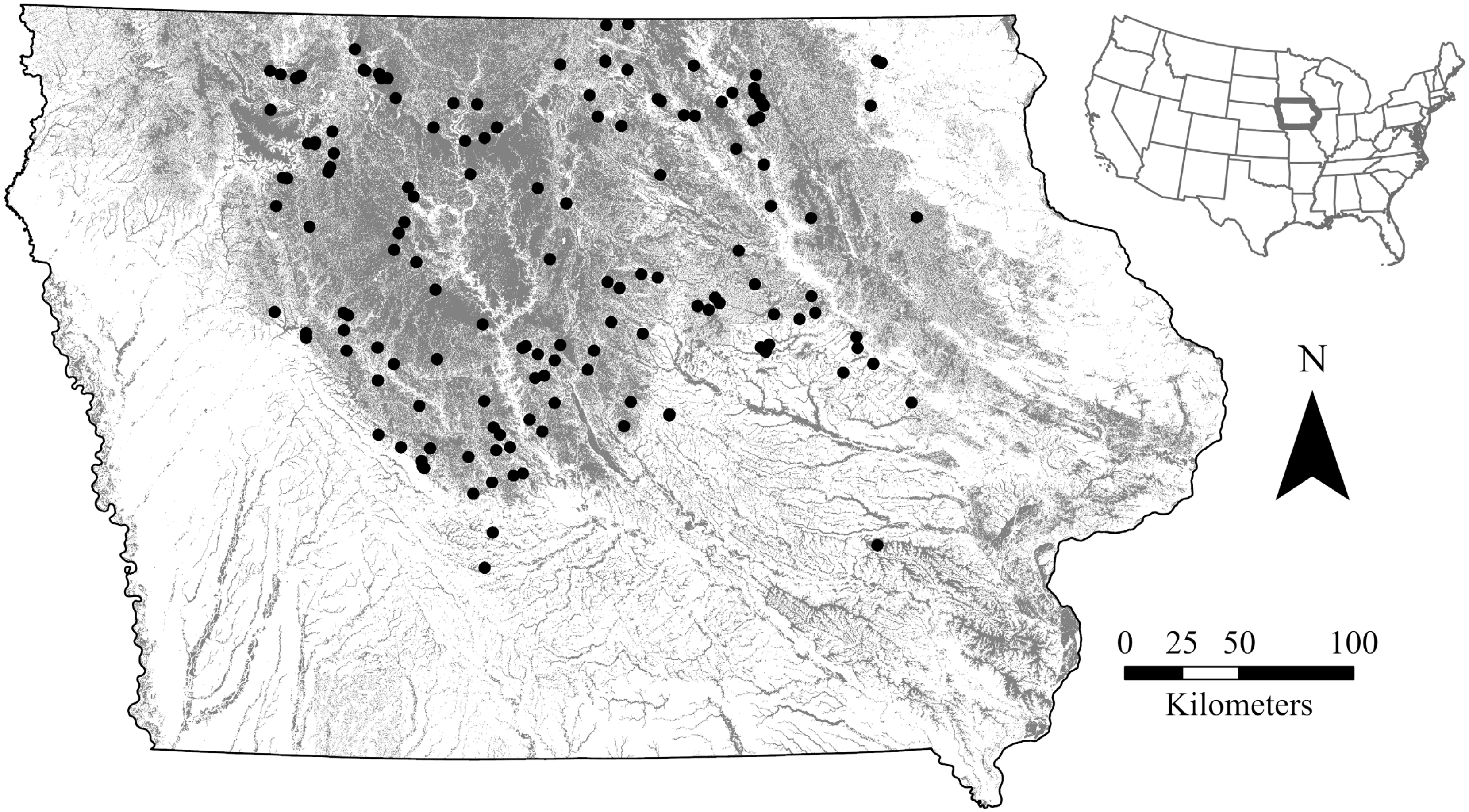


Water Quality Wetland Restoration in Palo Alto County Iowa

Photo credit: Lynn Betts

Water Quality Wetland Restorations in Iowa

One hundred and forty-six water quality restorations through the Iowa Conservation Reserve Enhancement Program and the Iowa Water Quality Initiative (Iowa Department of Agriculture and Land Stewardship)



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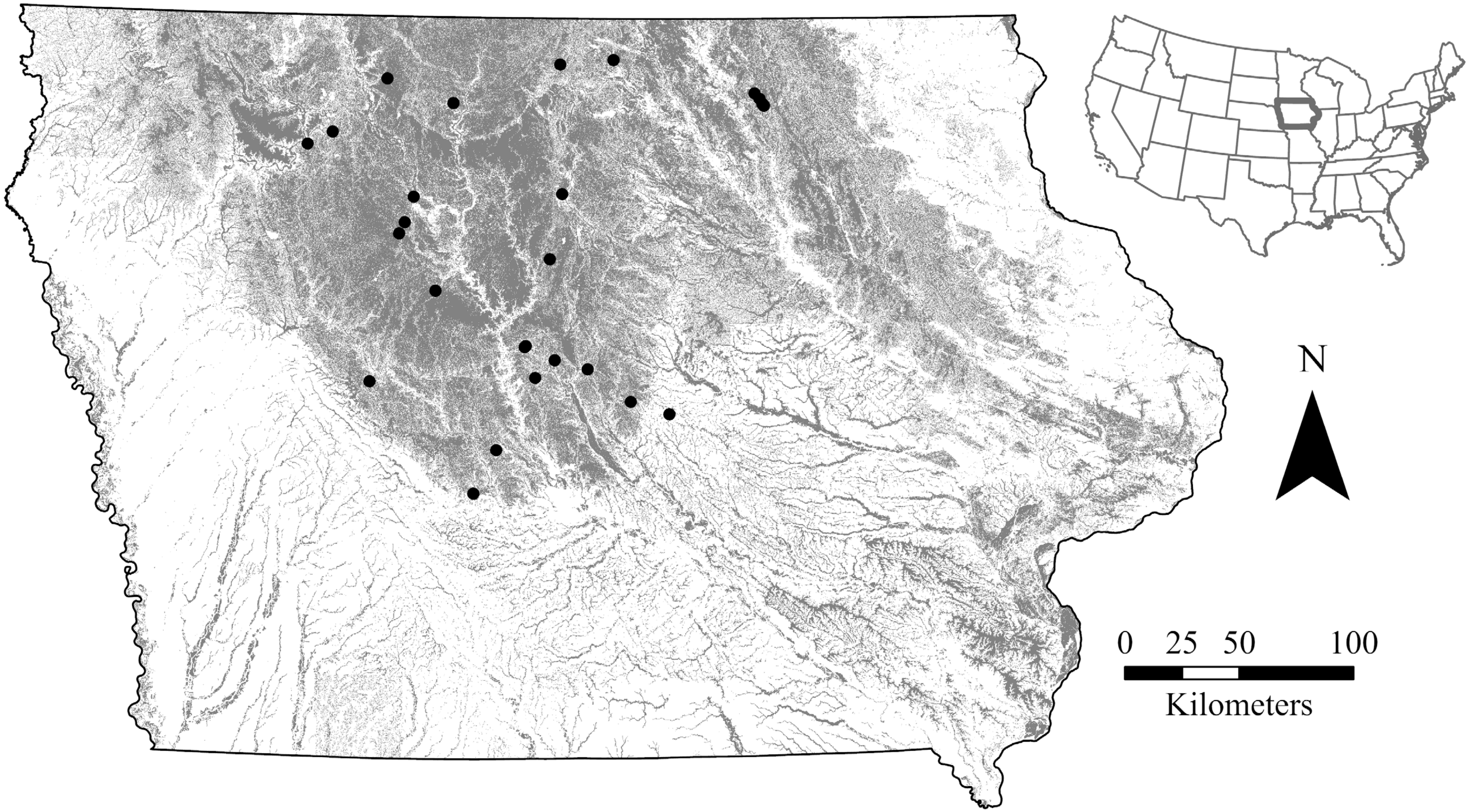
Wetland Performance Monitoring

Twenty-six wetlands monitored for nitrate and TN, representing a total of 69 site-years of data

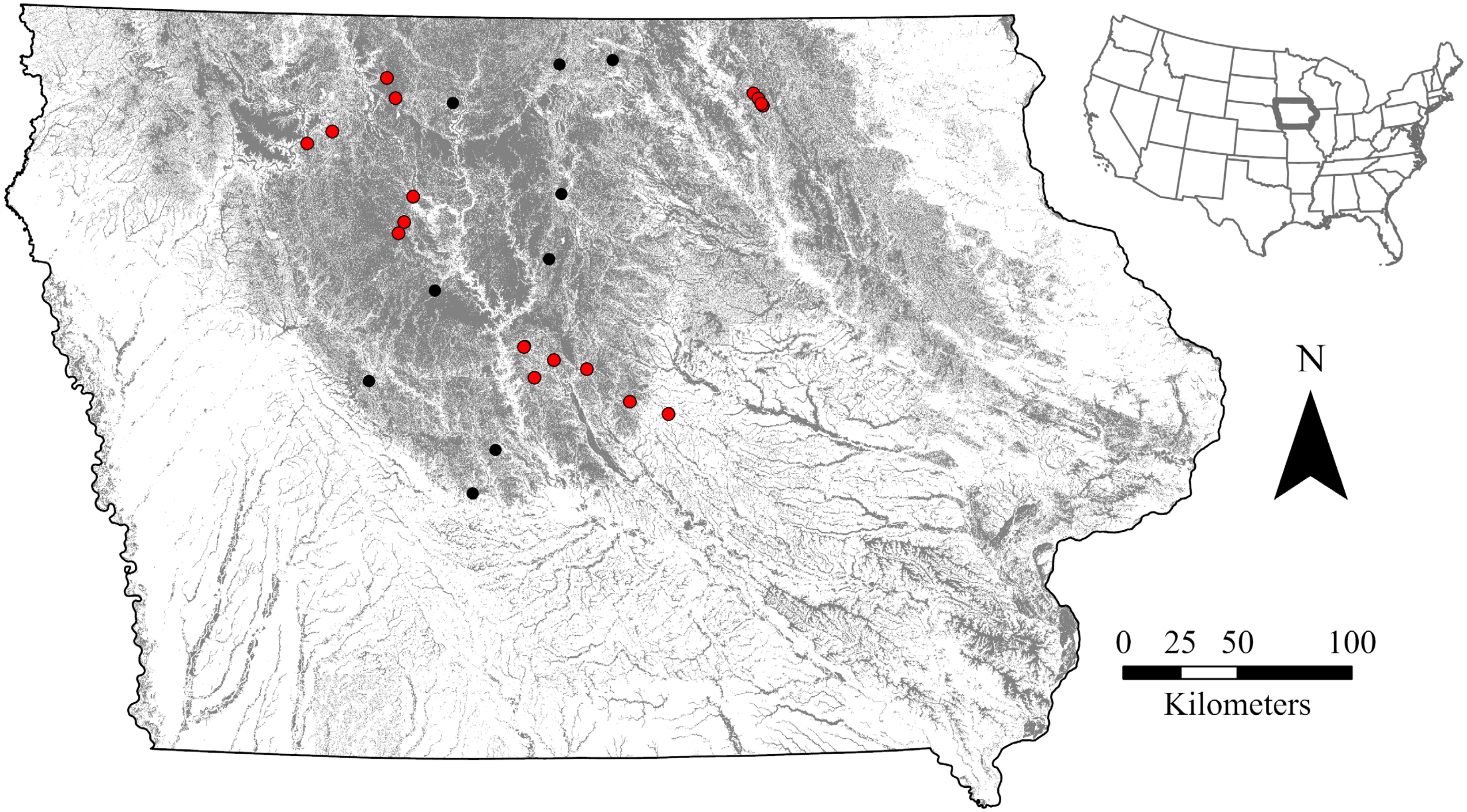
(Crumpton et. al 2020, Journal of Environmental Quality https://doi.org/10.1002/jeq2.20061)



Wetlands were chosen to ensure a broad range in factors expected to affect N loss rates, including hydraulic loading rate, N concentration, and N loading rate.

Wetland Performance Monitoring

Seventeen wetlands monitored for dissolved N_2O and CH_4 loads, representing a total of 39 site-years of data



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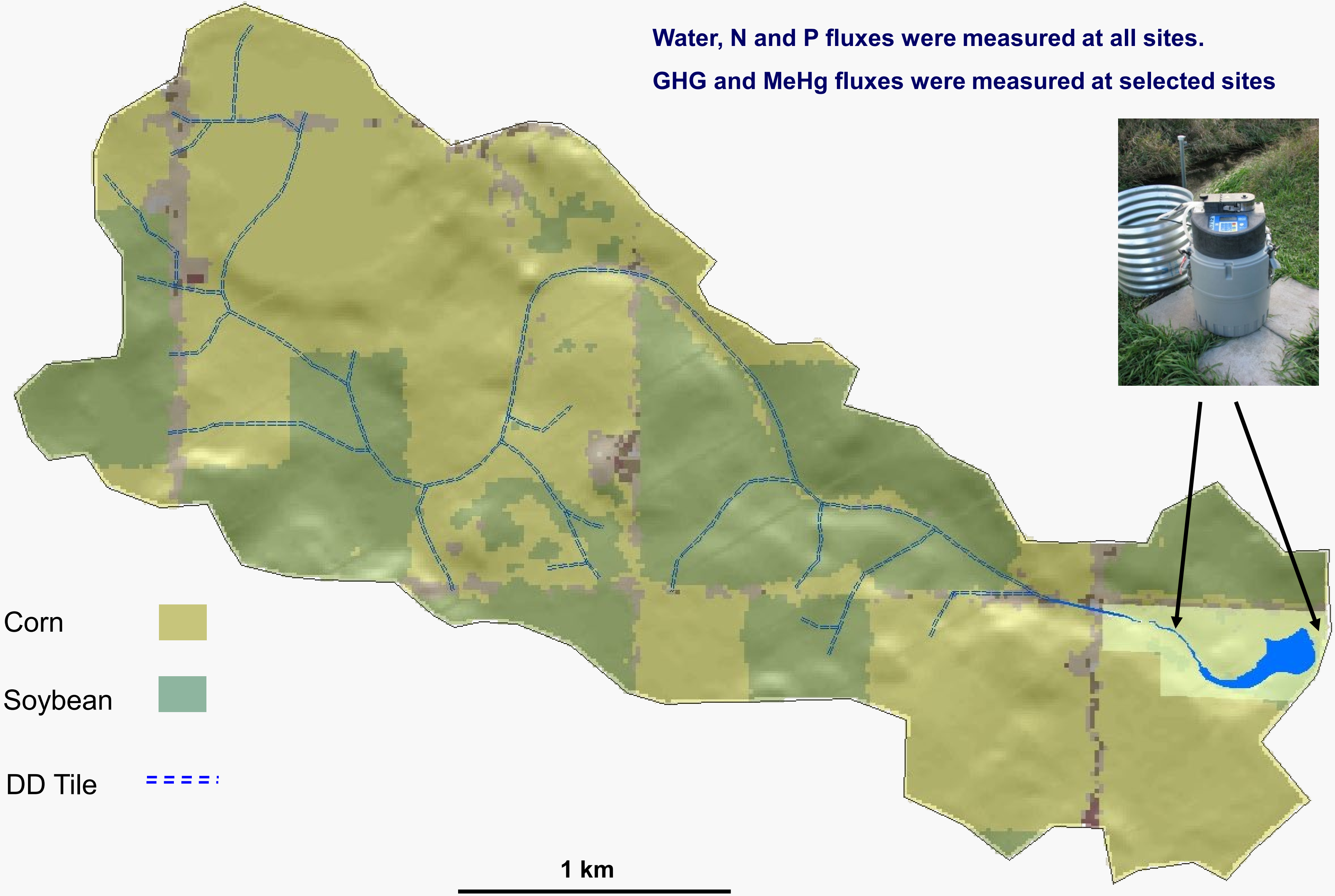
All sites were instrumented for flow measurement and automated sampling

Water, N and P fluxes were measured at all sites.

GHG and MeHg fluxes were measured at selected sites



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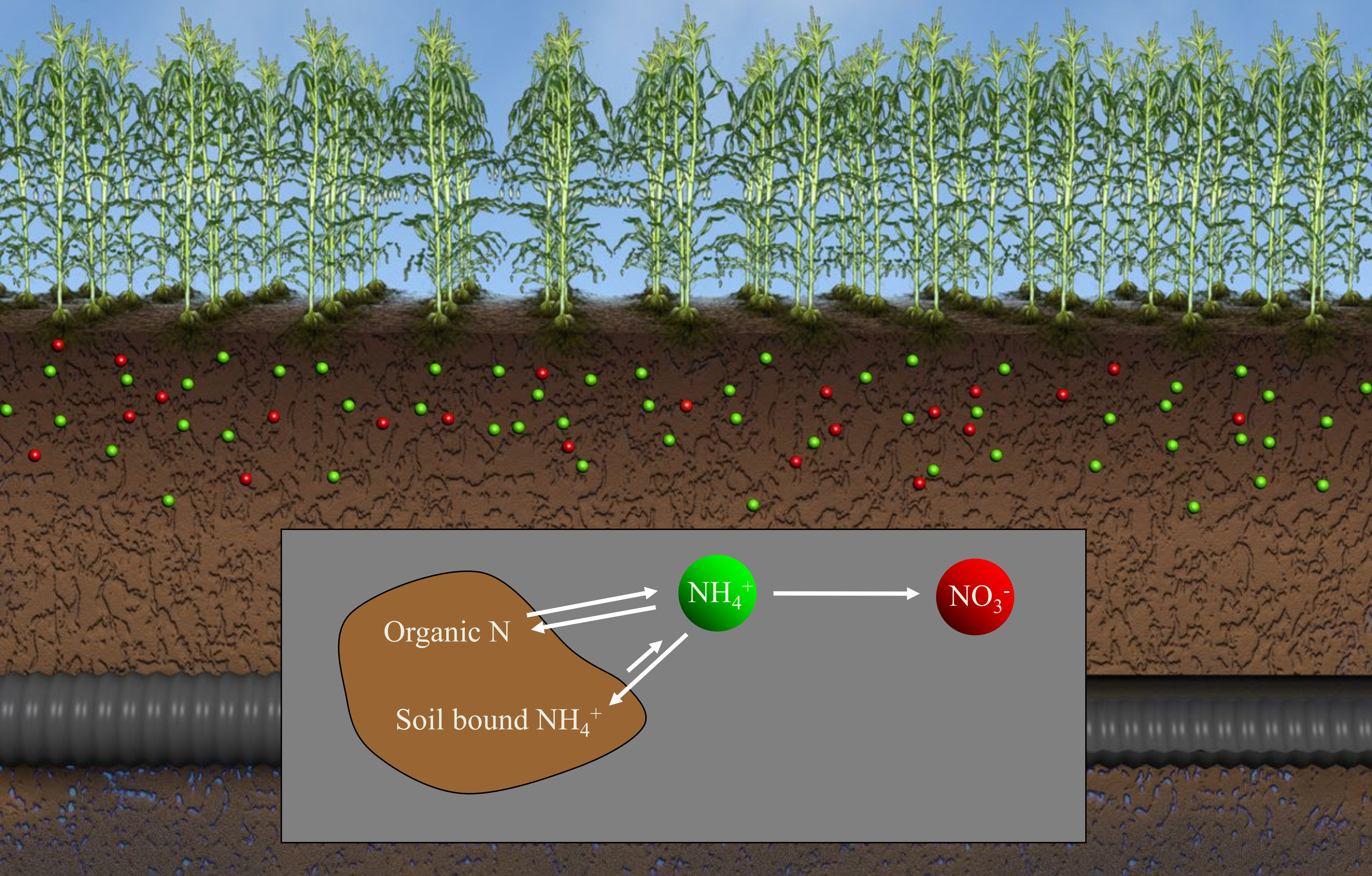
N transformation and transport in tile-drained cropland



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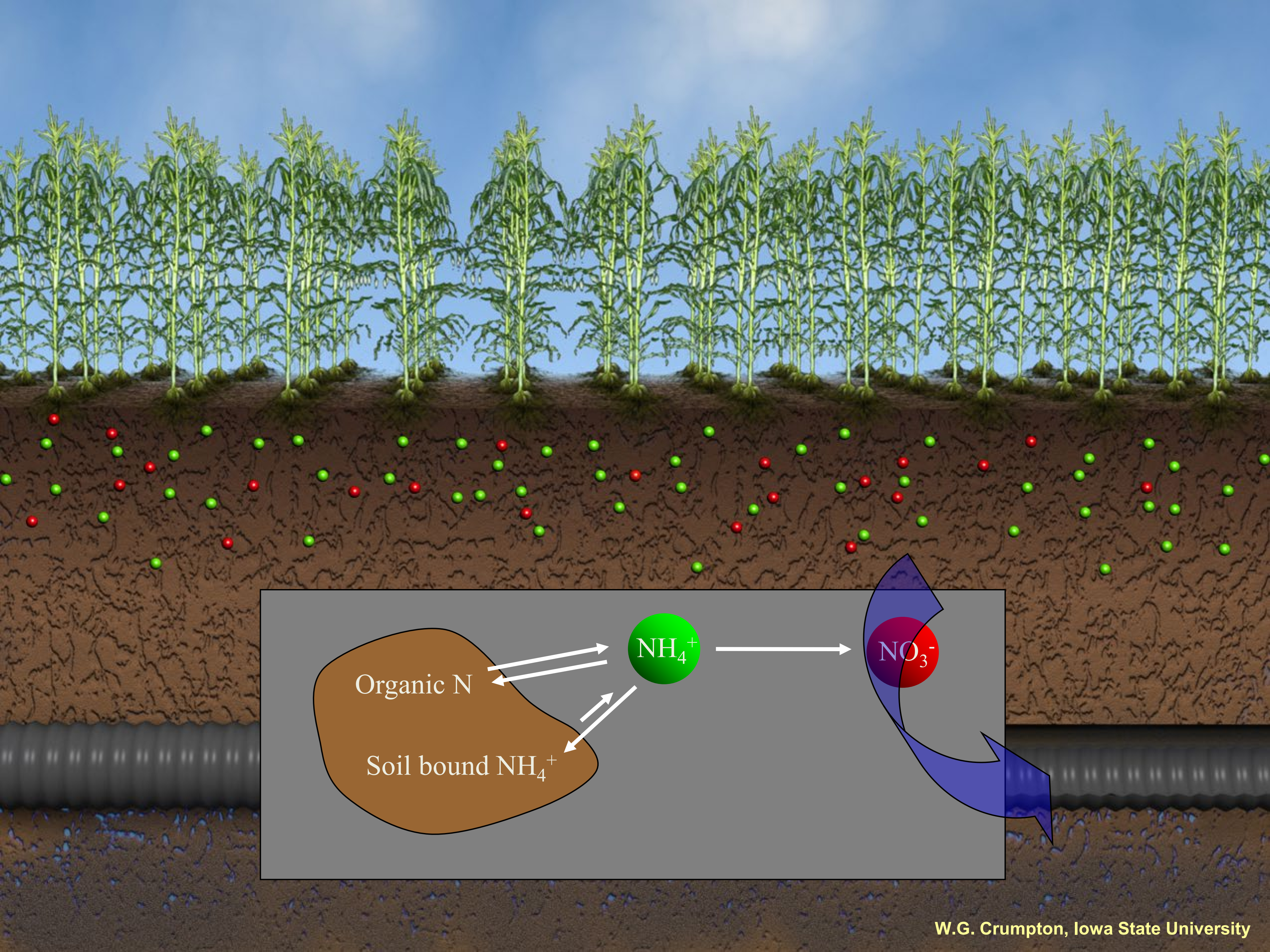

Organic N
NH_4^+
NO_3^-
Soil bound NH_4^+
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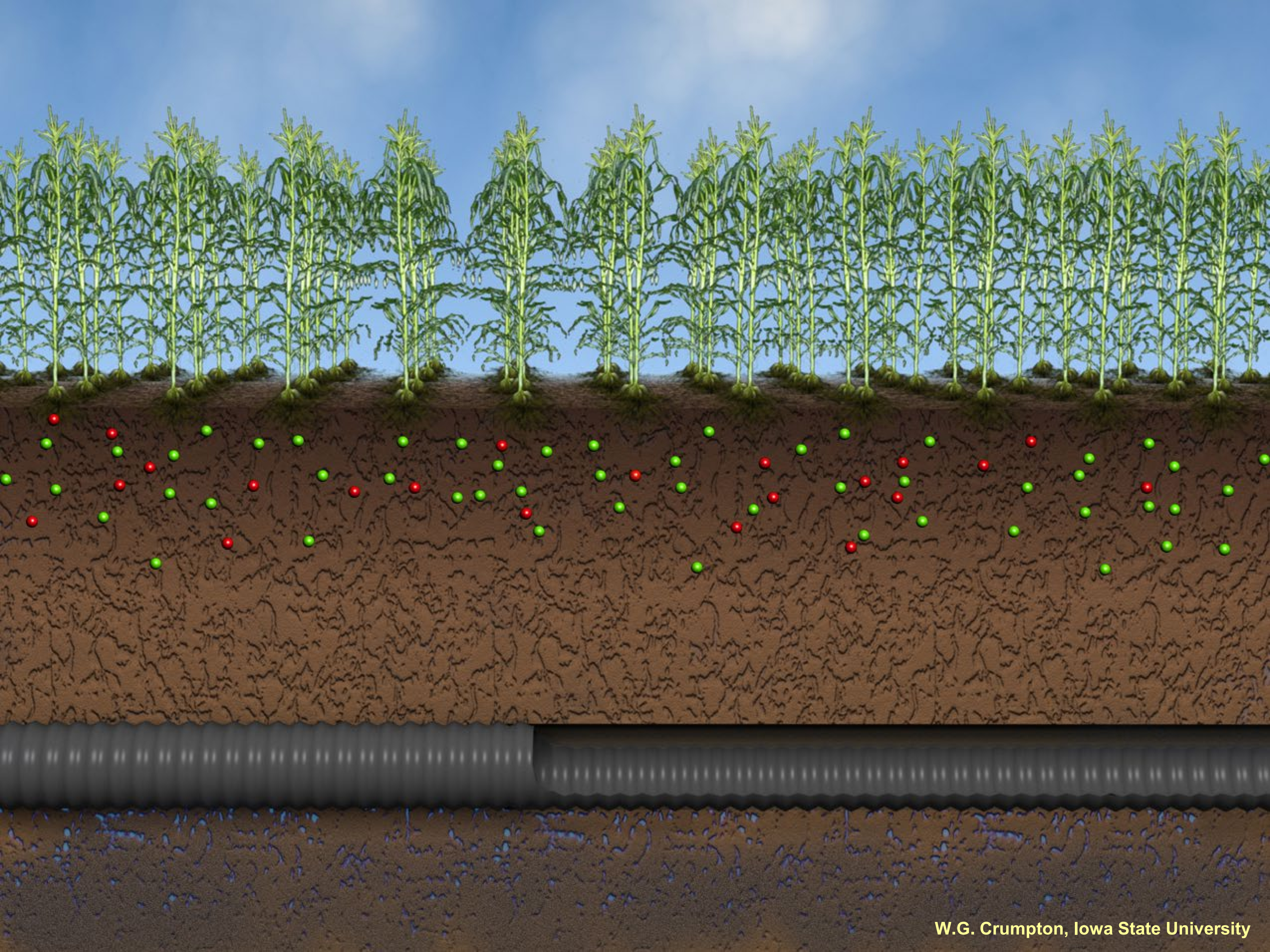
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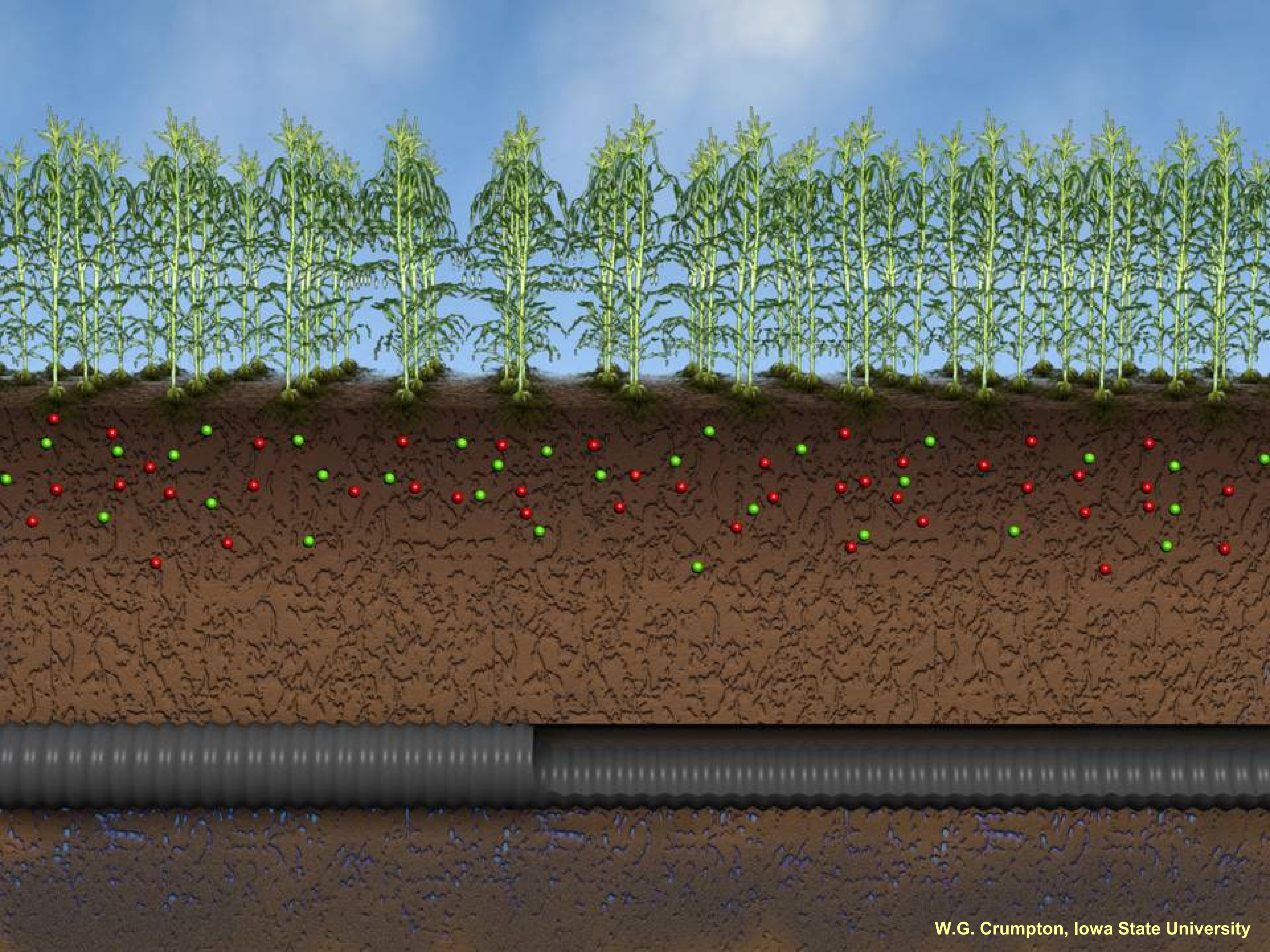

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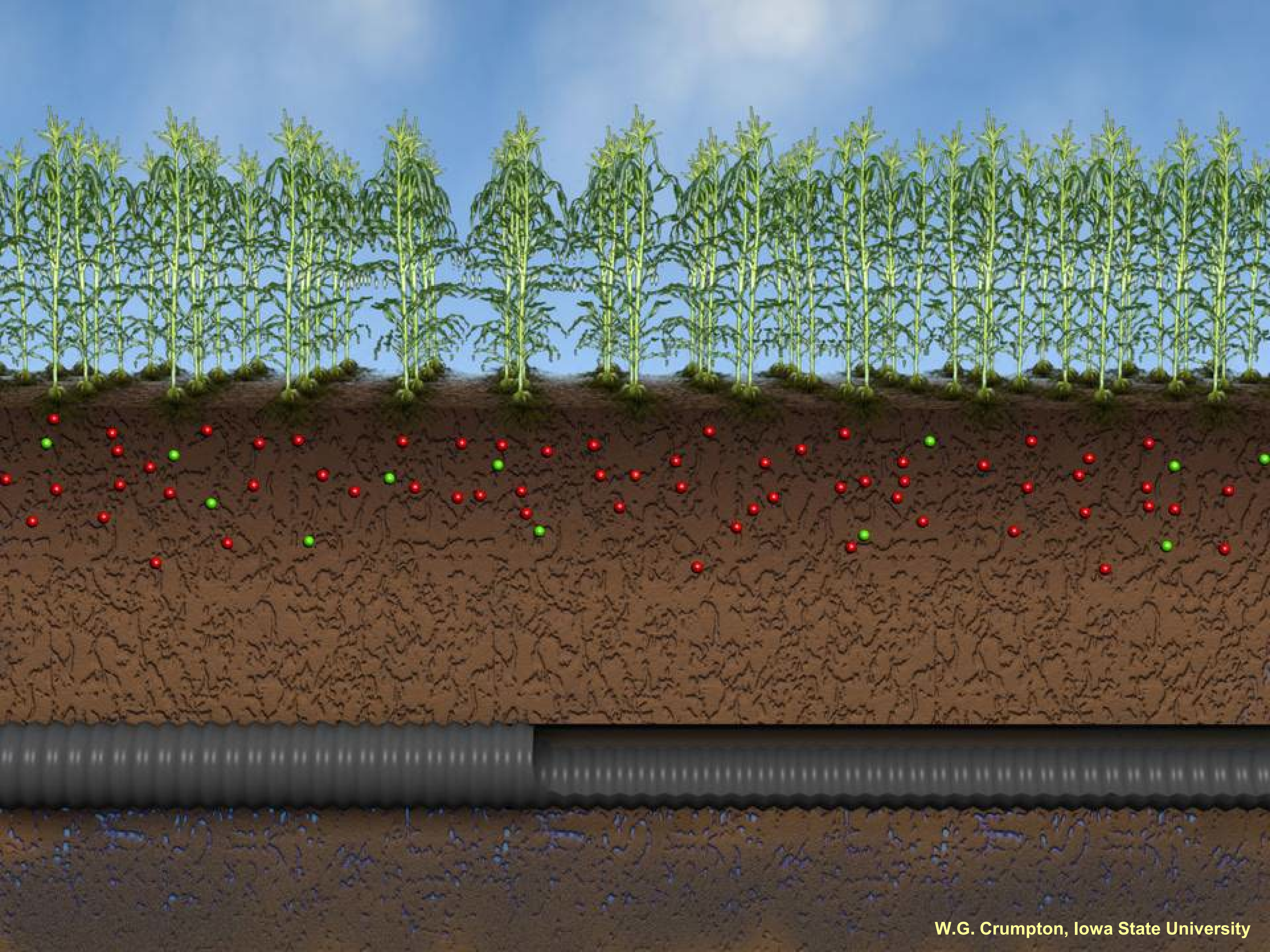
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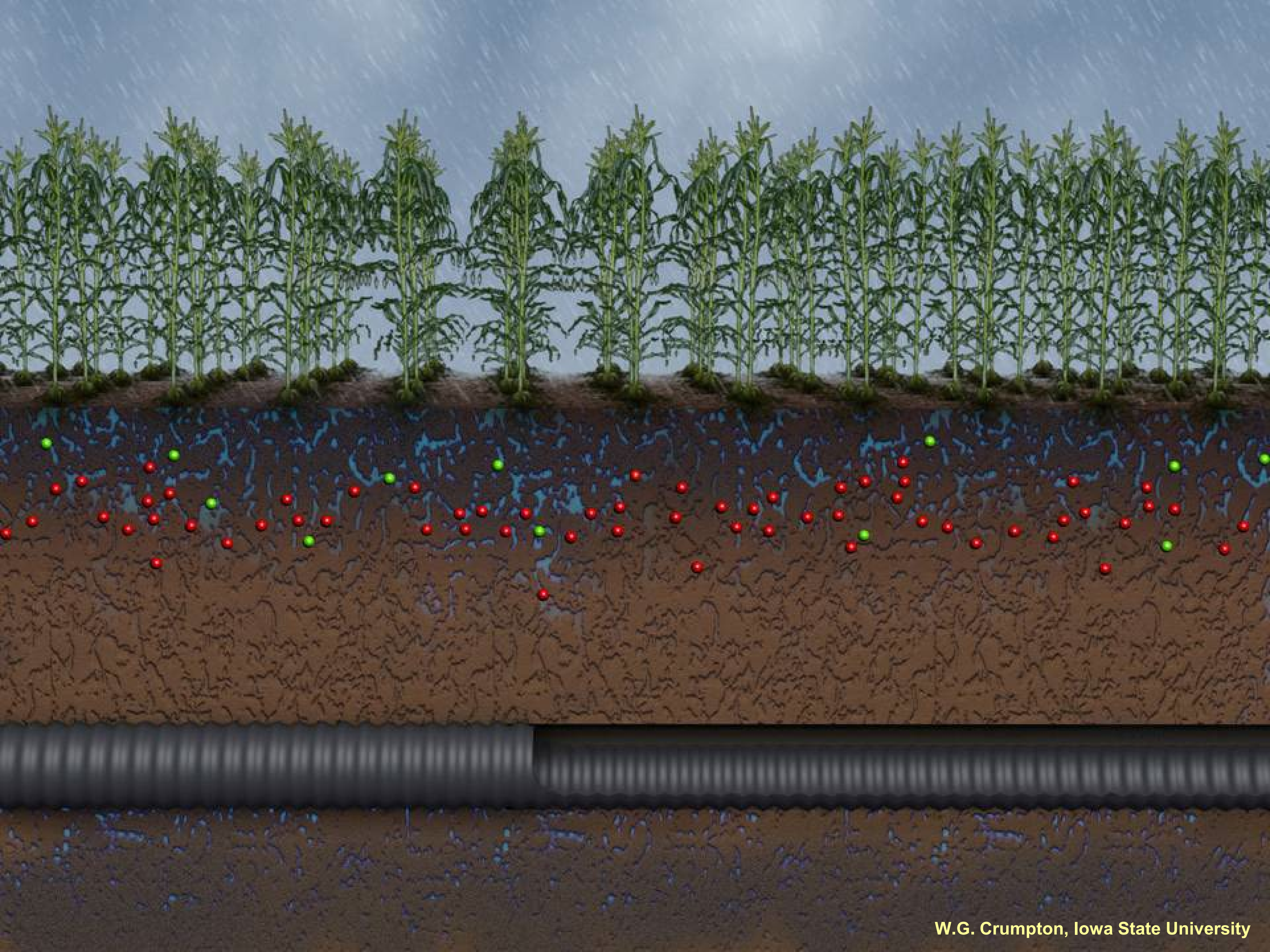
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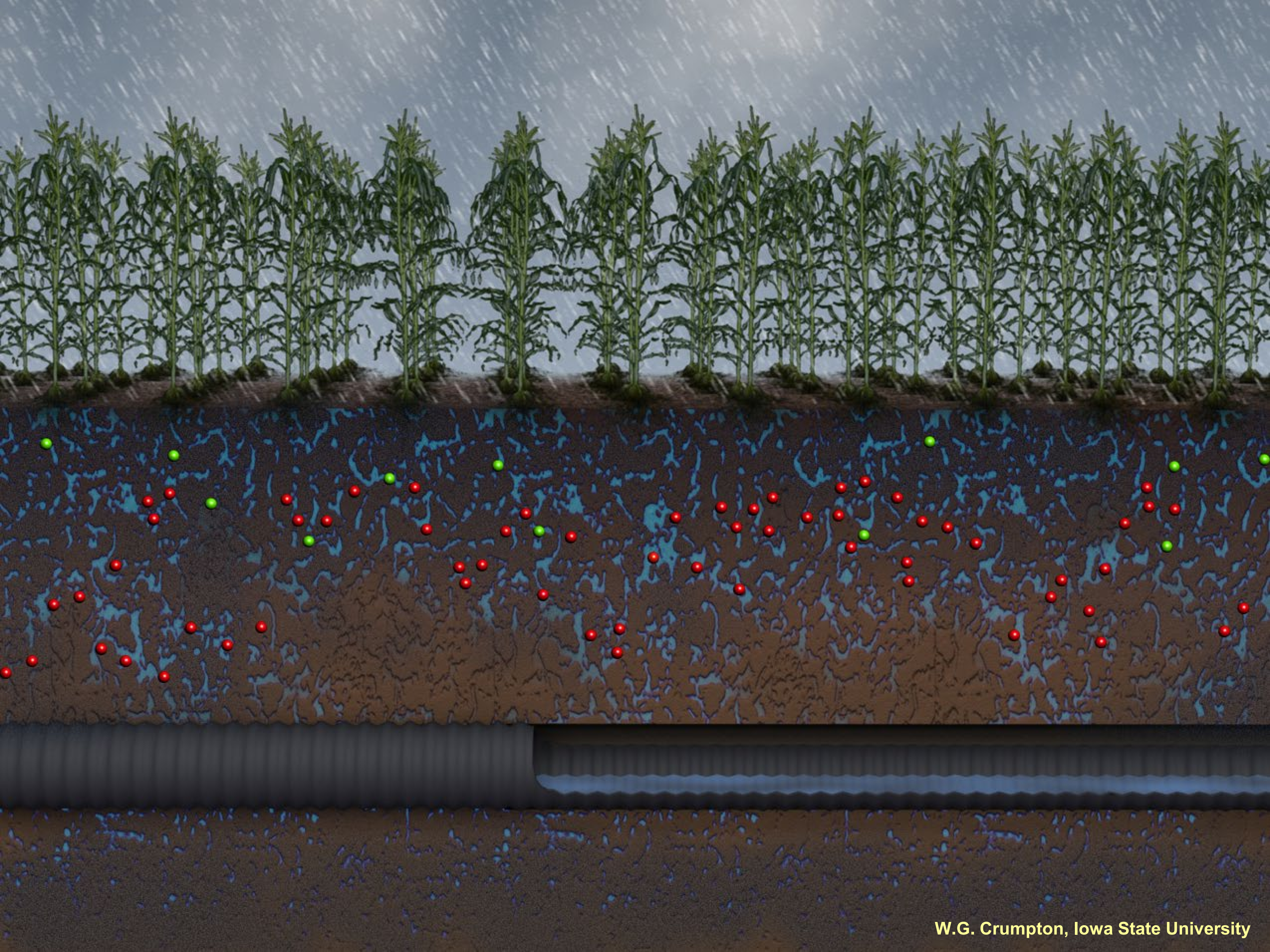
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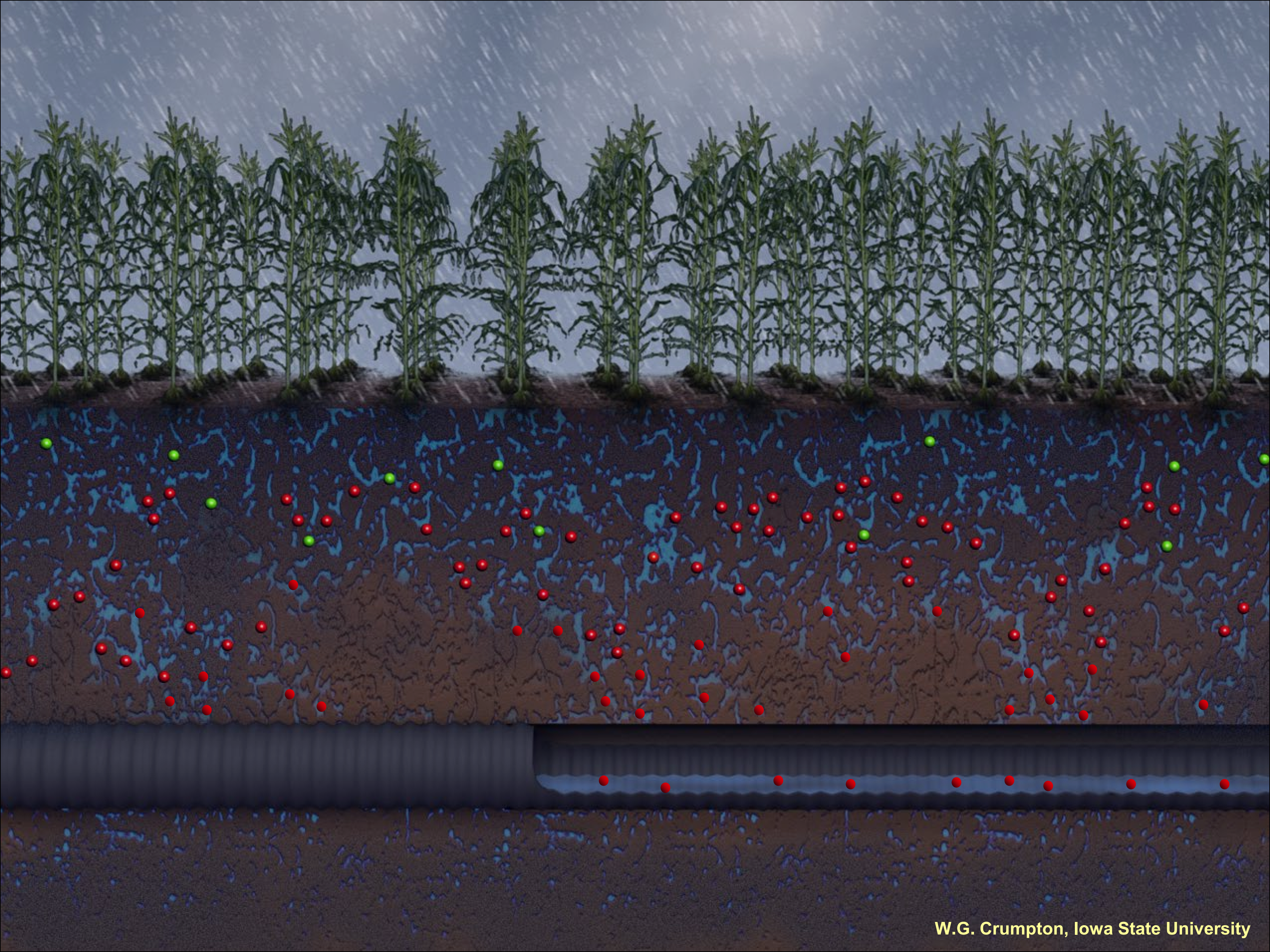
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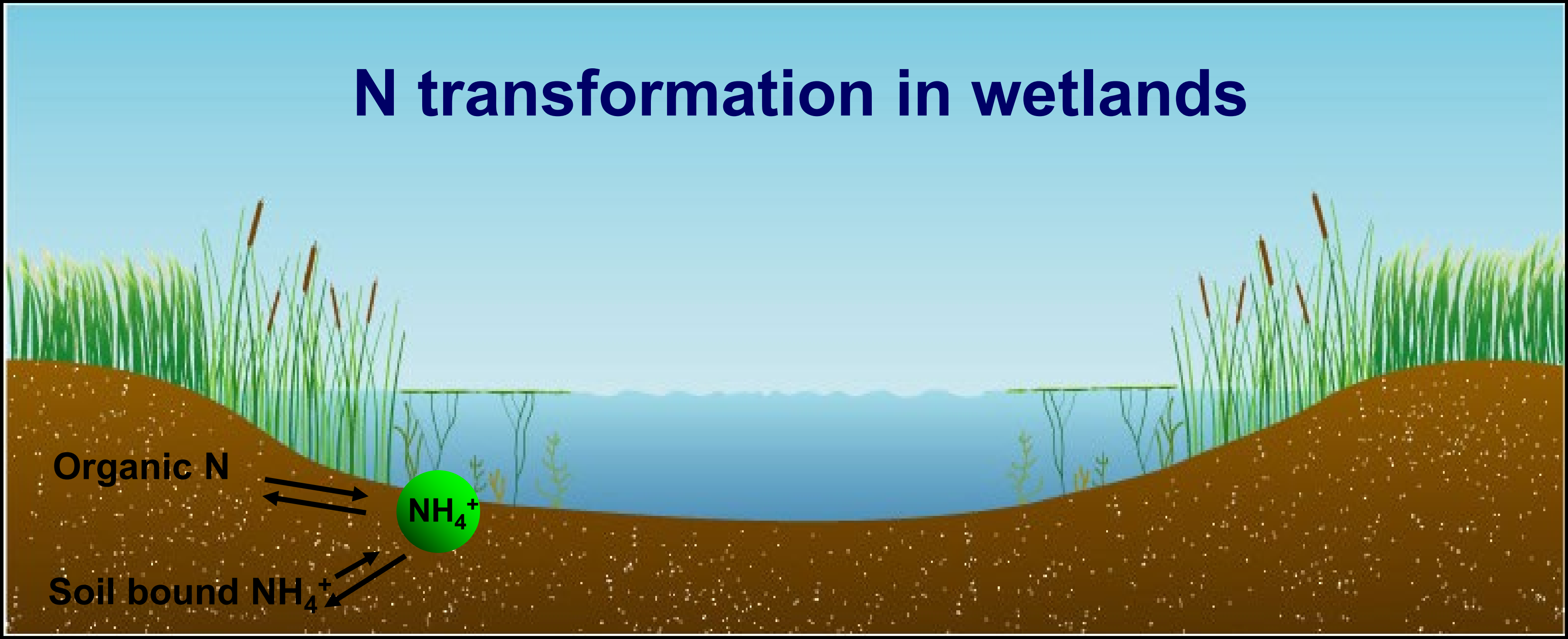

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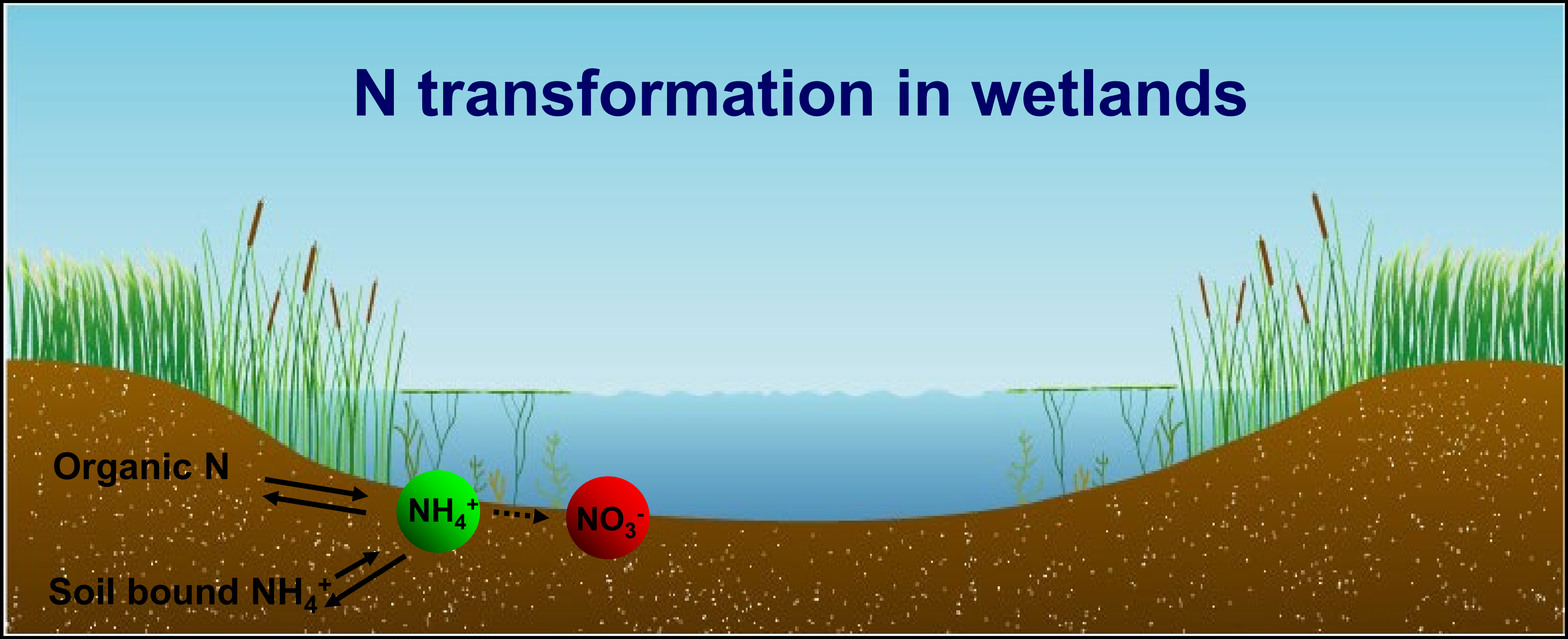

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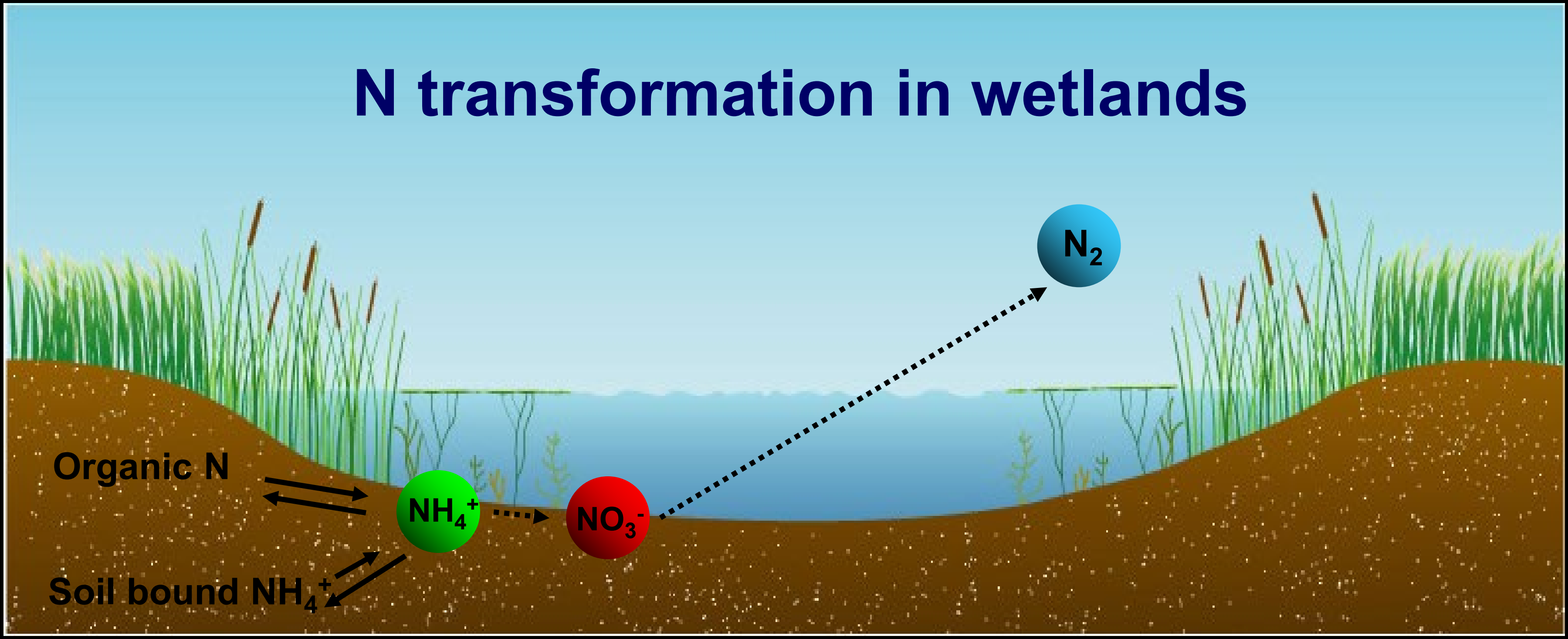

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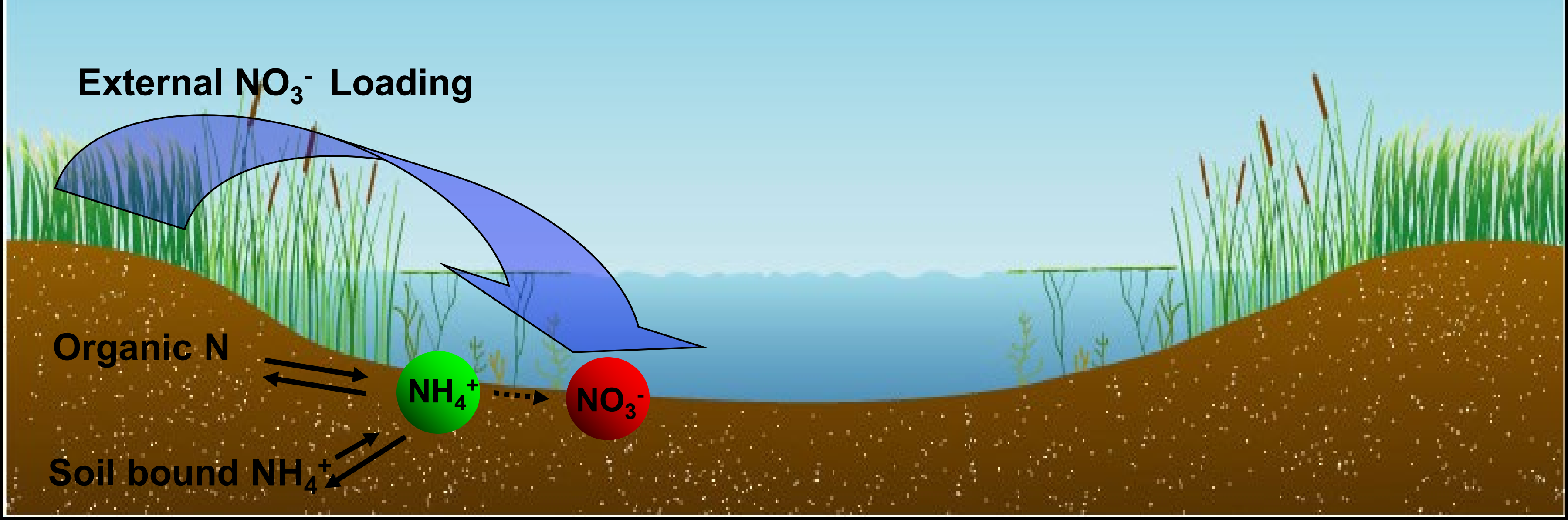
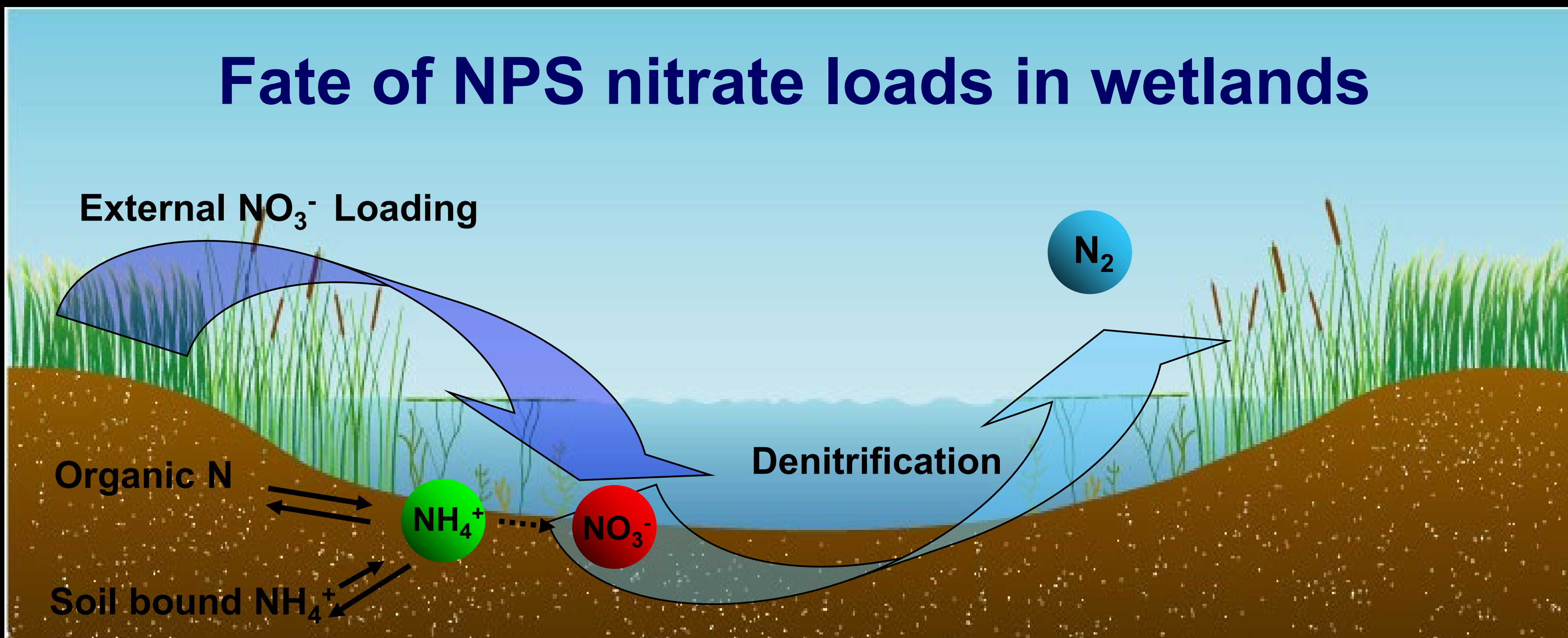
Fate of NPS nitrate loads in wetlands





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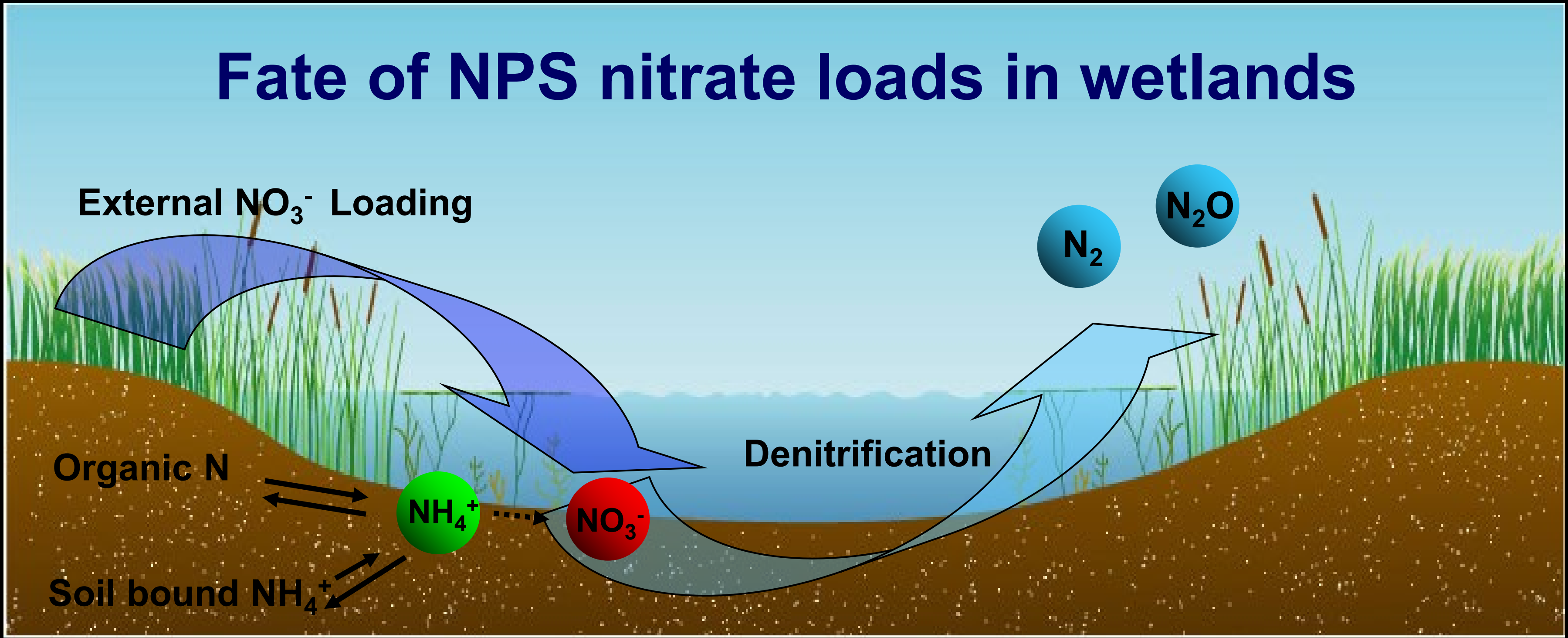

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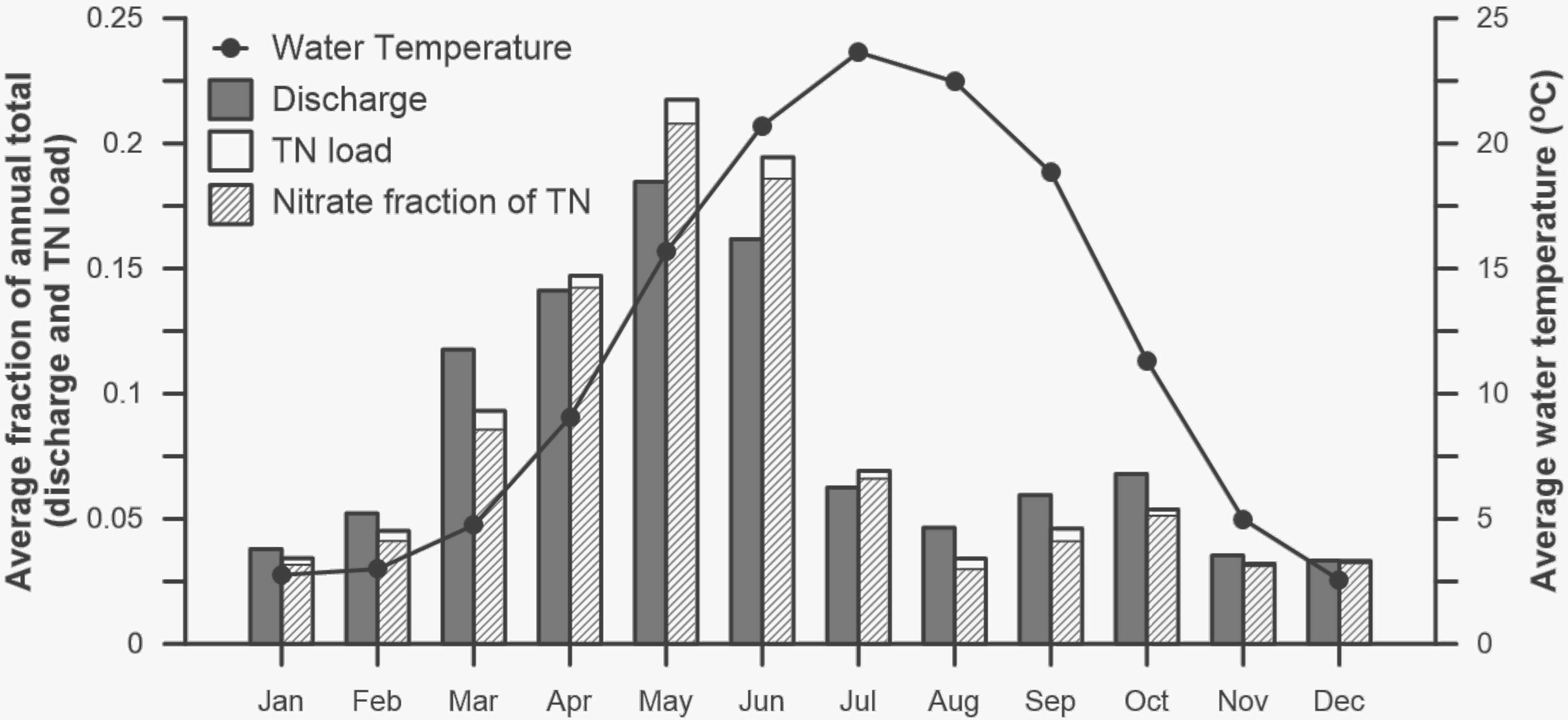
Seasonal Patterns in Water Temperature, discharge and N load.



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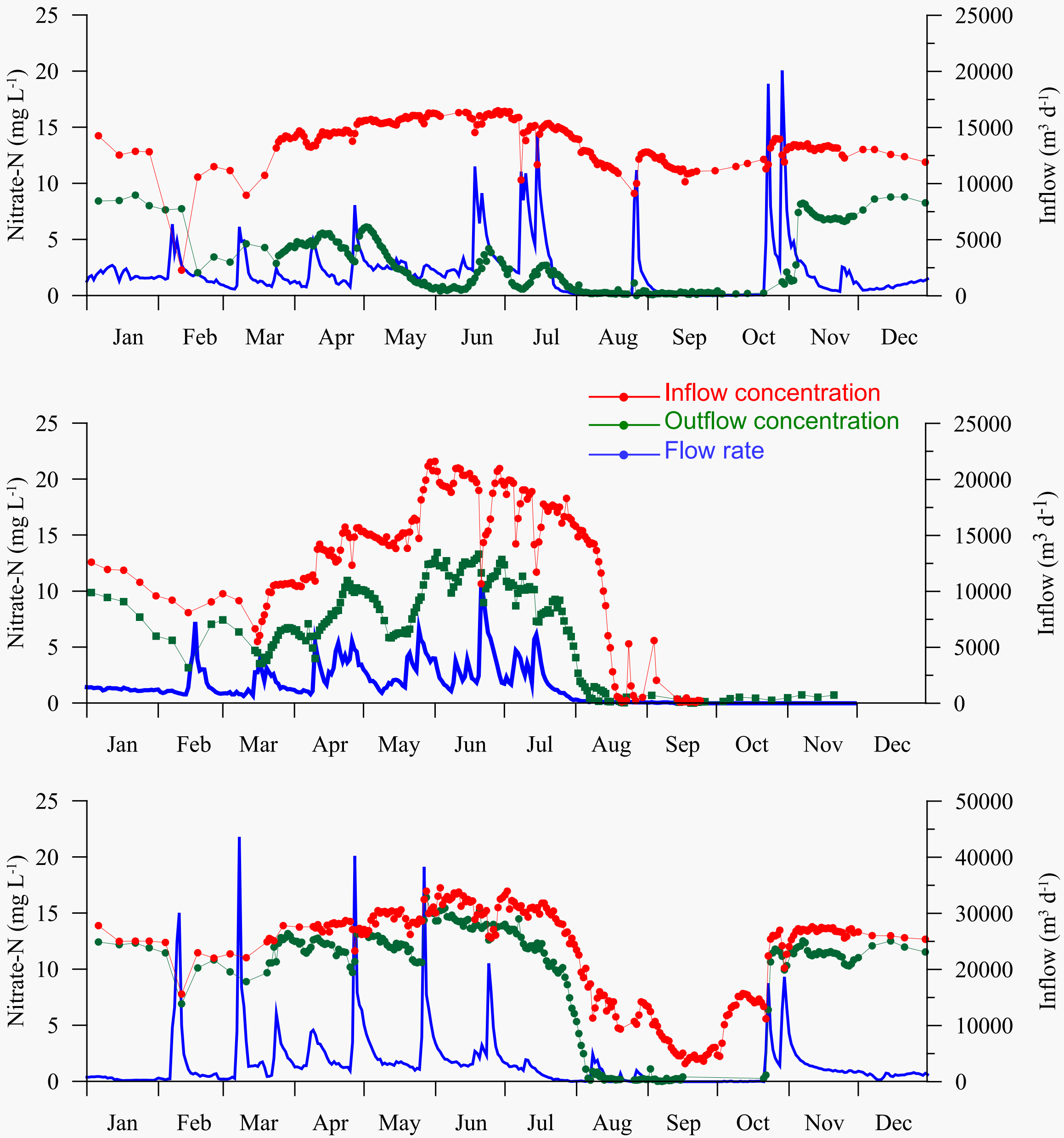
Seasonal Patterns in Flow and Nitrate Concentrations



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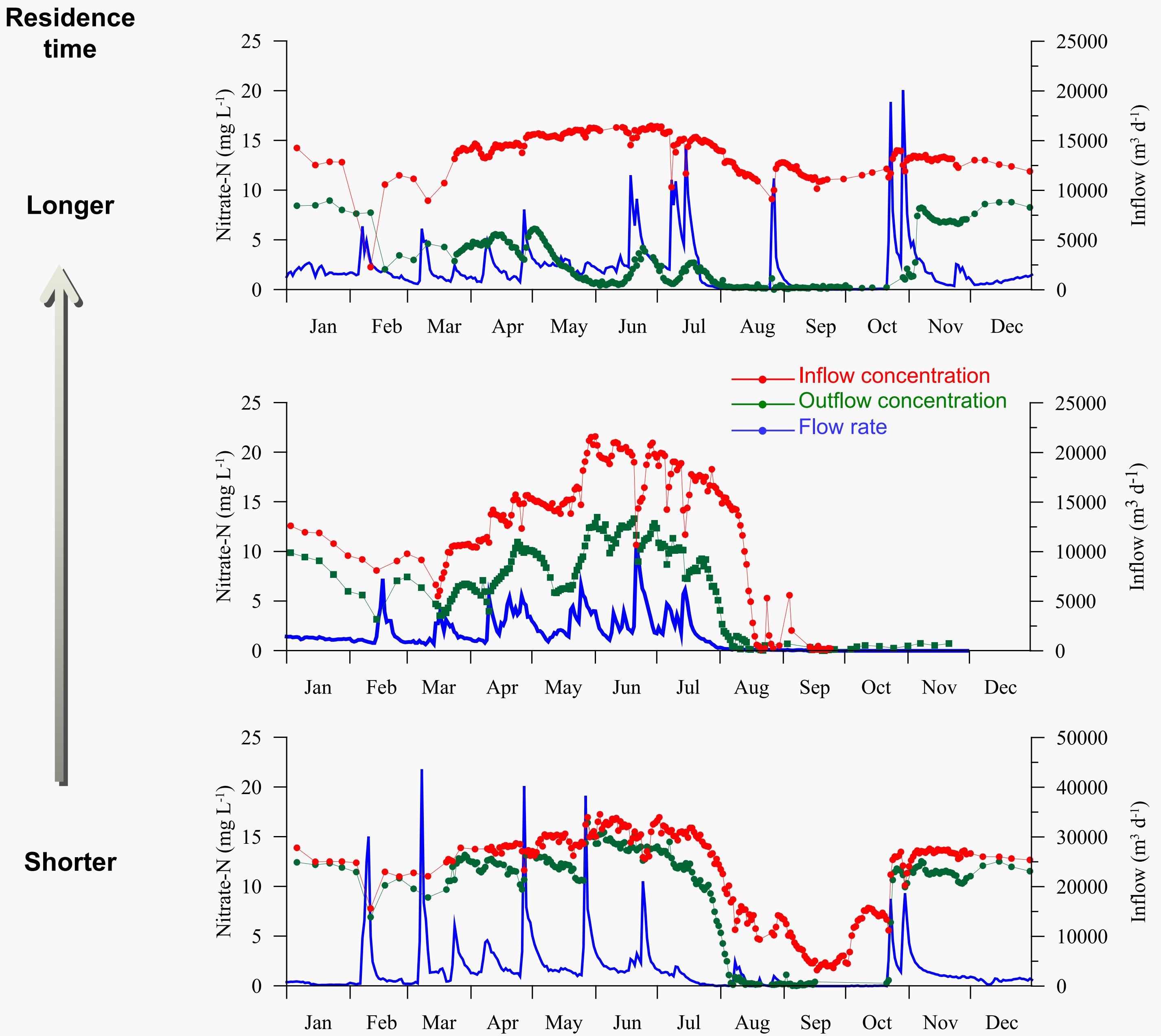

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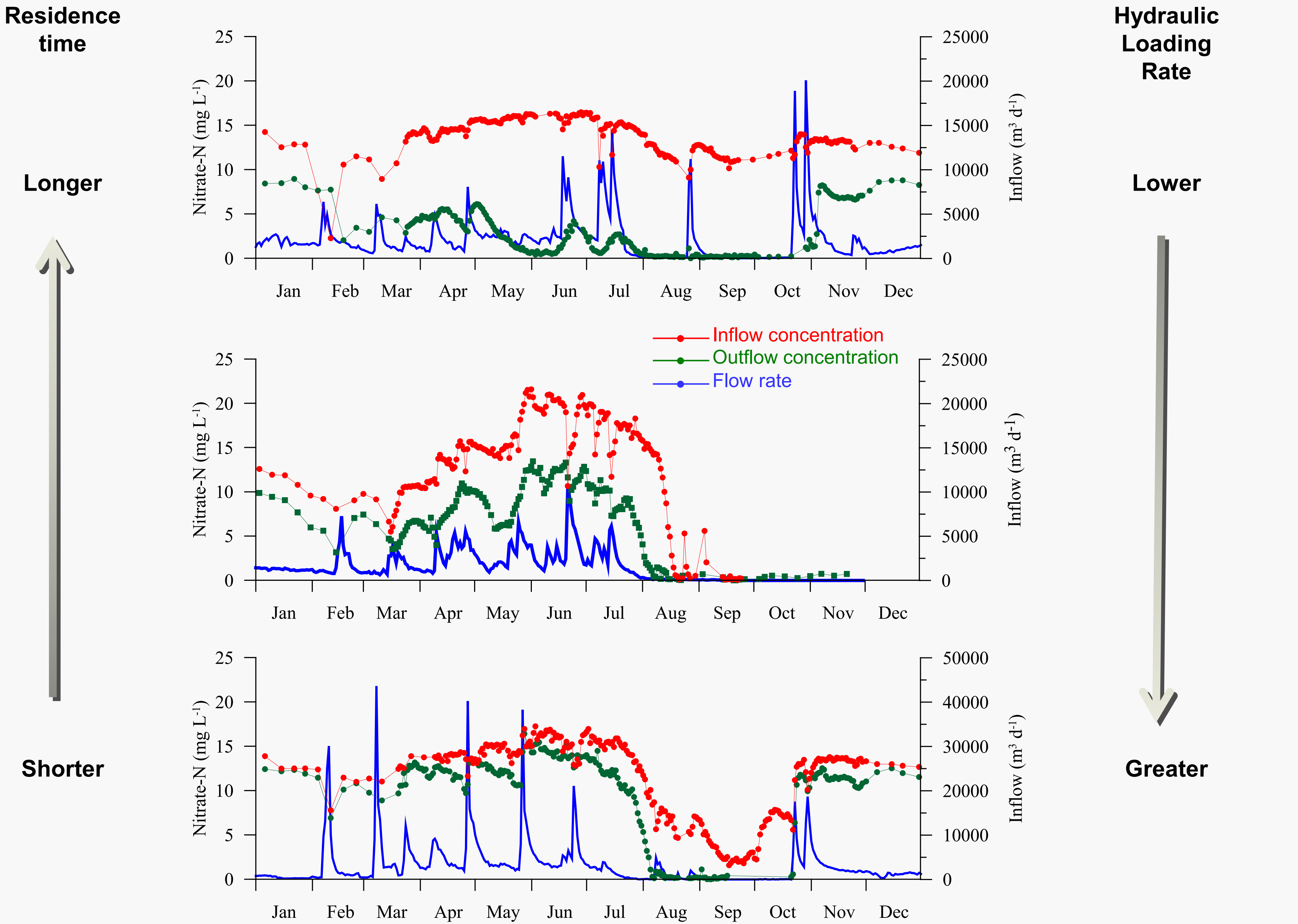

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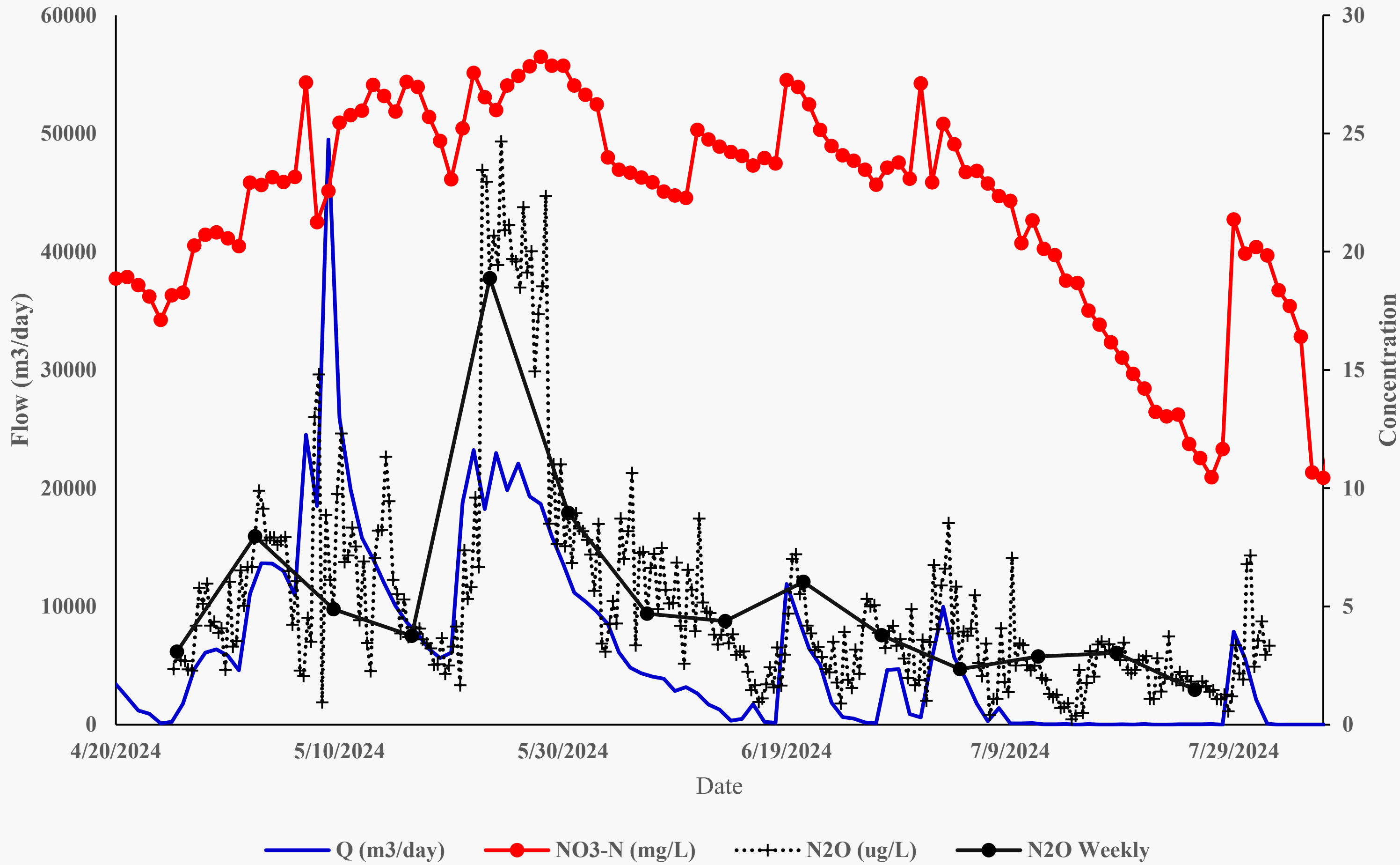
Seasonal Patterns in Flow, Nitrate, and Dissolved N_2O Concentrations at Wetland Inflows



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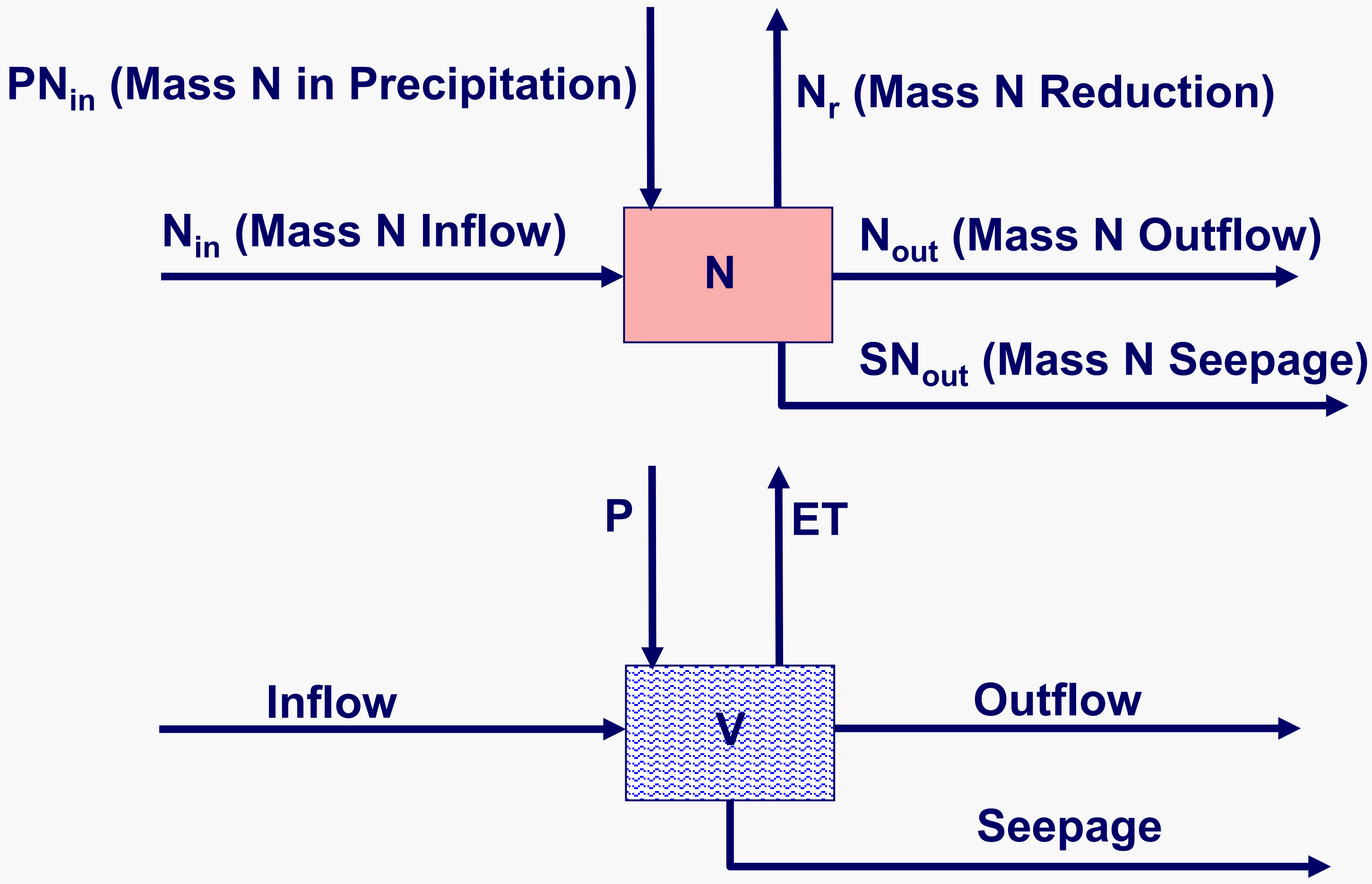
TN and NO_3-N Mass Balances



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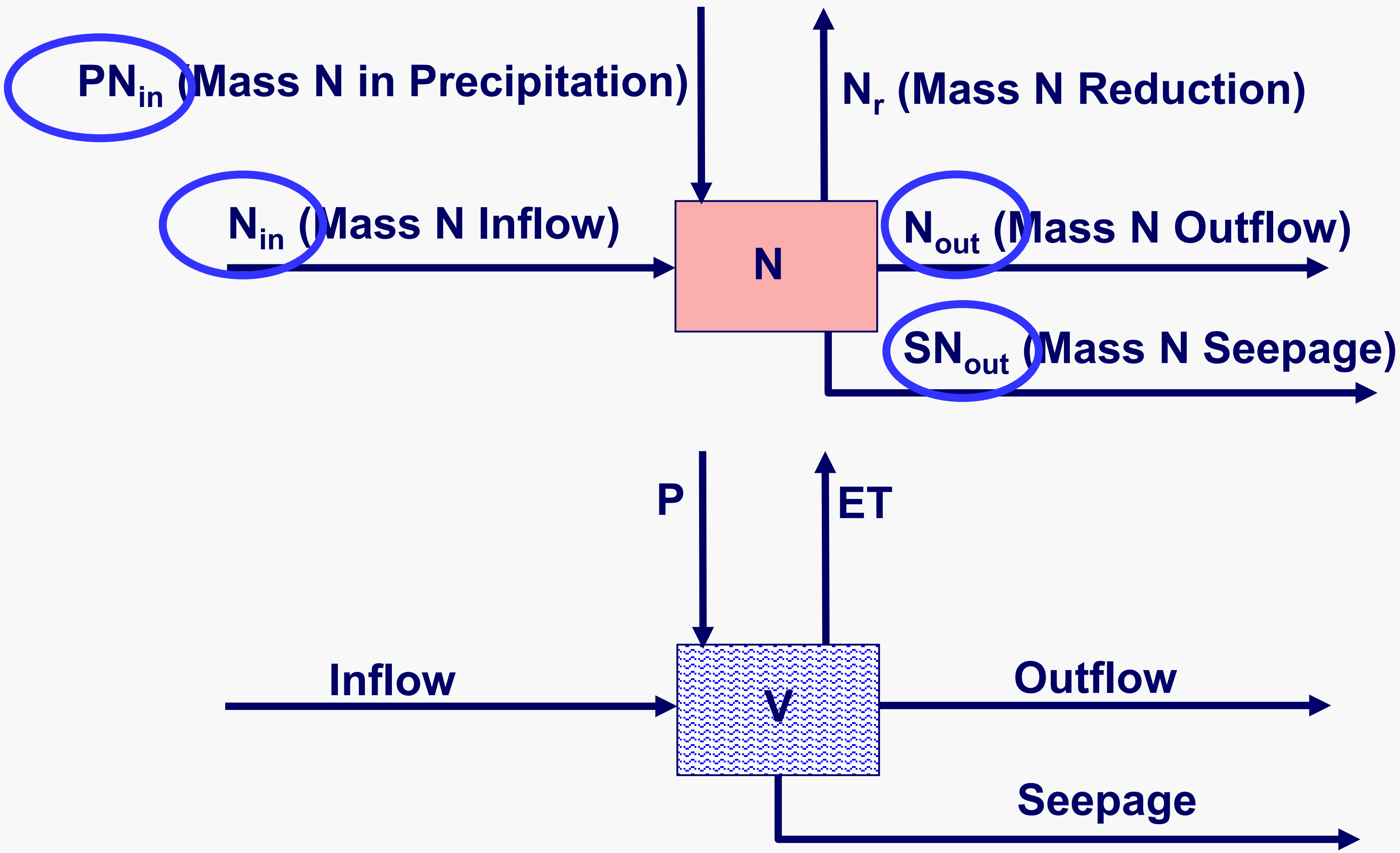
TN and NO_3-N Mass Balances

Directly estimated fluxes



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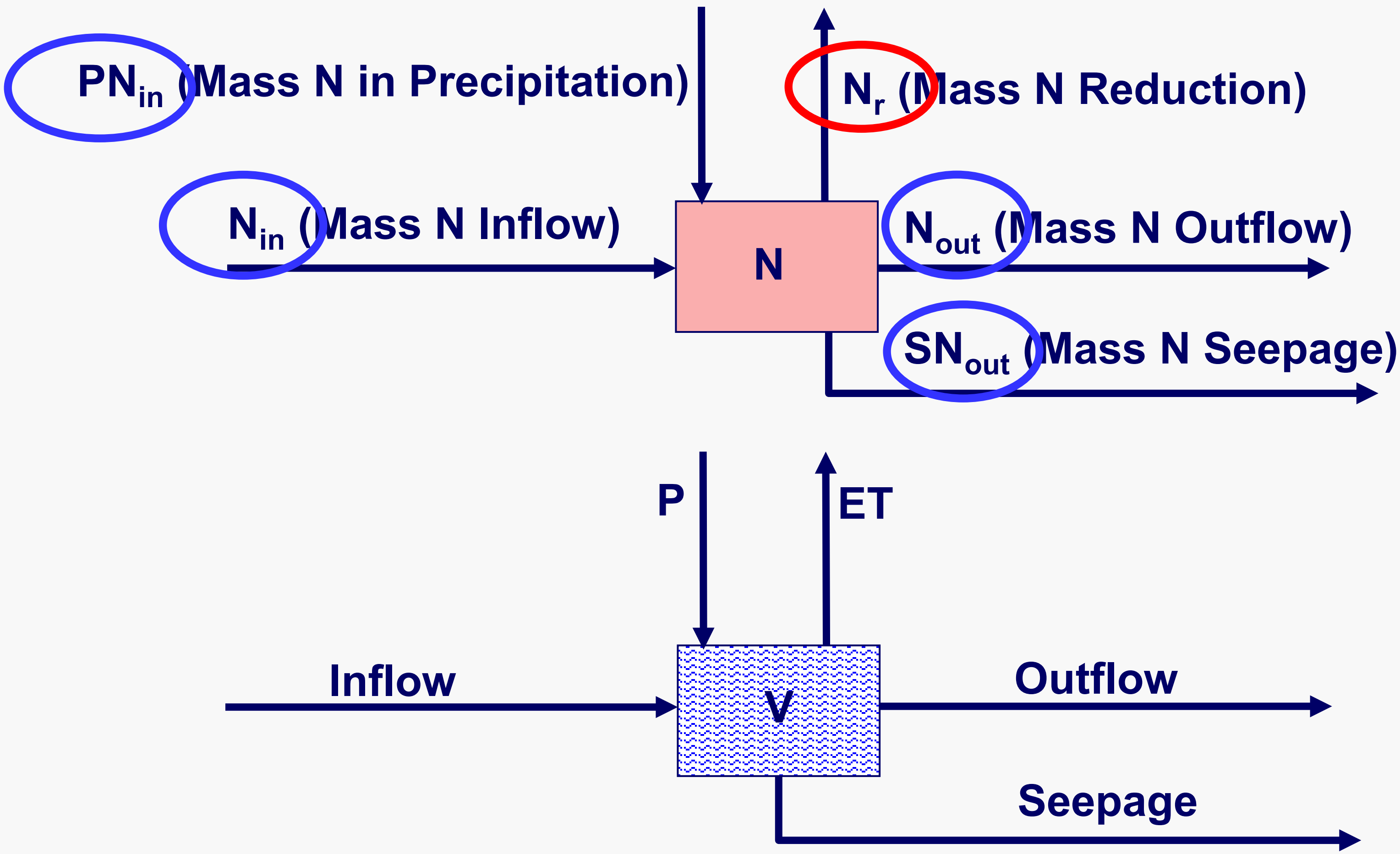
TN and NO_3-N Mass Balances

Directly estimated fluxes

Calculated from mass balance analyses

$N_r = N_{in} + PN_{in} - N_{out} - SN_{out} - \Delta N$



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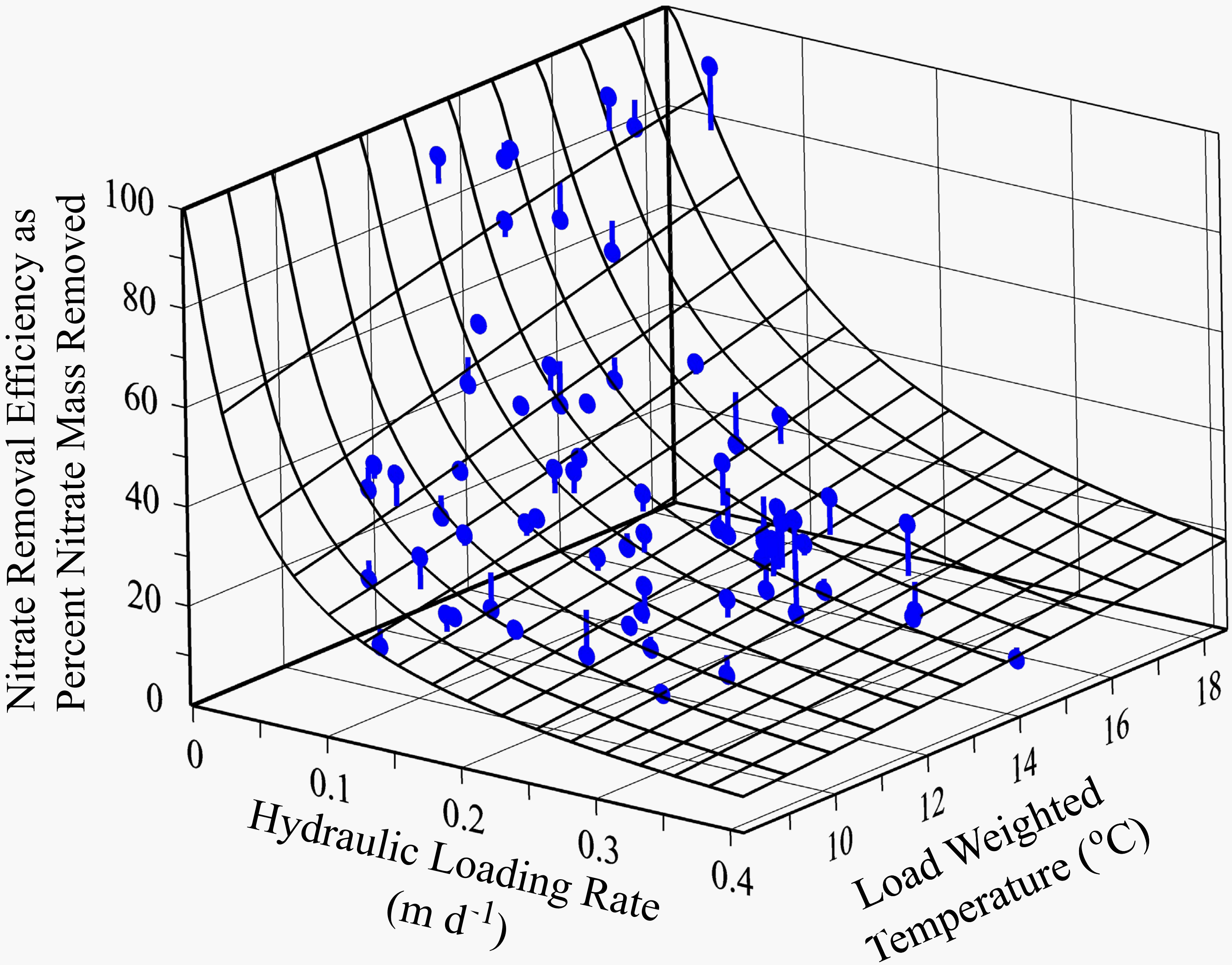
Effect of Hydraulic Loading Rate and Temperature on Nitrate Removal Efficiency

Twenty-six wetlands monitored for nitrate and TN, representing a total of 69 site-years of data

(Crumpton et. al 2020, Journal of Environmental Quality https://doi.org/10.1002/jeq2.20061)



R^2=0.93

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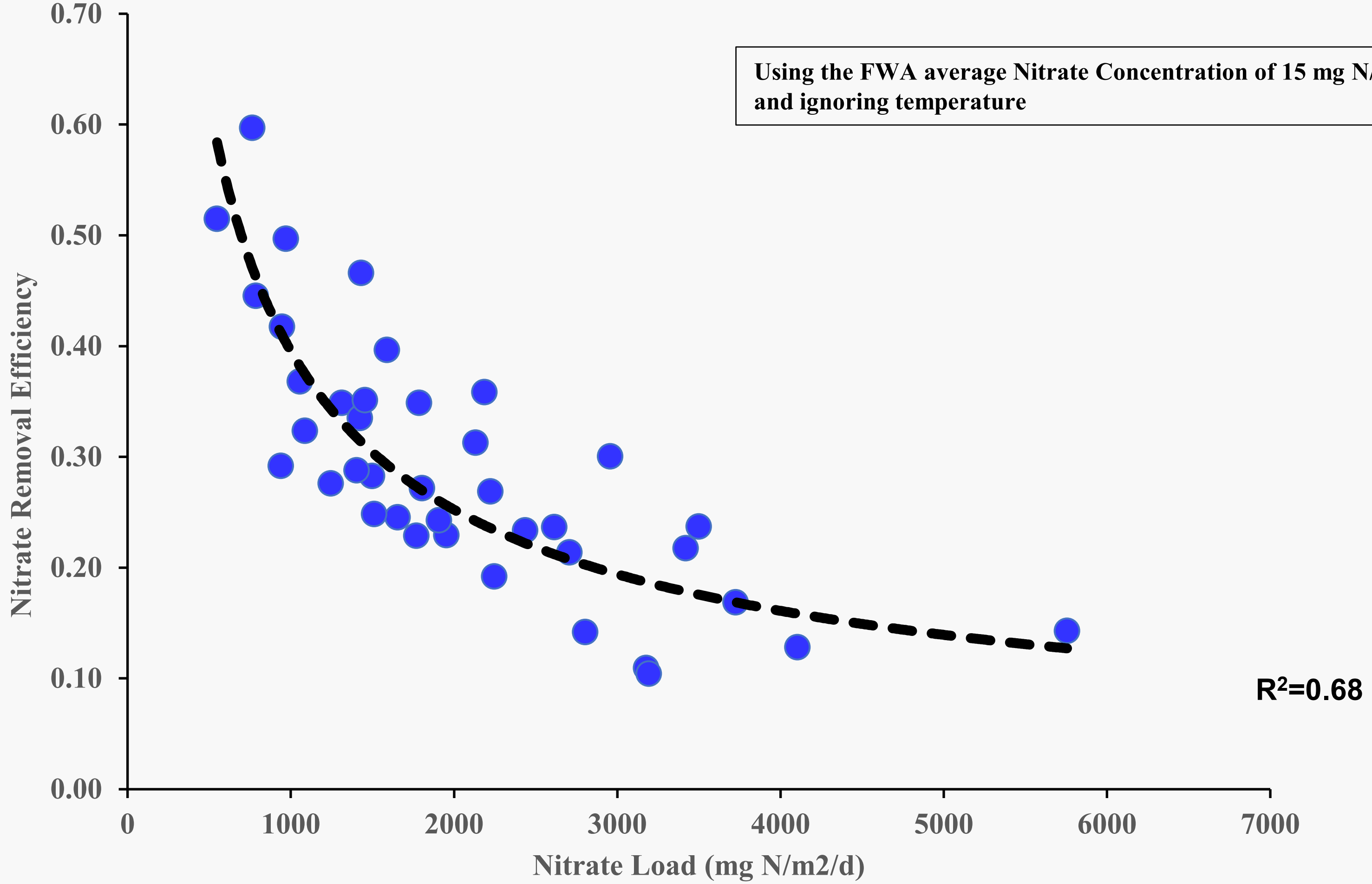
Nitrate Removal Efficiency as a Function of Nitrate Load Only

Seventeen wetlands monitored for NO_3 and dissolved N_2O loads, representing a total of 39 site-years of data



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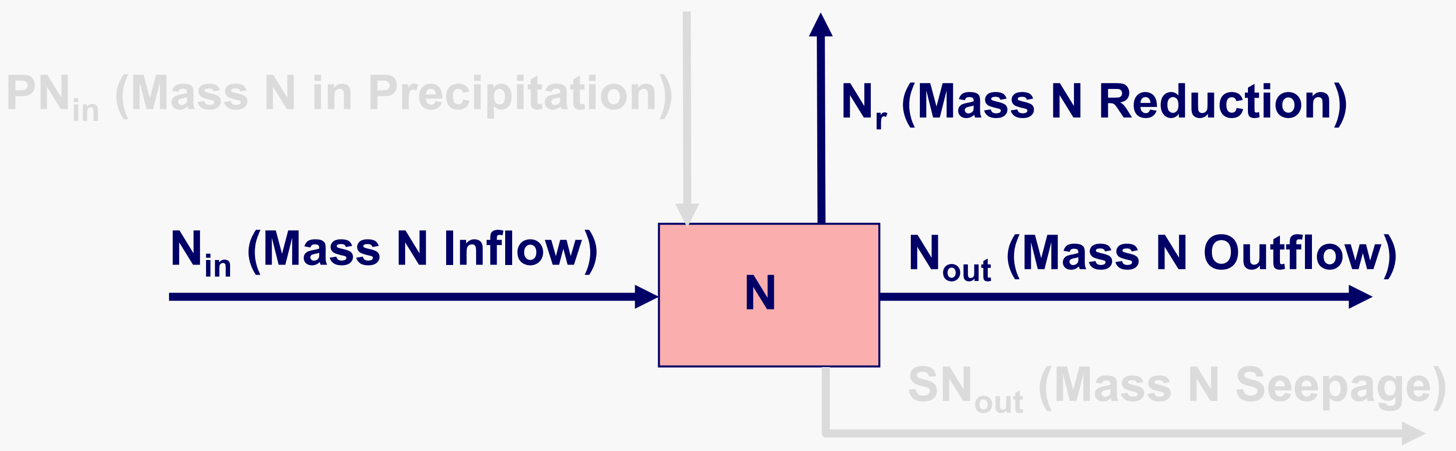
Coupled NO_3-N and N_2O-N Mass Balances



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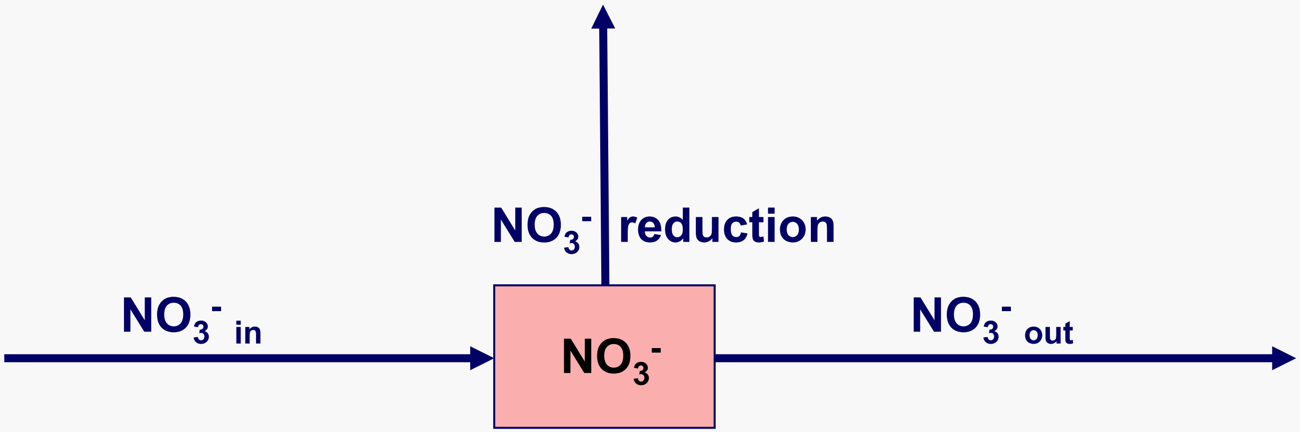

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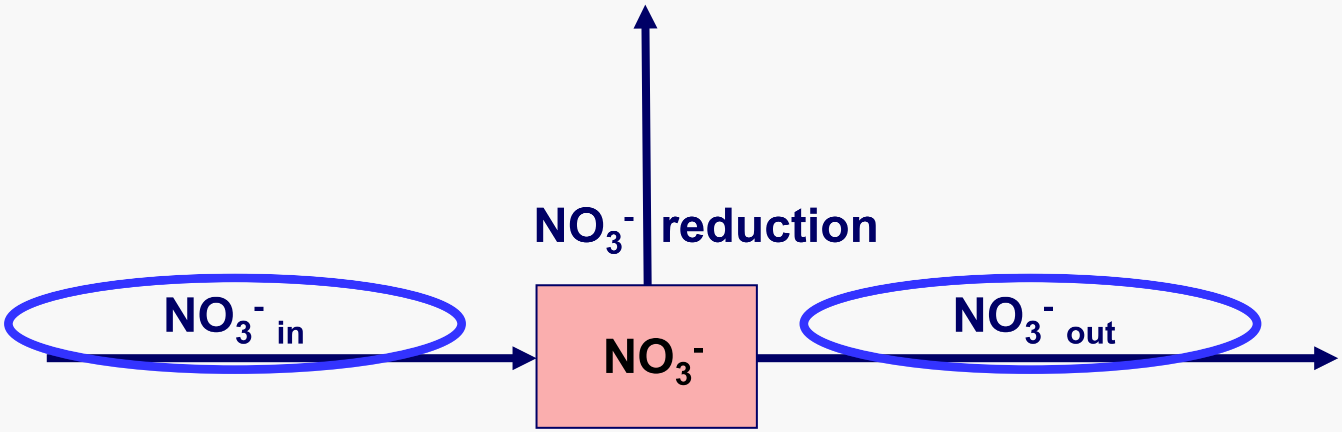
Directly estimated fluxes



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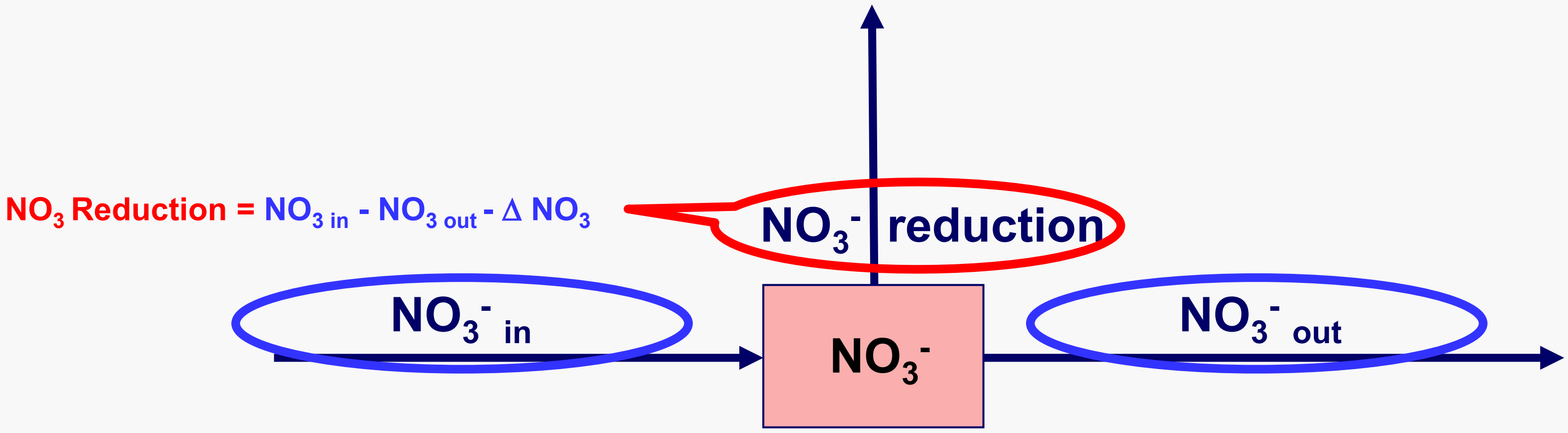
Directly estimated fluxes

Calculated from mass balance analyses



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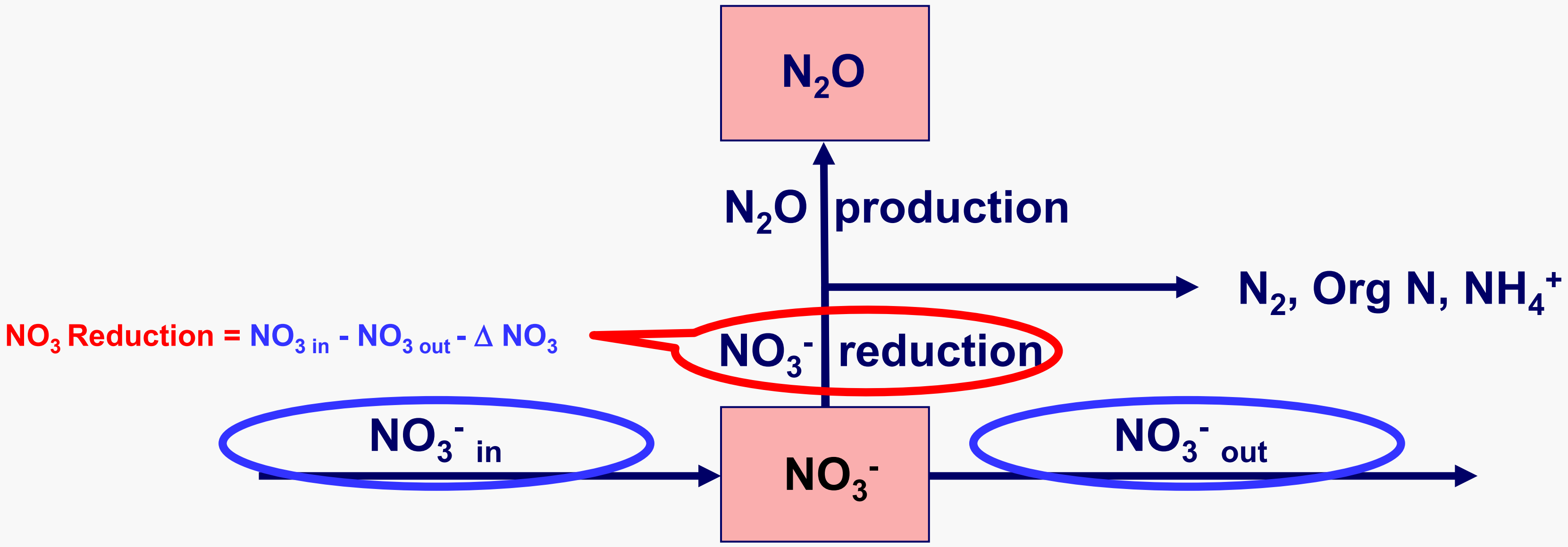

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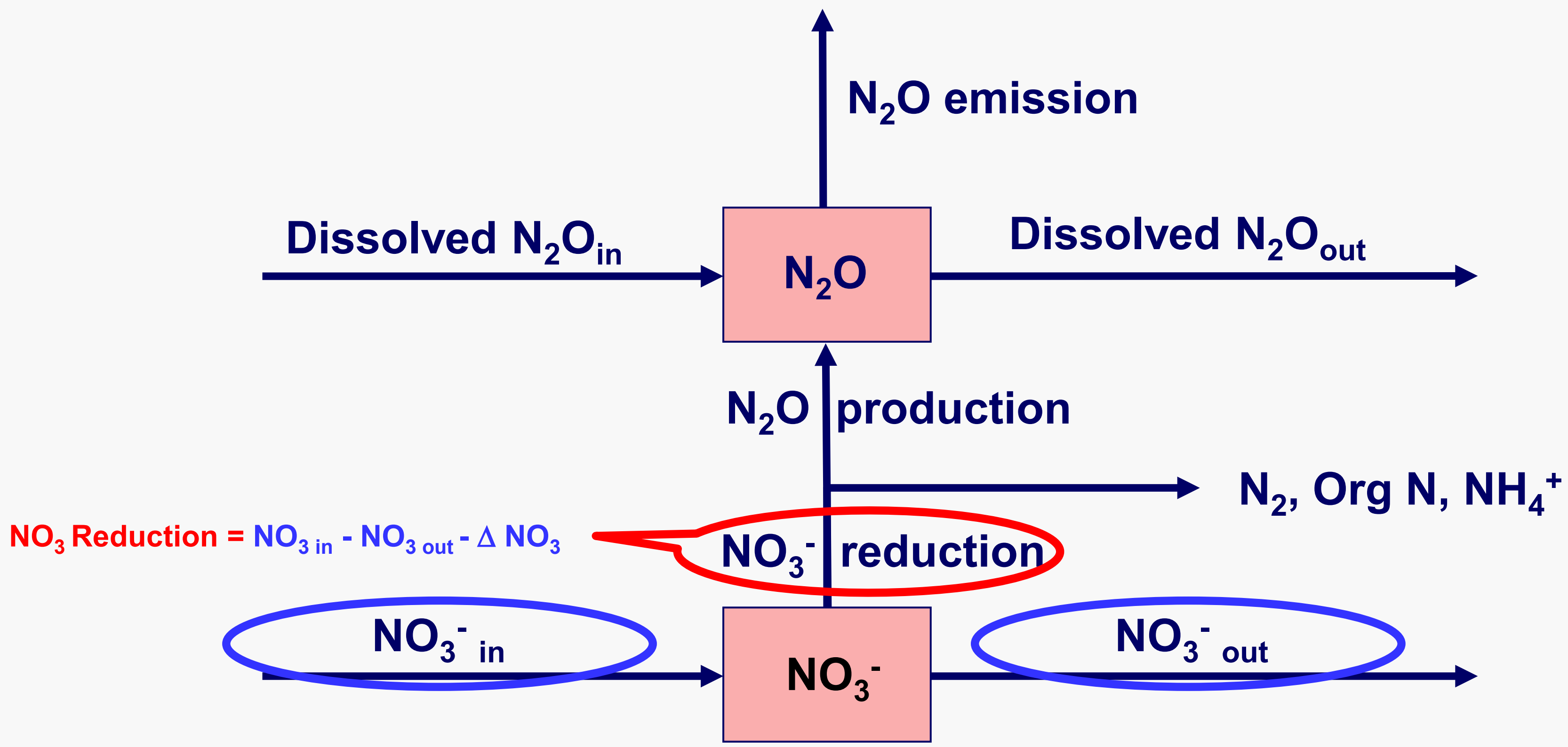

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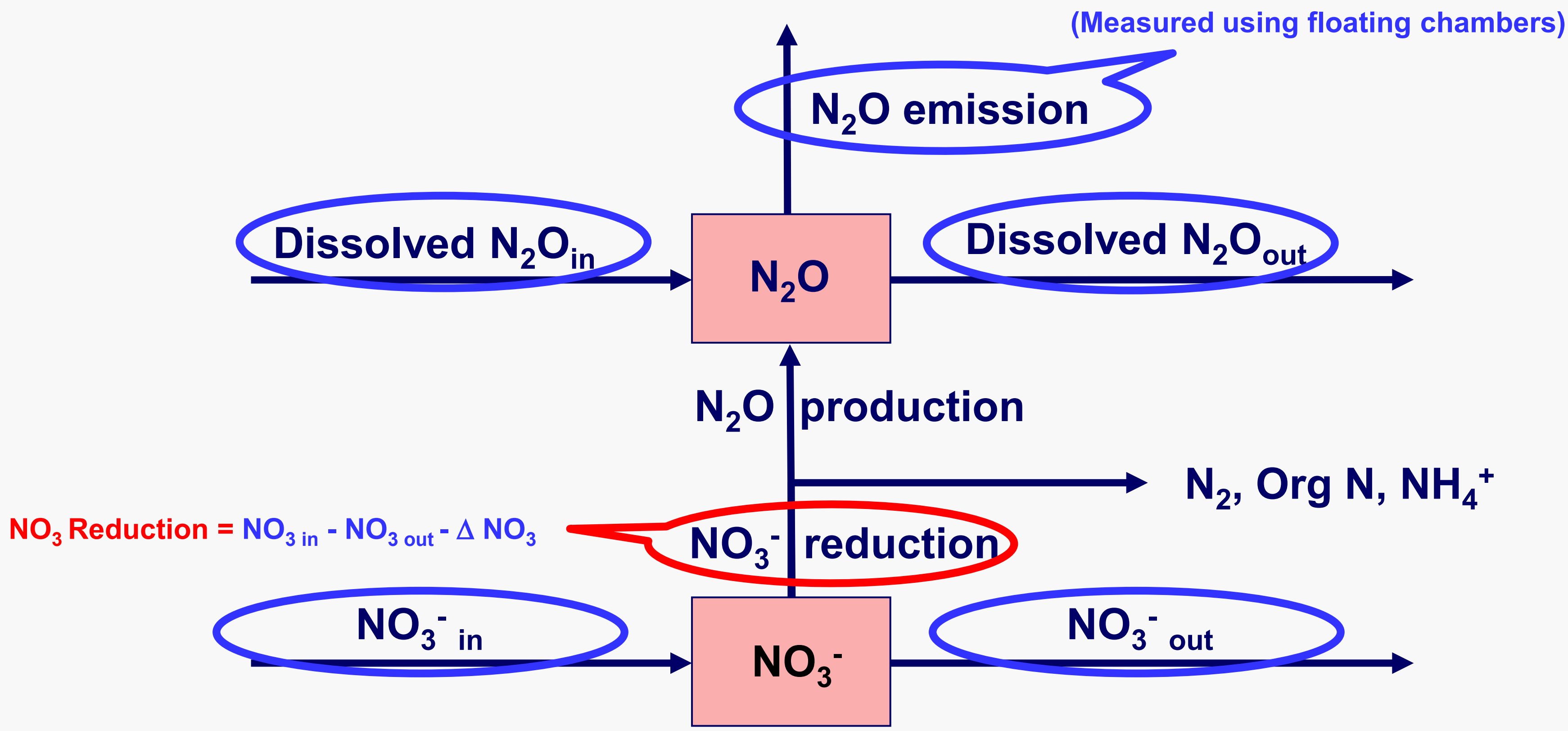

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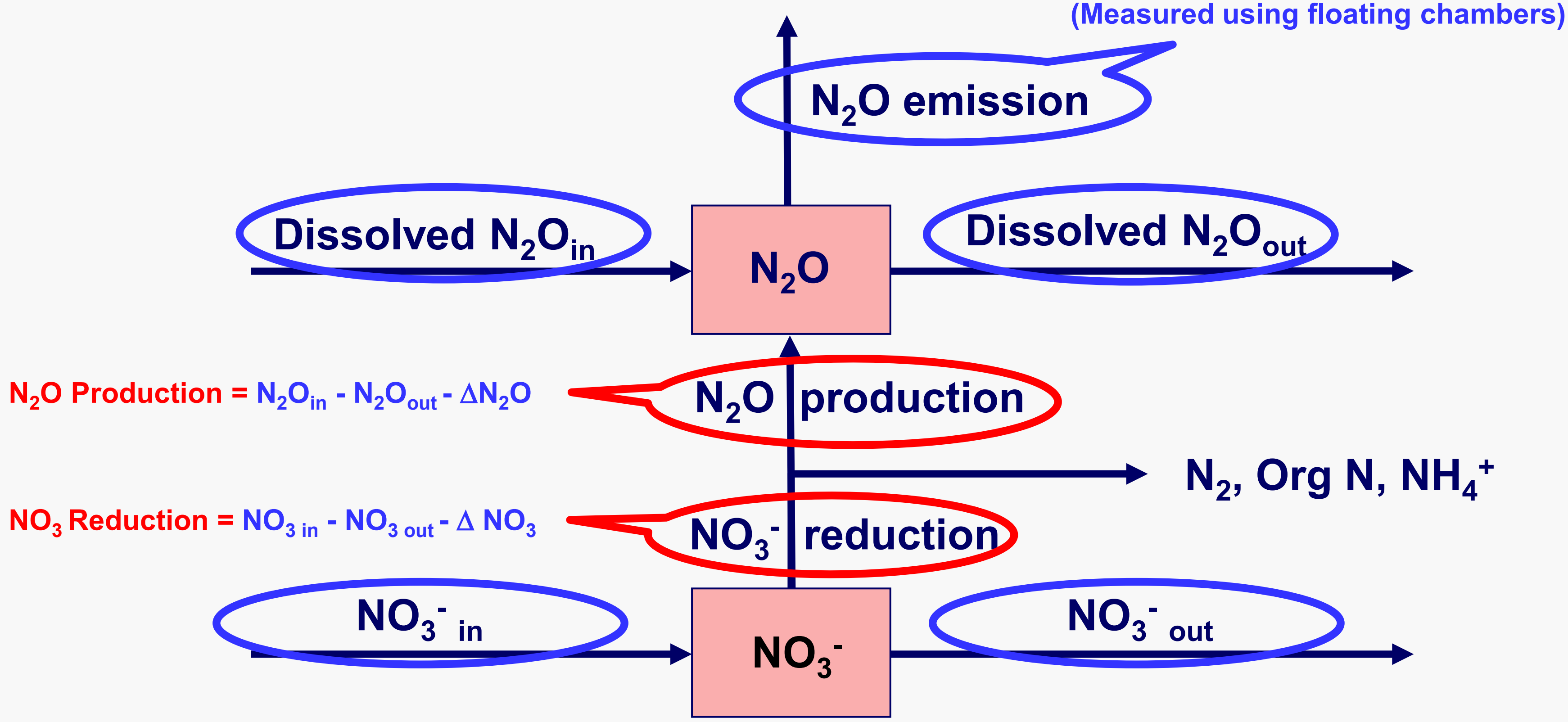

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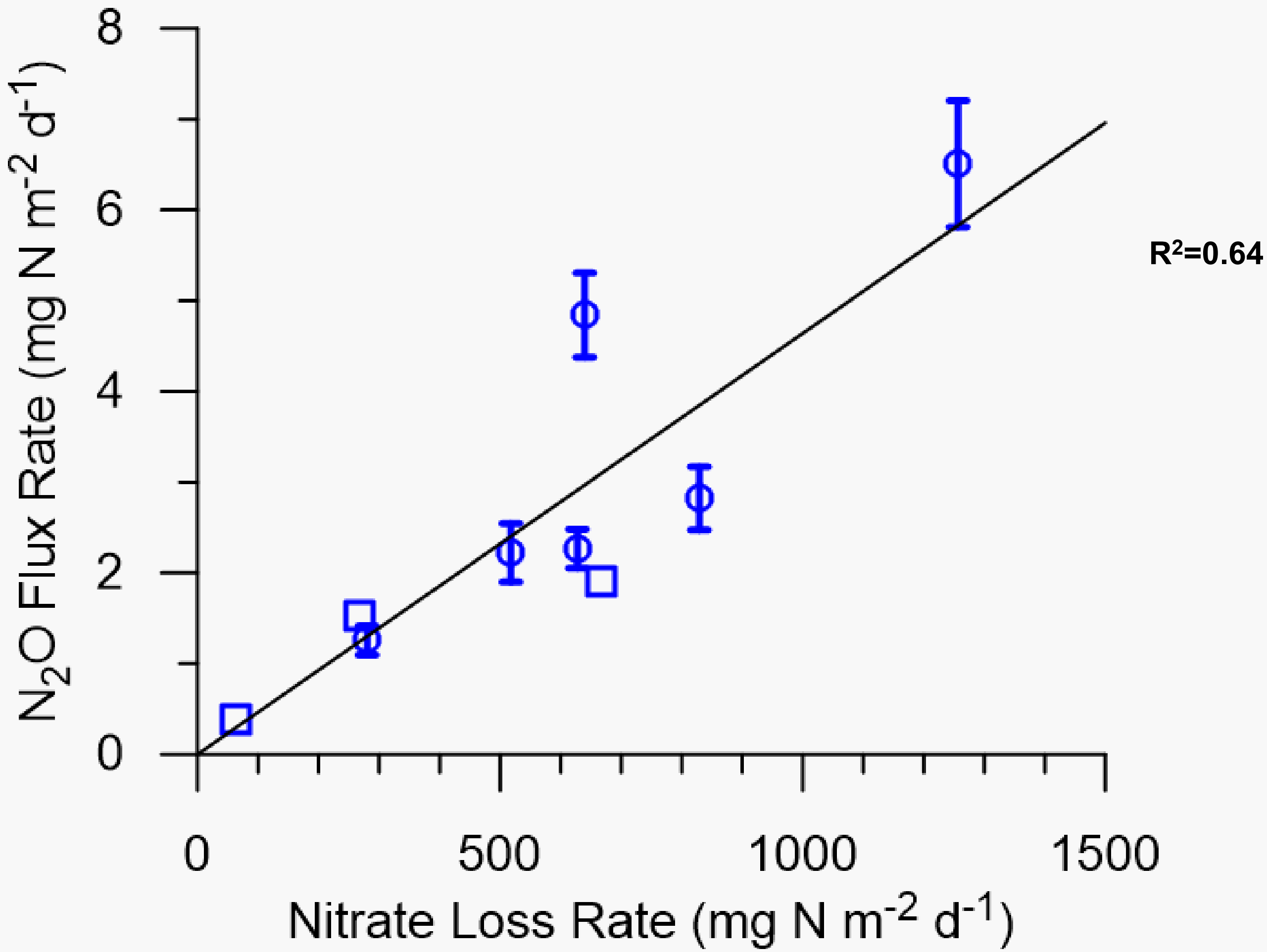
N_2O-N Production and Emission Increased with Increases in Nitrate Loading and Loss Rates

However, conversion efficiency was very high, with an average N_2O-N production : NO_3-N reduction ratio of 0.5%. Similar results were found using enclosure studies.



Five wetlands monitored for NO_3 and N_2O fluxes, representing a total of 9 site-years of data. H. Hoglund et al., In Review

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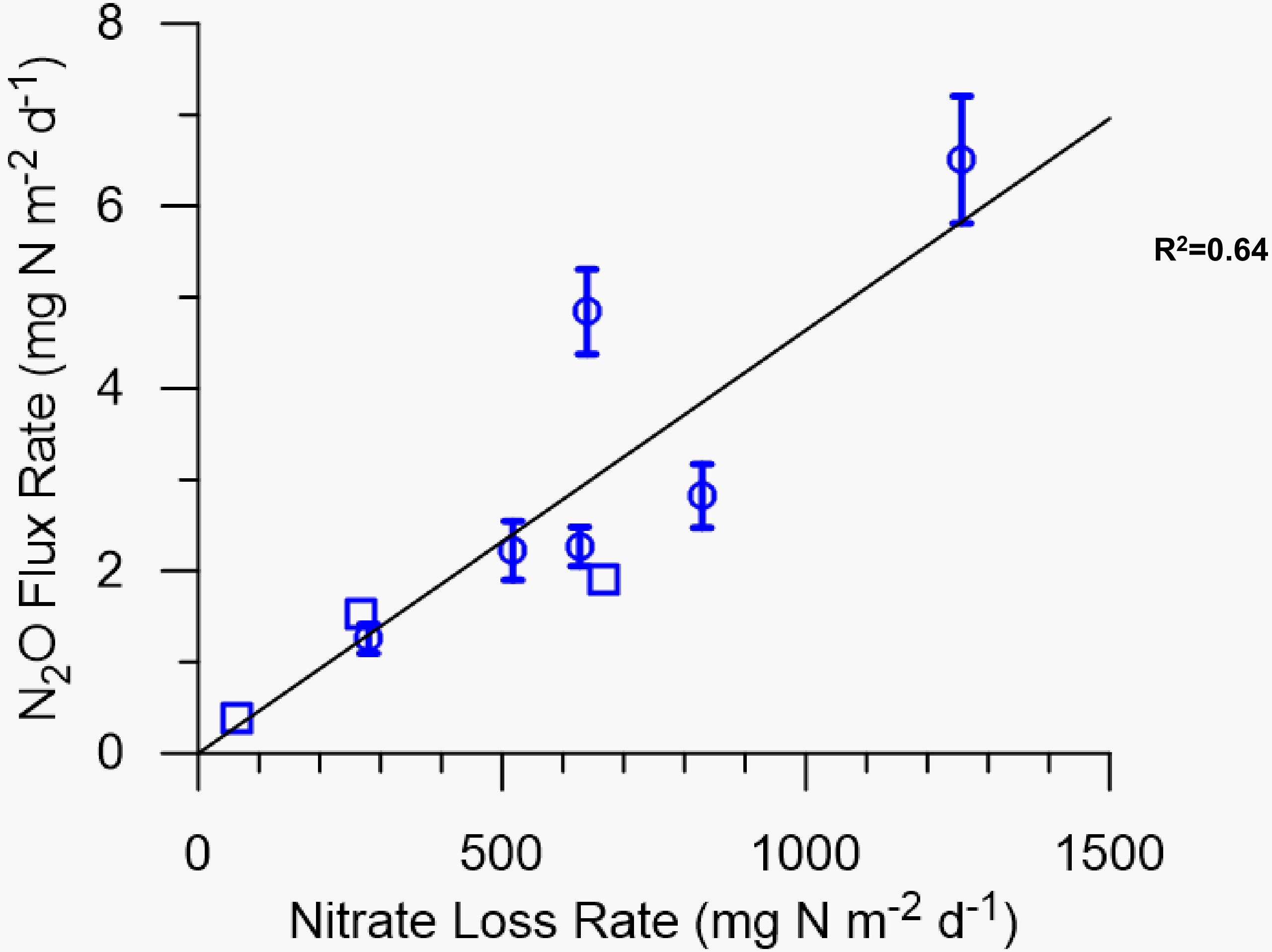

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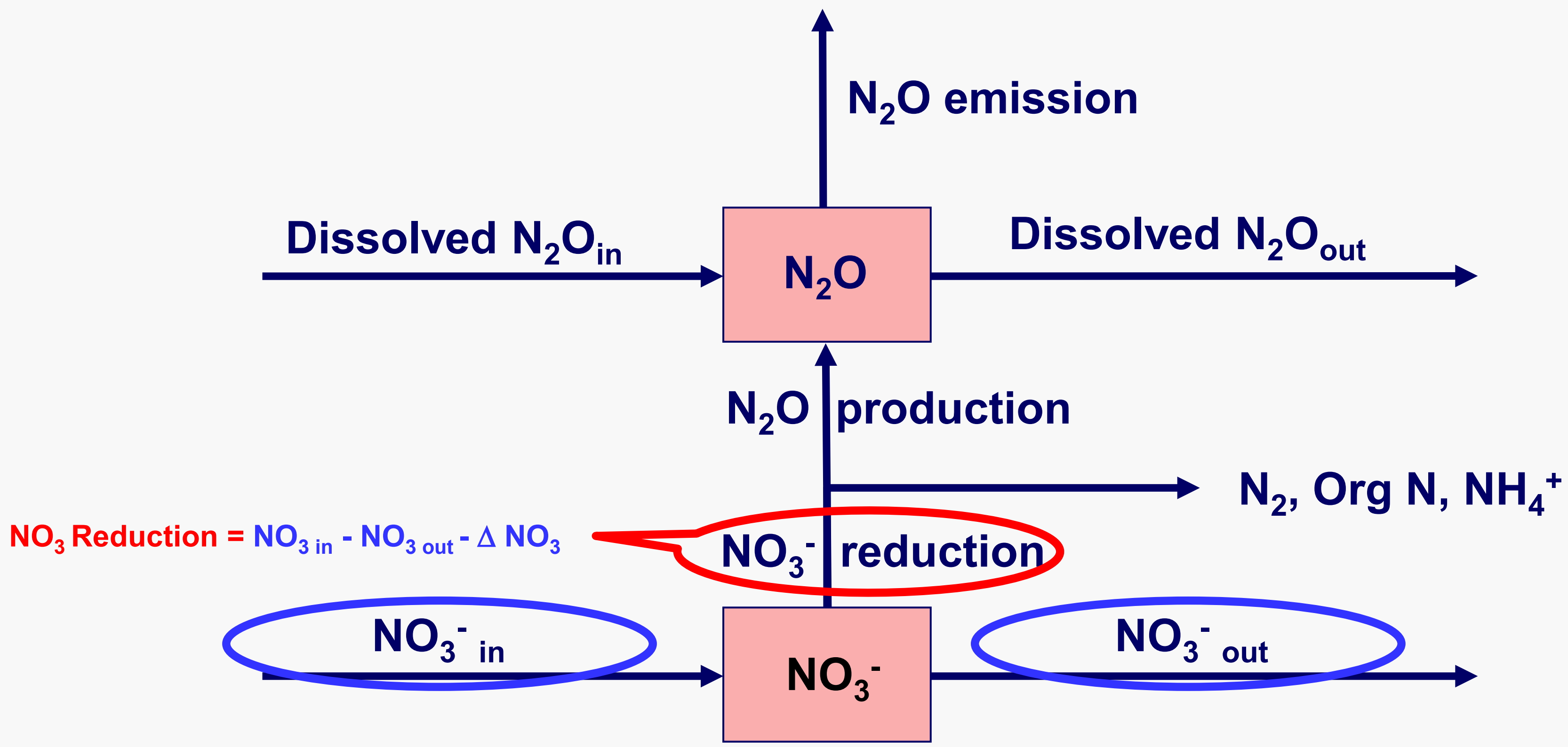
Extending N_2O Mass Balances Using N_2O-N Production:NO_3-N Reduction Ratio

Nitrate reduction calculated from nitrate mass balance.

→ N_2O-N production calculated as 0.5% nitrate-N reduction.

→ N_2O-N emission calculated from N_2O-N mass balance.



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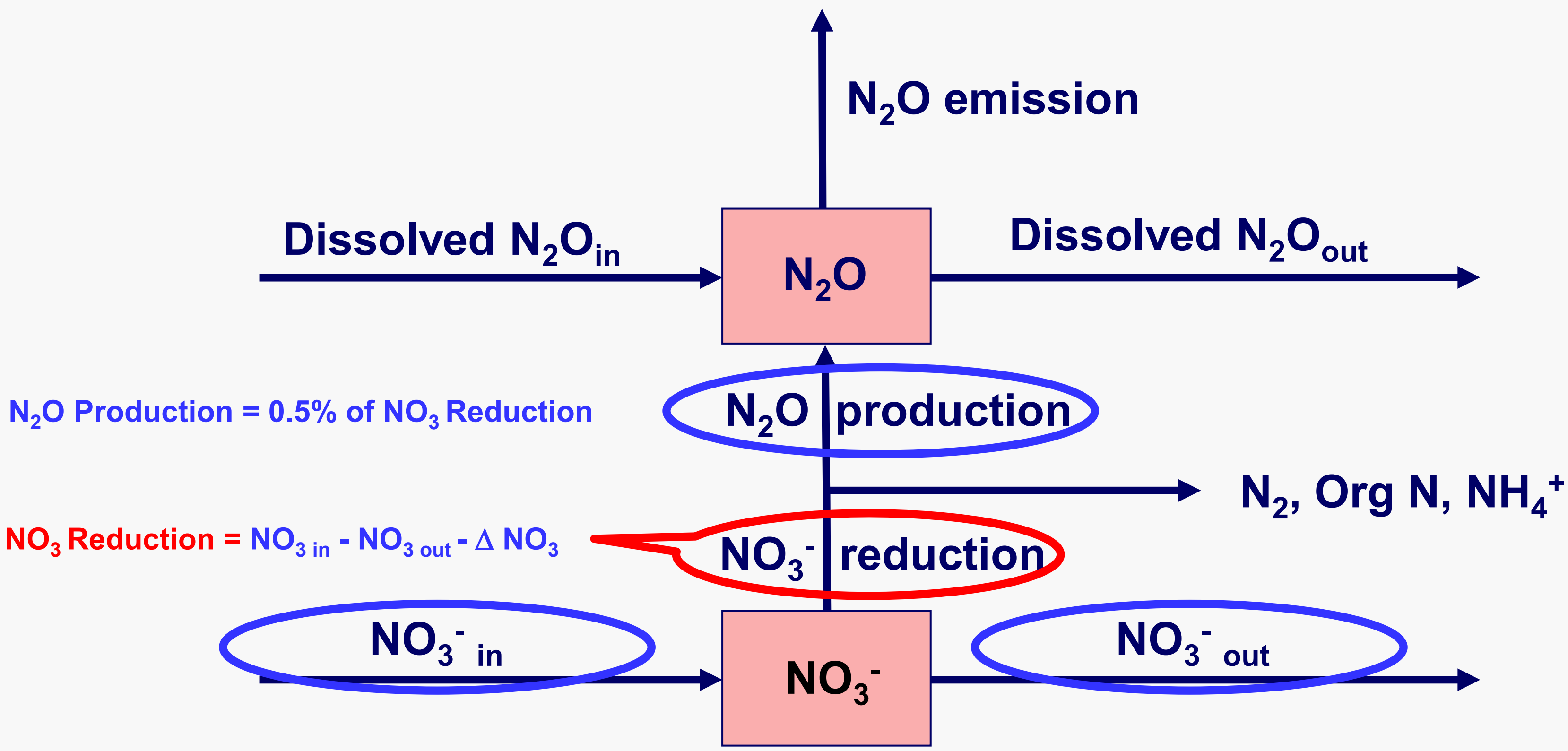

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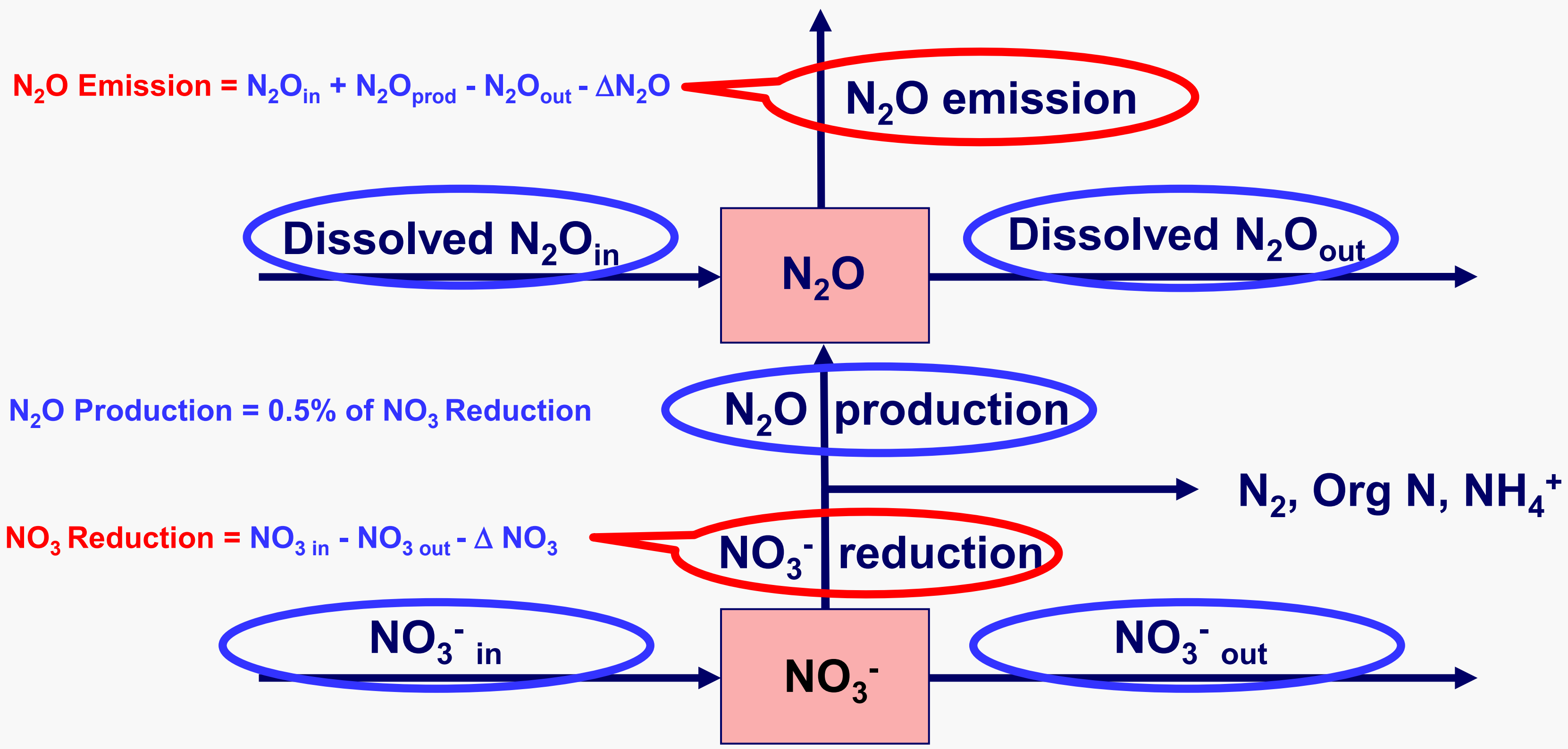
→ **N_2O-N emission calculated from N_2O-N mass balance.**

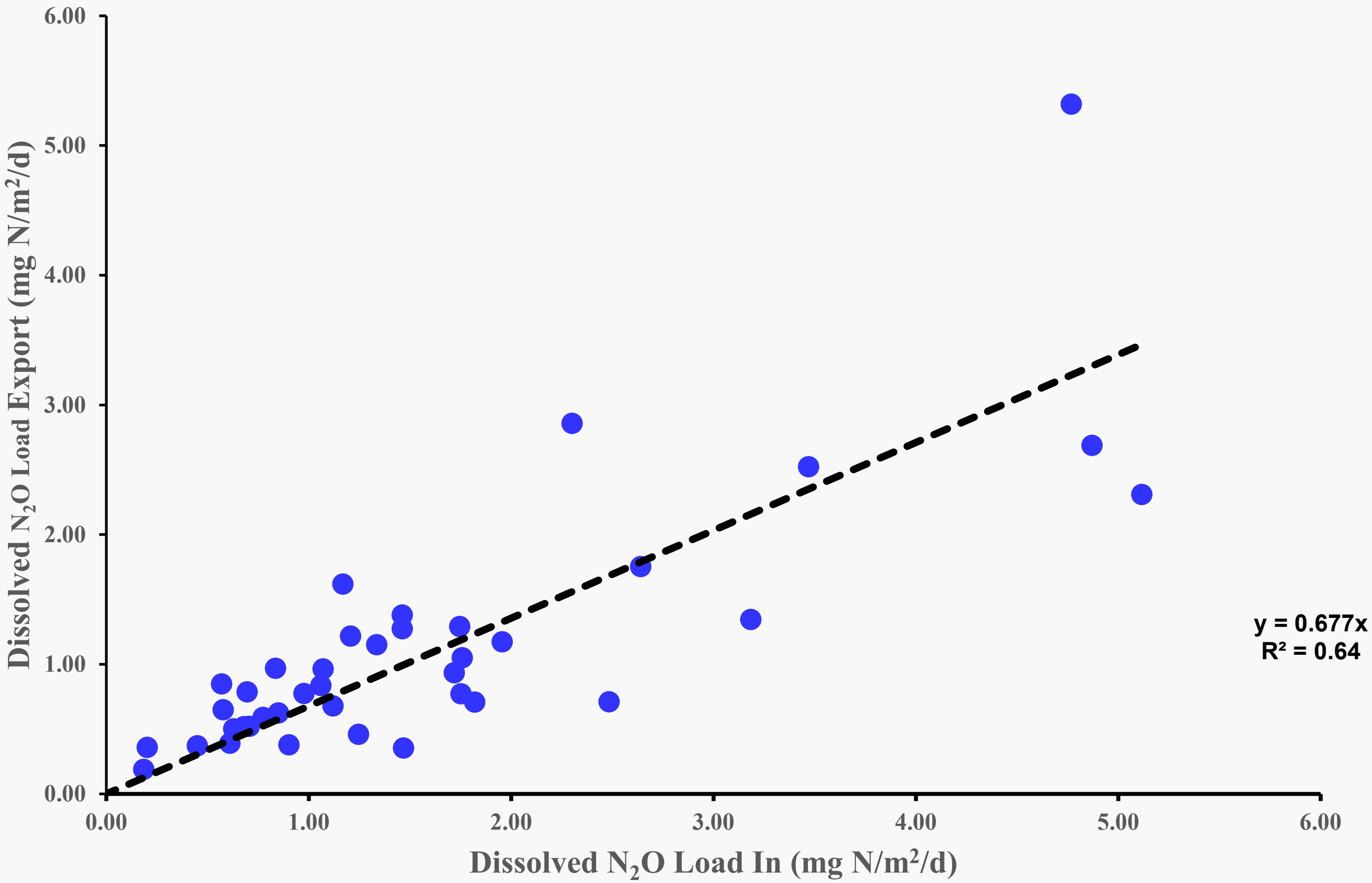


Seventeen wetlands monitored for NO_3 and dissolved N_2O loads, representing a total of 39 site-years of data

W.G. Crumpton, Iowa State University

Dissolved N_2O Export vs Dissolved N_2O Load to the Wetlands

Dissolved N_2O exported from the wetlands was about one third less than the dissolved N_2O load entering the wetlands.



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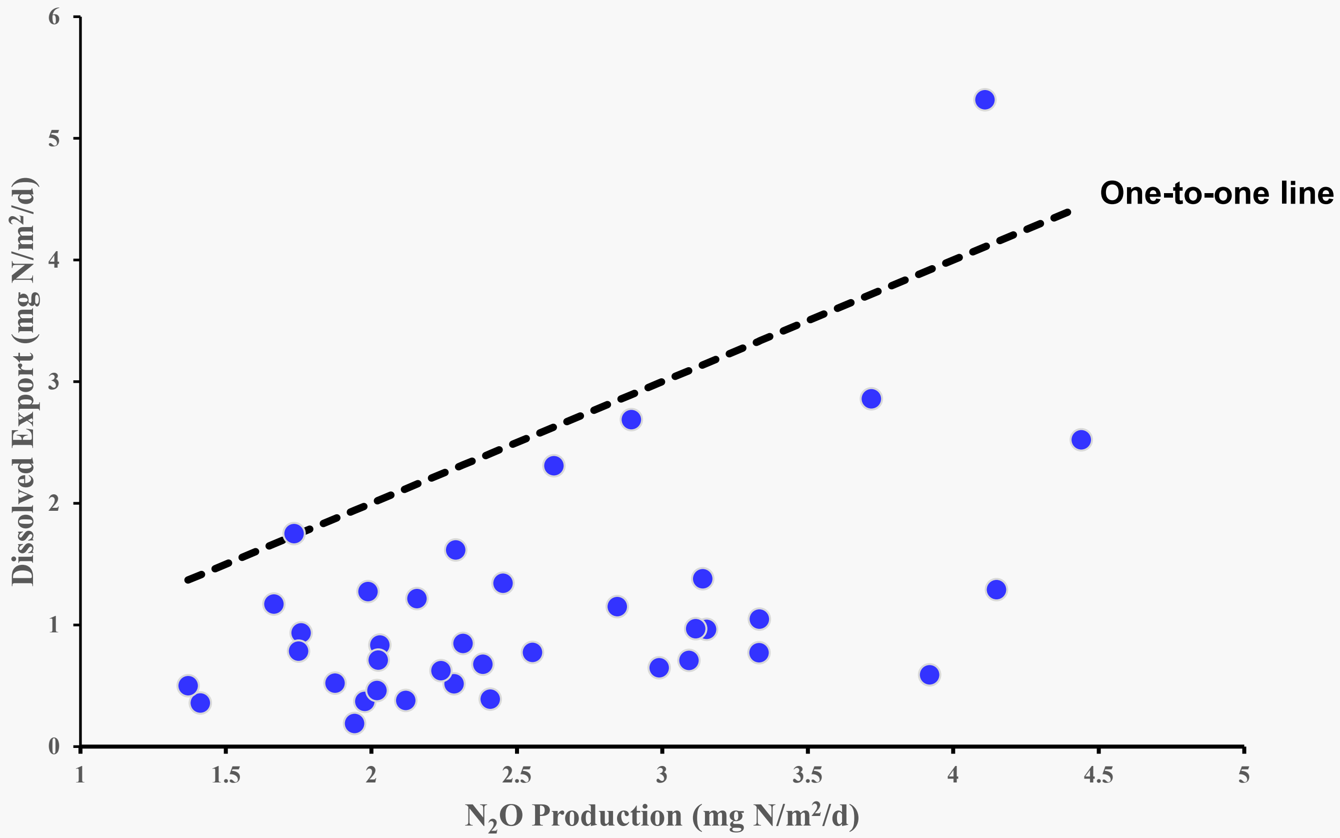
N_2O Emission and Dissolved Export vs N_2O Production Within the Wetlands

N_2O production within the wetlands nearly always exceeded dissolved N_2O export from the wetlands.



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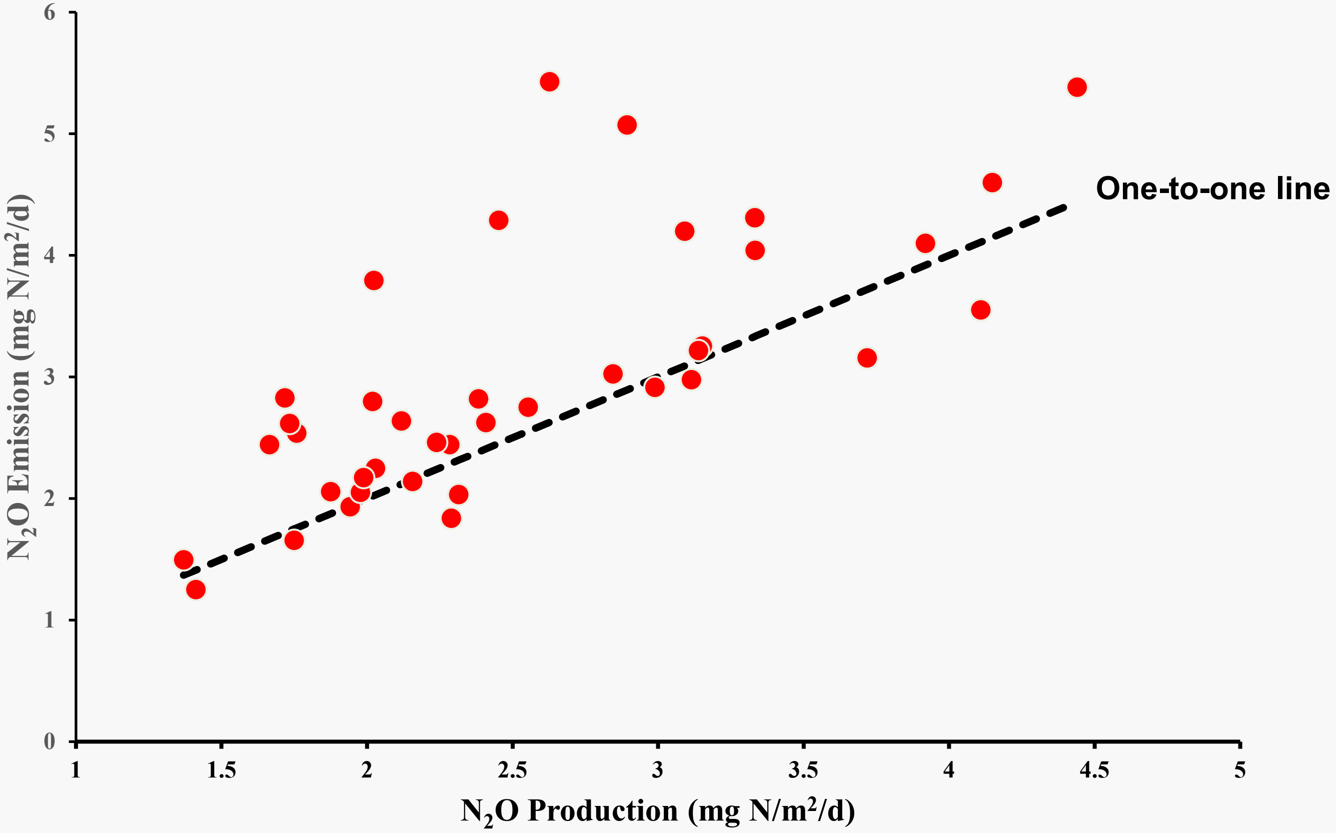
N_2O Emission vs N_2O Production Within the Wetlands

N_2O emission frequently exceeded N_2O production within the wetlands, suggesting the importance of dissolved N_2O load as a source of emissions.



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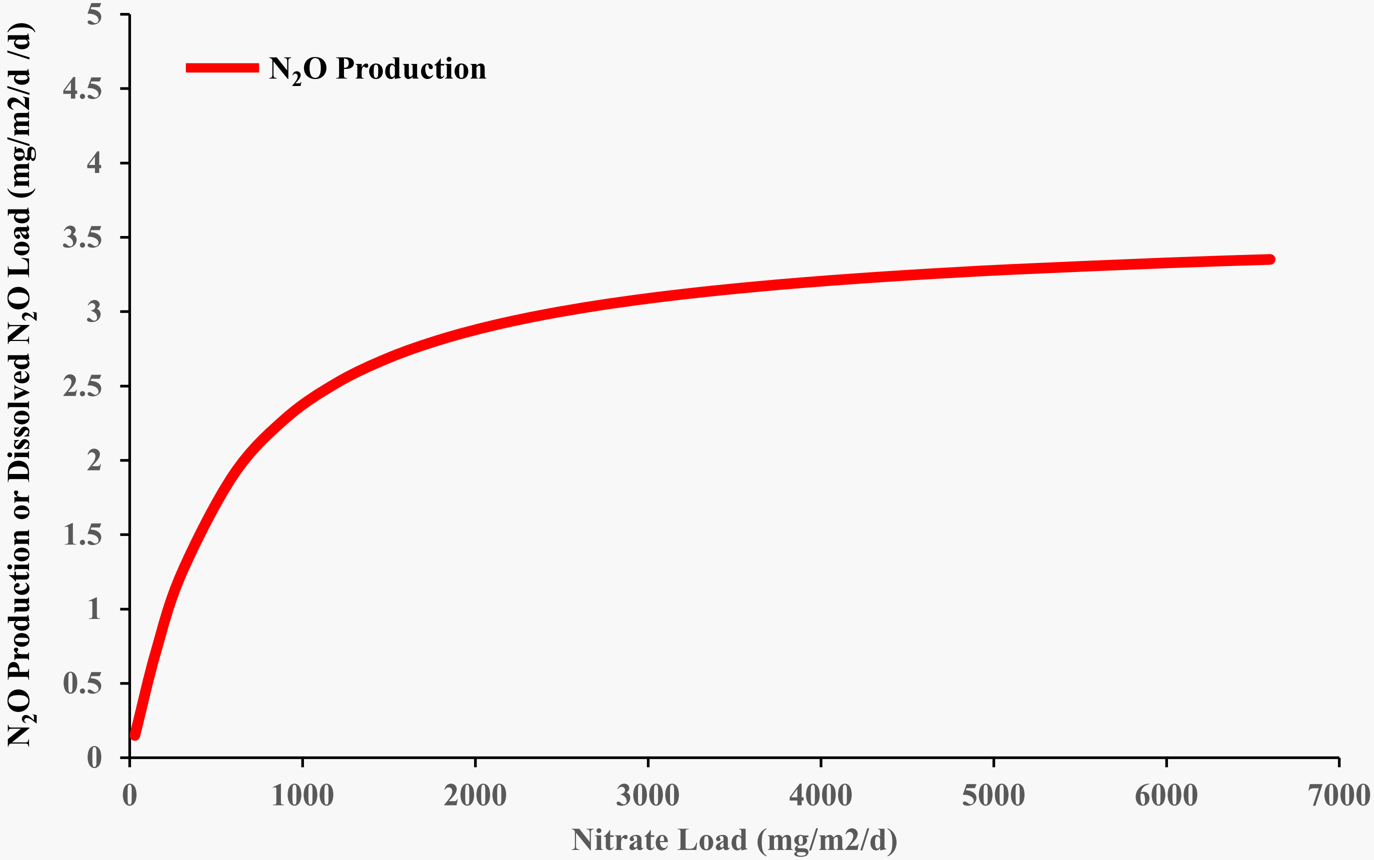
Both N_2O Production Within the Wetlands and Dissolved N_2O Load to the Wetlands Increased with Increasing Nitrate Load, but as Different Functions



>N_2O-N production = 0.5% of Mass NO_3-N reduction

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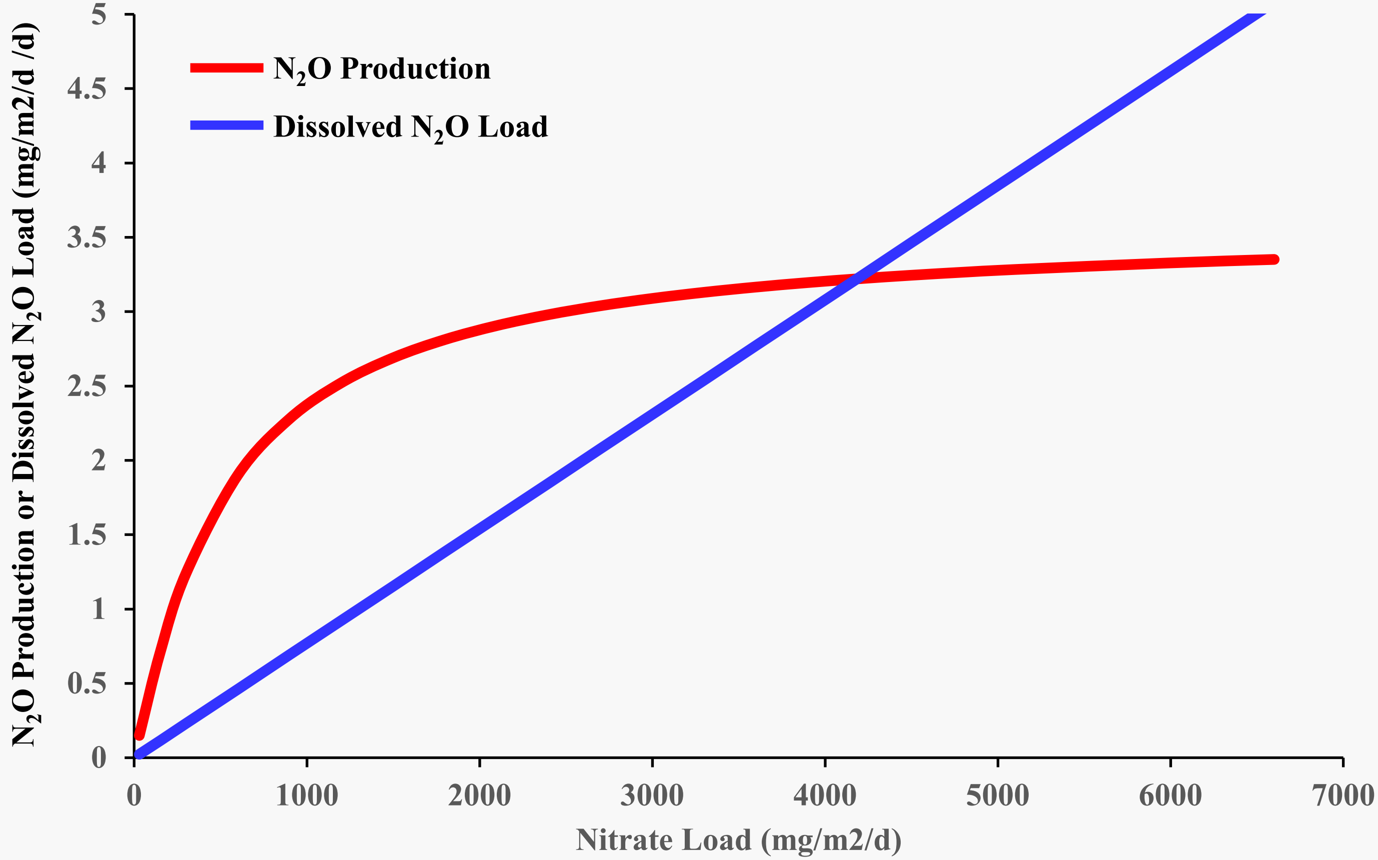

>N_2O-N production = 0.5% of Mass NO_3-N reduction
>Dissolved N_2O-N load = 0.078% of NO_3-N Load

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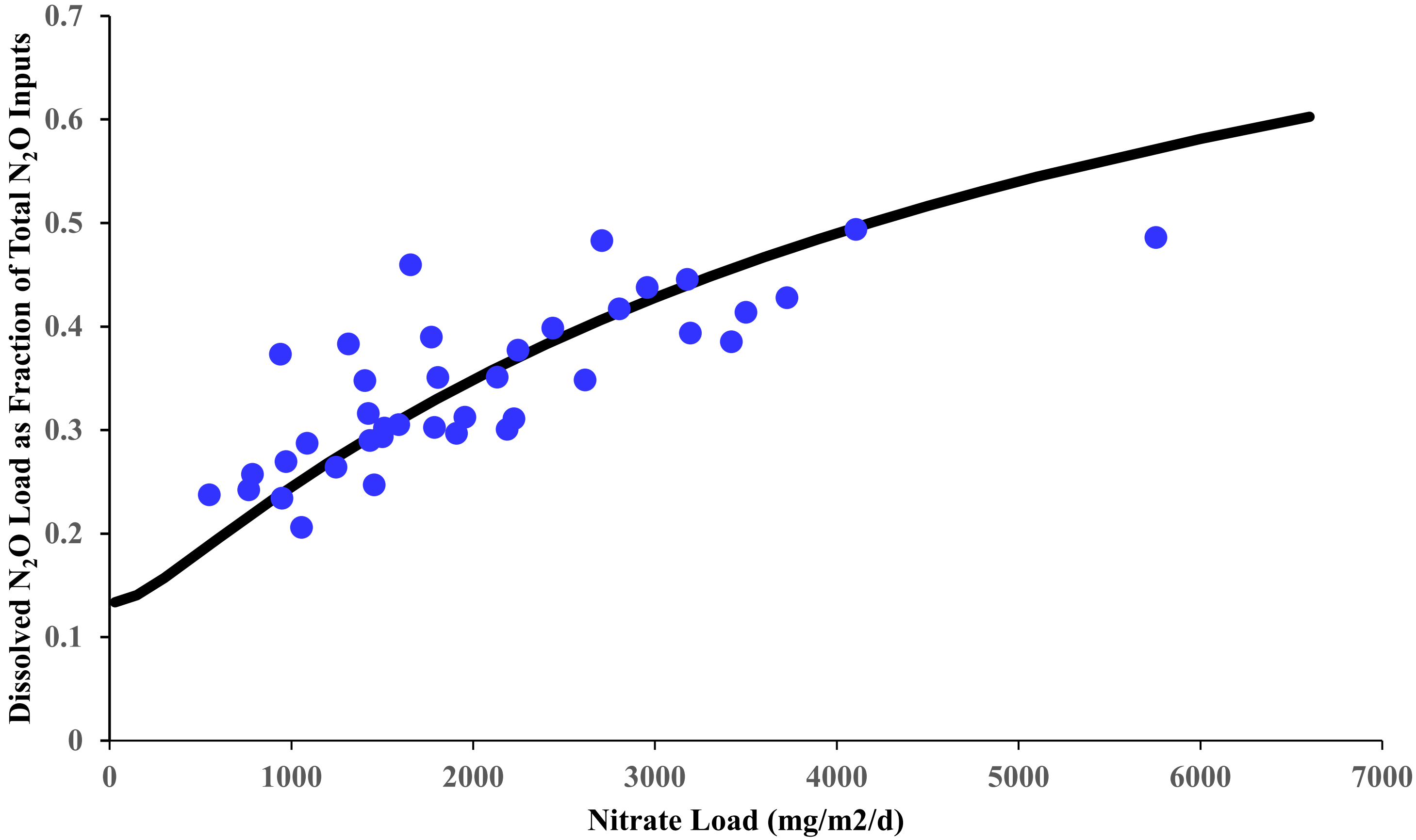
As a result, the Relative Contribution of Dissolved N_2O Load to Total N_2O Inputs Increases with Increasing Nitrate Load



>Total N_2O-N inputs = sum (N_2O-N production and dissolved N_2O-N load)
>Dissolved N_2O-N load measured directly
>N_2O-N production = 0.5% of Mass NO_3-N reduction

W.G. Crumpton, Iowa State University

Key Takeaways

- Wetlands can be effective sinks for NPS nitrate loads across a broad range of conditions
- N_2O production increases with increasing nitrate load, but conversion efficiency is very high
- N_2O emission can significantly exceed N_2O production in wetlands, suggesting the importance of dissolved N_2O loads as a source of emissions
- Dissolved N_2O loads and exports increase with nitrate load and can be a significant fraction of total N_2O inputs and outputs

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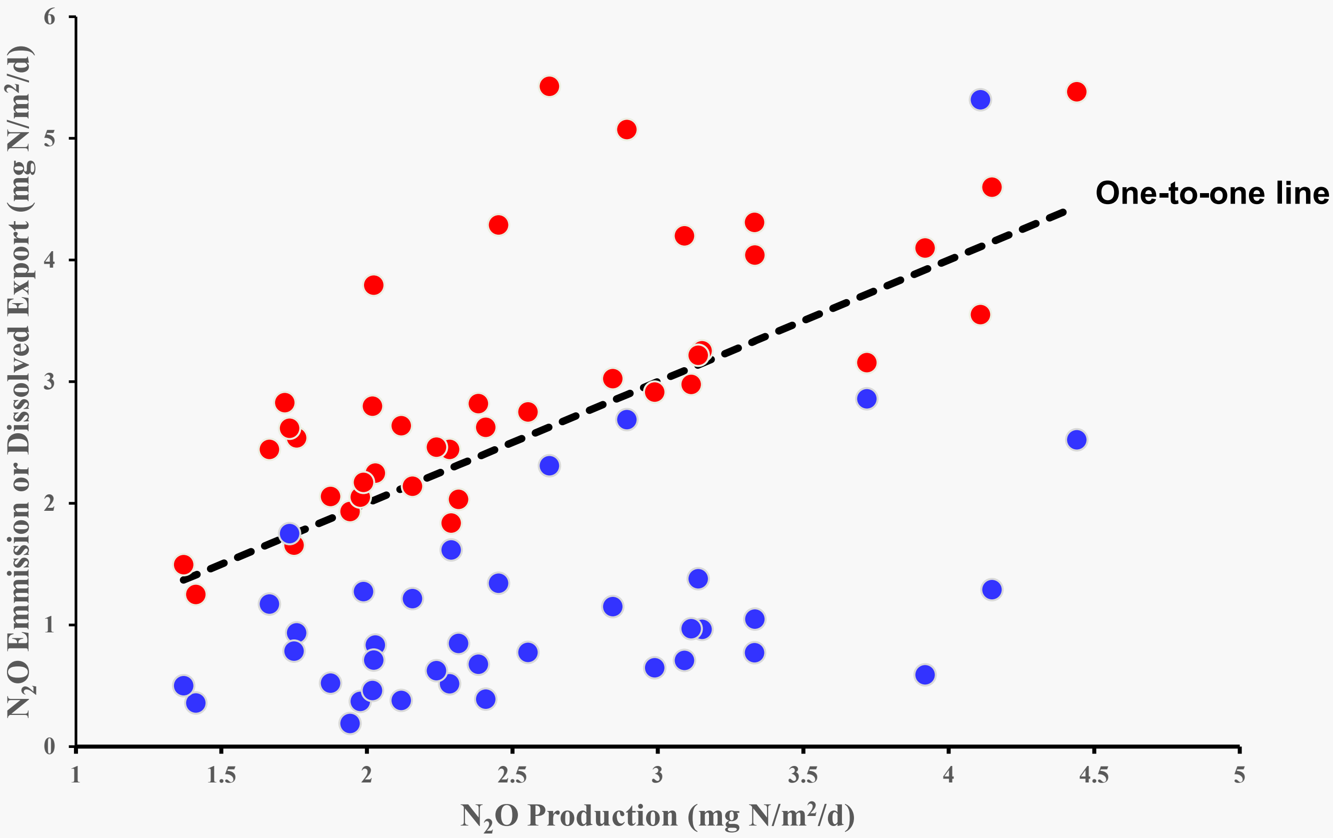

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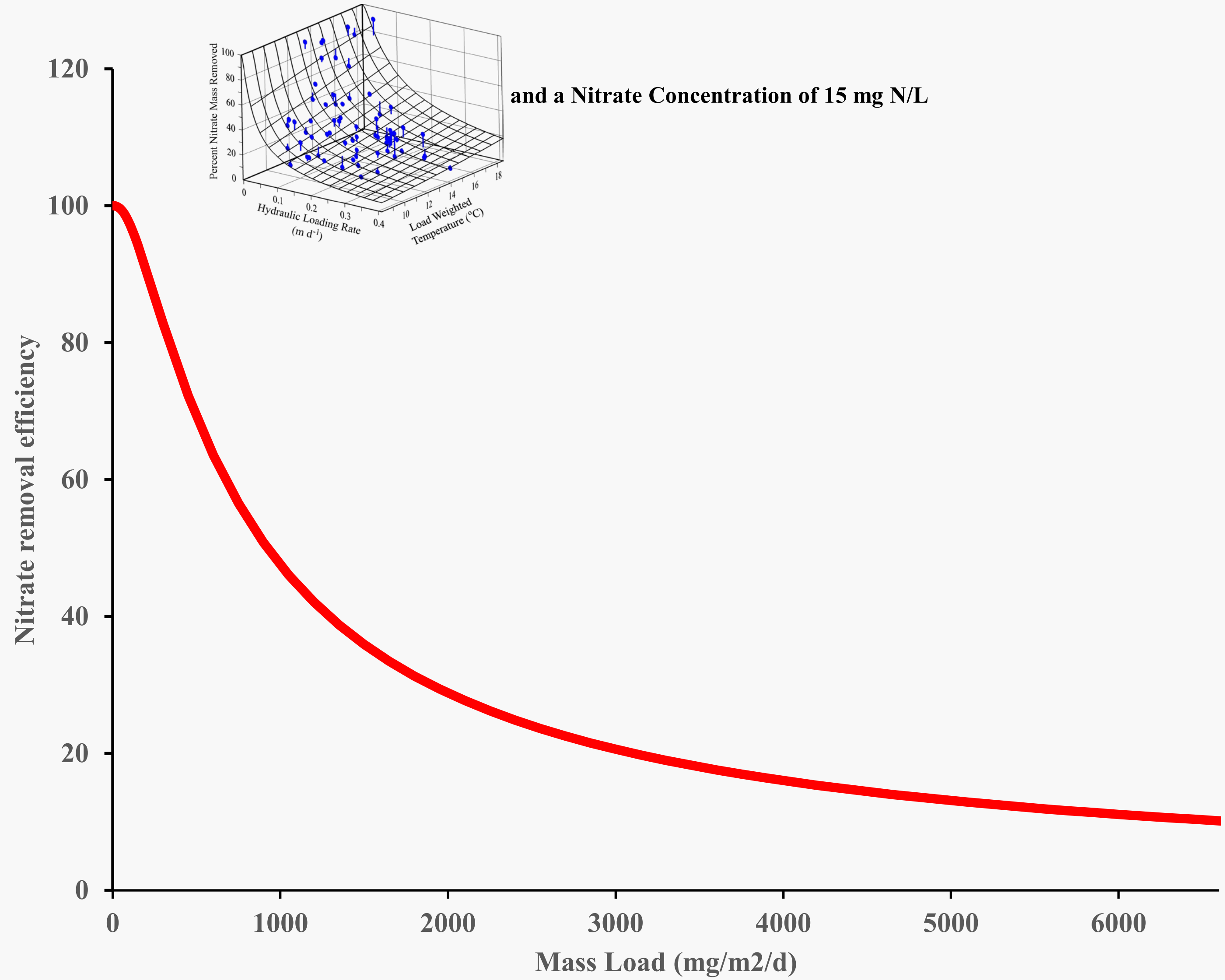
Nitrate Removal Efficiency and Nitrate Mass Loss as Function of Nitrate Load Only

and a Nitrate Concentration of 15 mg N/L



R^2=0.68

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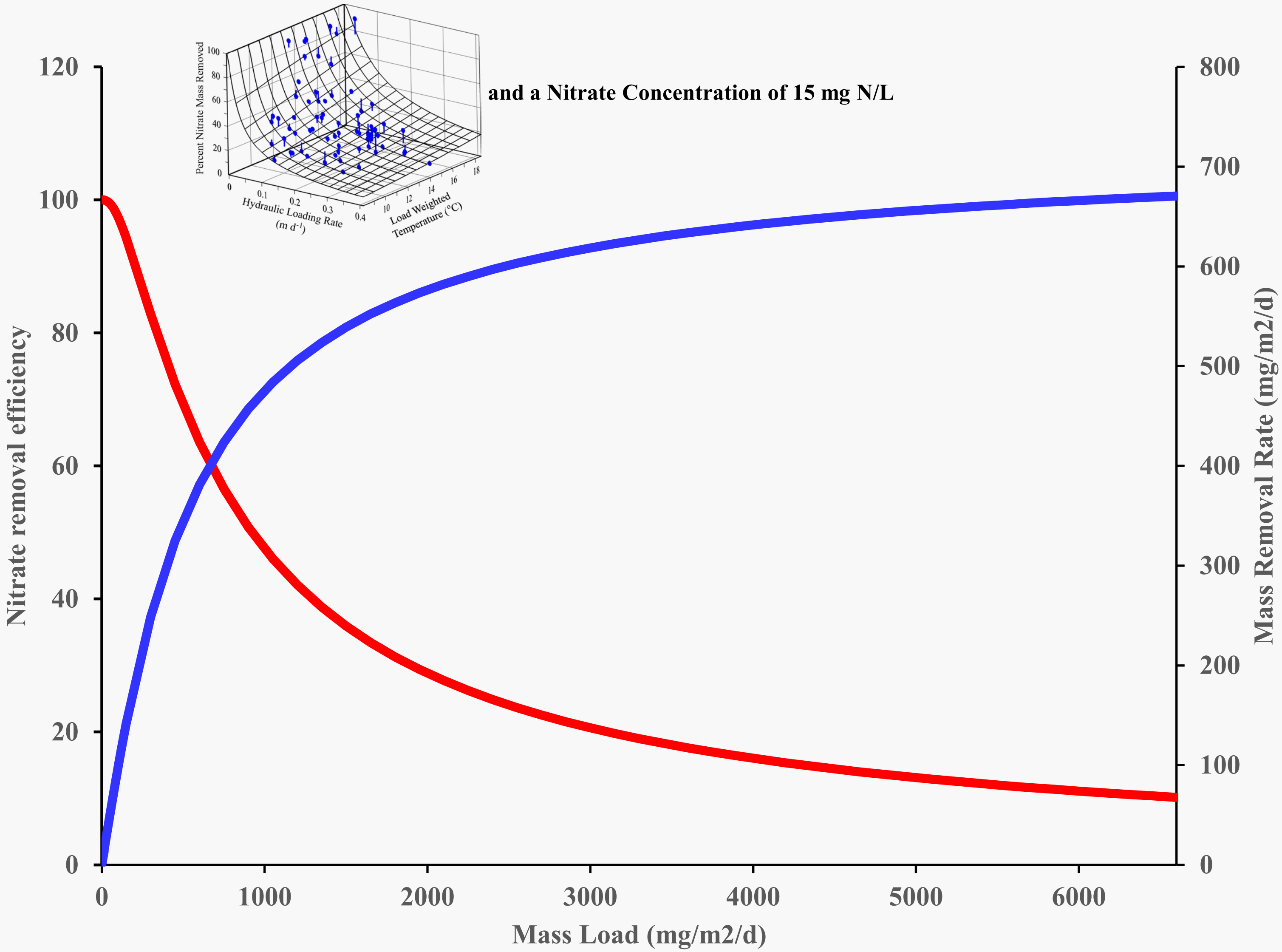

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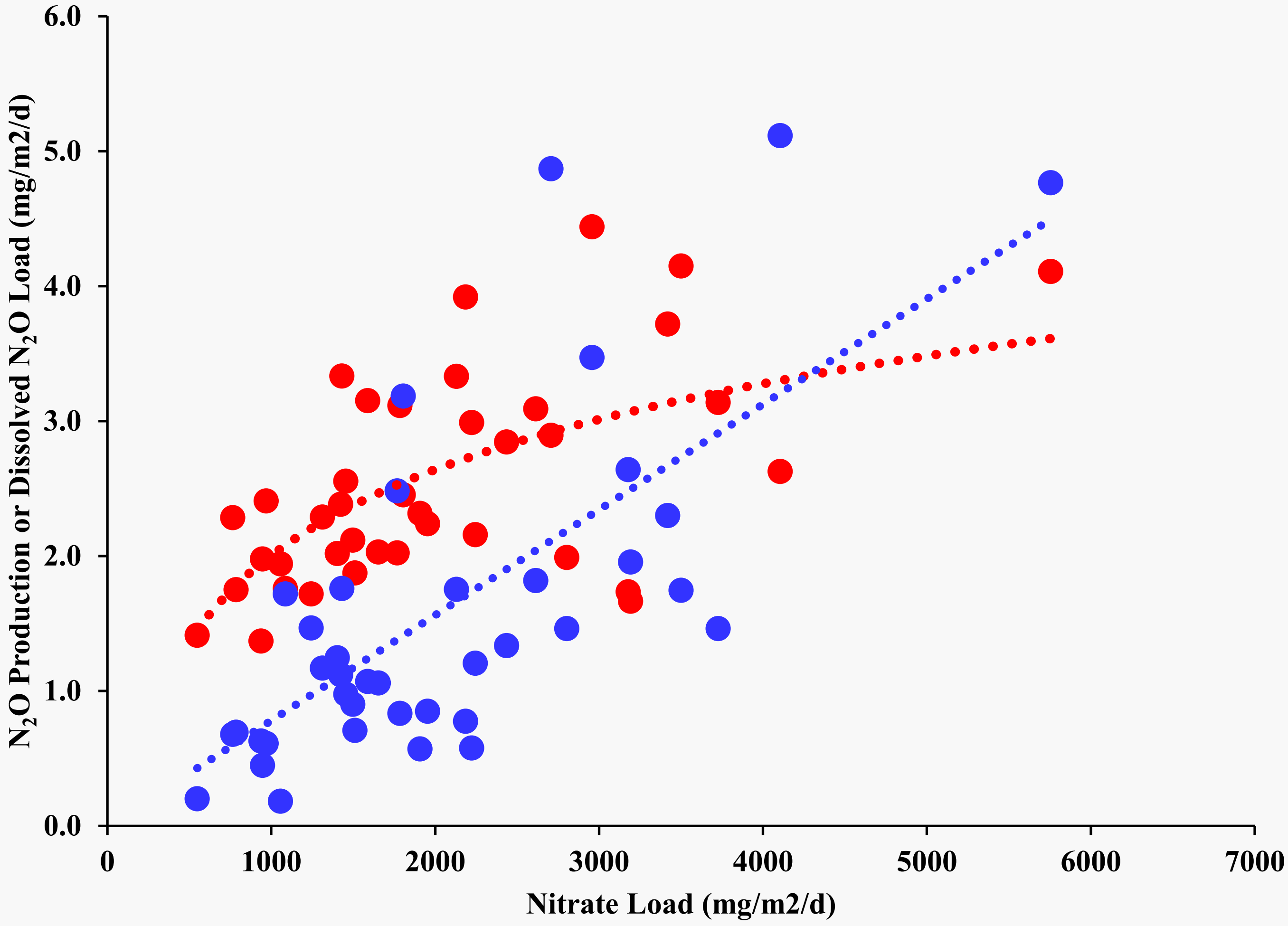
N_2O Production and Dissolved N_2O Load as Functions of Nitrate Load



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