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Smart ecosystems: using the concept of eco-engineering for large-scale wetland construction in the Netherlands

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Research in perspective

In the Netherlands, a soft clay-rich lake-bed sediment in the Markermeer (an artificial lake of 691 km^2) is causing serious turbidity problems: primary productivity is impeded and biodiversity in the lake is declining. To improve the ecological conditions in the lake, the Dutch Society for Nature Conservation (Natuurmonumenten) and Boskalis (a dredging company) designed a plan to dredge some of the soft clay-rich sediment and use it to construct approximately 10,000 ha of wetland: the Marker Wadden.

The acquired scientific knowledge will be used to assess which ecosystem services will evolve and how such systems should be managed. The results of this project may both guide the design of the project and serve as an international, scientific example of building with mud to create new land.

PRESENT: Turbid water of lake Markermeer (right of embankment) impedes primary productivity.

FUTURE: The Marker Wadden project will decrease turbidity in the lake, while at the same time constructing wetland.

Overall aim

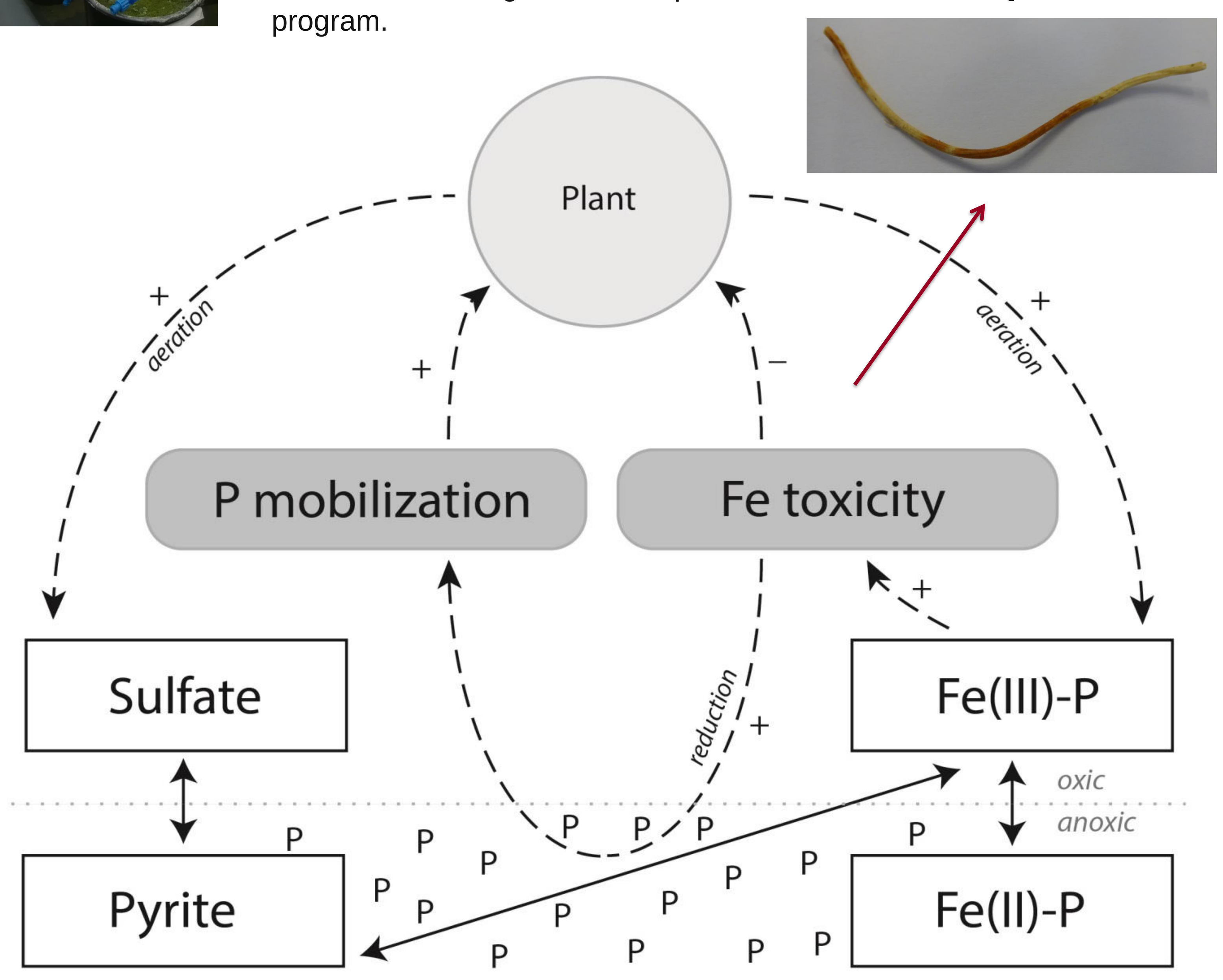
To understand how wetland ecological processes will feedback and interact with the consolidation and soil forming processes and also with hydrological and biogeochemical processes.

Experiment 1:

(*Saaltink et al., 2016*)[1]

Aim Identifying biogeochemical plant-soil feedbacks during oxidation and drying.

Method A greenhouse experiment was conducted where reed (*Phragmites australis*) was used as an eco-engineer. For 24 weeks, porewater-, soil- and plant quality was measured and used to model biogeochemical processes in the PHREEQC program.



Most important biogeochemical processes and feedbacks identified in this study. + indicates positive feedback, - indicates negative feedback. A negative feedback loop was found, where plant-induced iron toxicity is hampering plant growth, and a positive feedback loop was found, where iron toxicity promotes P mobilization, enhancing plant growth (Saaltink et al., 2016).

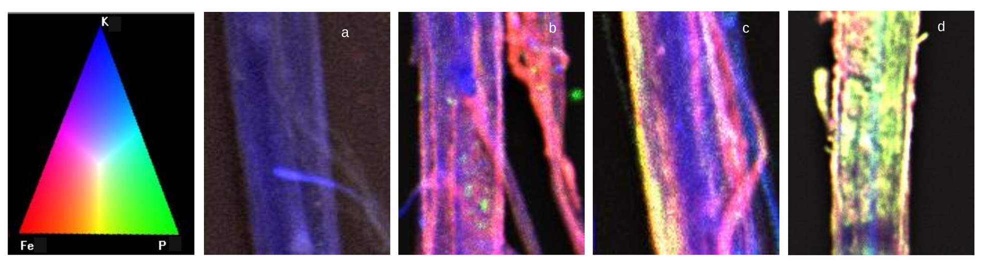
Experiment 2:

(*Saaltink et al., submitted*)[2]

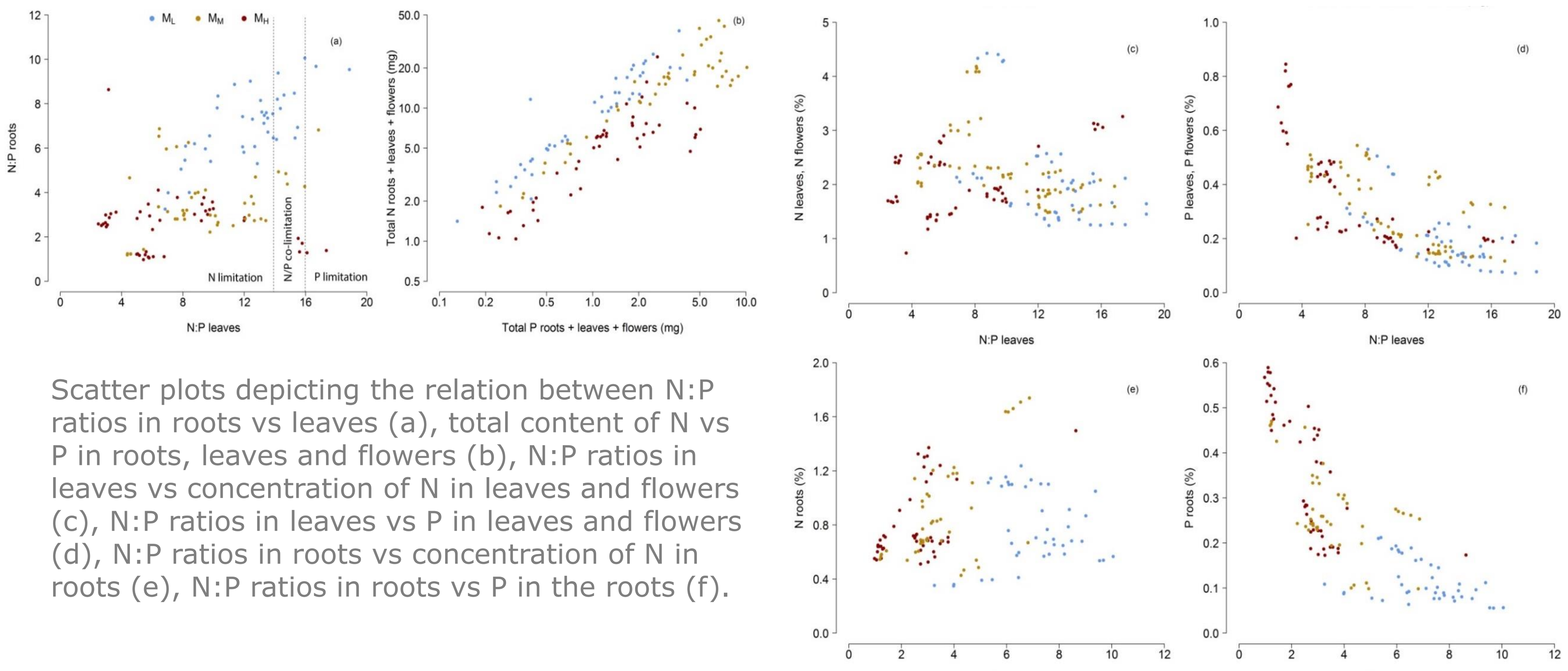
Aim Understanding Fe-toxicity and Fe-plaque and its stoichiometric effects of *P. australis* in four different Fe-rich soils.

Method Using three potential sediment sources that varied in total Fe and Fe-P content and a control substrate, we performed a greenhouse experiment to study the development of *Rumex maritimus*, *Phragmites australis* and *Eupatorium cannabinum*.

Sediment types	
Control	Potting soil
M_L	Markermeer mud: low amounts of Fe-P
M_M	Markermeer mud: moderate amounts of Fe-P
M_H	Markermeer mud: high amounts of Fe-P



Surface composition in terms of Fe, K, and P on roots of *P. australis* in four sediment types. Control (a) shows no signs of iron plaque, M_L (b) shows iron plaque with no co-precipitation of P, M_M (c) shows iron plaque with moderate co-precipitation of P, and M_H (d) shows iron plaque with high co-precipitation of P. Colors indicate presence of Fe (red), K (blue), and P (green).



Scatter plots depicting the relation between N:P ratios in roots vs leaves (a), total content of N vs P in roots, leaves and flowers (b), N:P ratios in leaves vs concentration of N in leaves and flowers (c), N:P ratios in leaves vs P in leaves and flowers (d), N:P ratios in roots vs concentration of N in roots (e), N:P ratios in roots vs P in the roots (f).

Conclusions experiment 1

- We identified **a negative feedback loop** that arises because plant roots induce aeration, which promotes iron toxicity that decreases plant growth.
- We identified **a positive feedback loop**, as iron toxicity induces reduction processes as a result of root death, which leads to P mobilization and hence enhances plant growth and regeneration.

To study the effects of iron toxicity and P mobilization in greater detail, we recommend further testing with different plant species and sediment types (**experiment 2**).

Conclusions experiment 2

- The composition of iron plaque mainly depends on the Fe(III) and iron-bound phosphorus concentration of the sediment.
- Plaque formation caused stoichiometric imbalances in leaves, suggesting an inhibited translocation of P to the leaves.
- These results highlight the importance of considering the Fe and Fe-P availability in sediments, as these properties may constrain plant performance in pioneer ecosystems.

Overall conclusion

In eco-engineering projects where wetlands are to be constructed by using iron-rich sediments and where plants are used as ecological engineers – like wetland construction in the Markermeer – important soil characteristics should be measured and plant response should be monitored prior to deciding which building material and plant species to use.

1. Saaltink R, Dekker SC, Griffioen J, Wassen MJ (2016) Wetland eco-engineering: measuring and modeling feedbacks of oxidation processes between plants and clay-rich material. *Biogeosciences Discussions*
2. Saaltink R, Dekker SC, Eppinga MB, Griffioen J, Wassen MJ (submitted) Experimental testing of iron toxicity for three wetland species grown on iron-rich sediments. *Plant and Soil*