

# Linking watershed phosphorus management to eutrophication responses in European lakes

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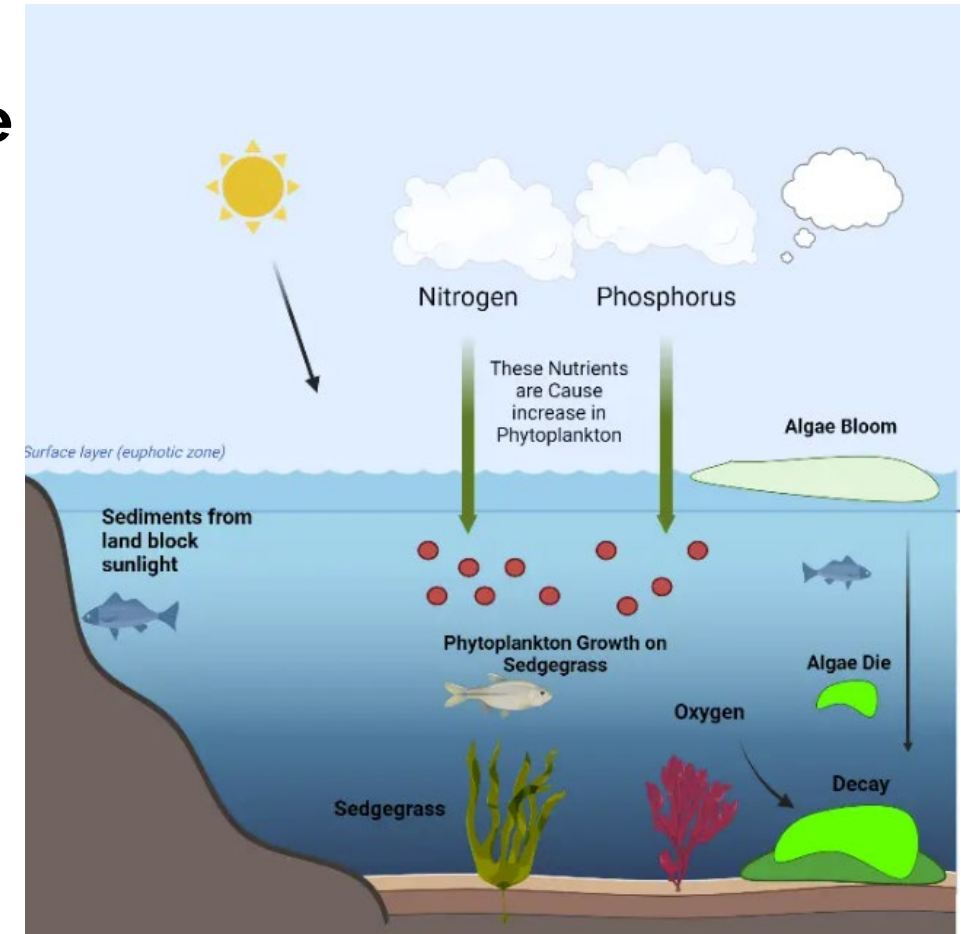
A photograph of a sunset over a body of water. The sun is low on the horizon, creating a bright, shimmering reflection on the water's surface. In the foreground, three people are silhouetted against the water, standing in a long, narrow canoe. They are holding long poles, likely for rowing or steering. The water is calm, with gentle ripples. In the background, a dark, silhouetted shoreline is visible under the twilight sky.

# Context



# Context - Eutrophication

- Eutrophication is caused by an **excessive presence of nutrients** (Nitrogen & Phosphorus)
- Generates **excessive algae** that causes many problems, e.g. **deoxygenation** and water toxicity
- Still affecting adversely **large portions of European lakes** (Ibisch et al., 2016)



# Context – EUROLakes project

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*INTEGRATED PROTECTION AND RESTORATION APPROACHES FOR NATURAL LAKE ECOYSTEMS*

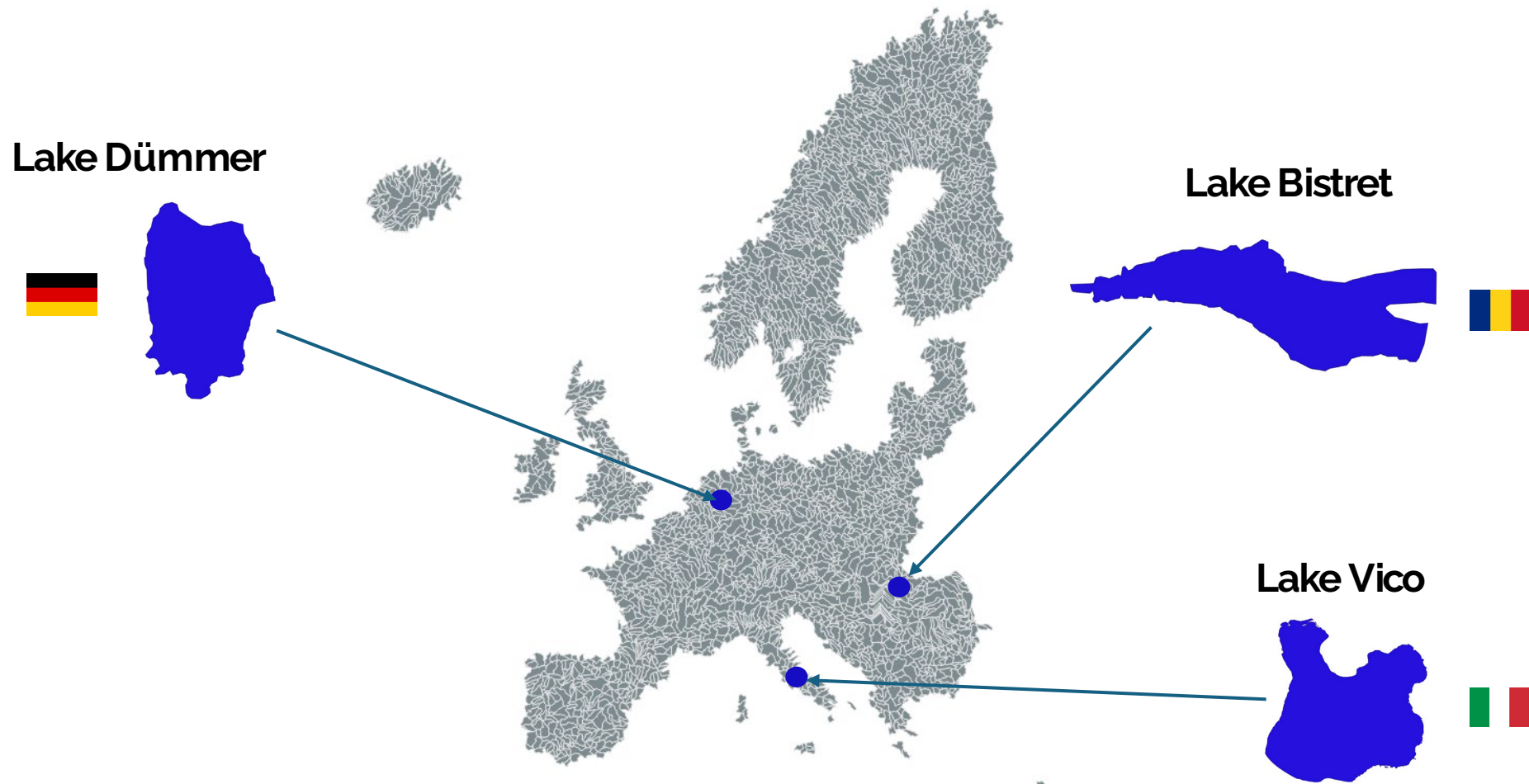
**EUROLakes** project is addressing **eutrophication** challenges by proposing an innovative, **holistic**, and **science-based** approach to the protection and restoration of European natural lakes and their ecosystems

Implement **ecosystem modelling (SWAT+)** techniques to simulate the impact of selected protection and restoration **(P&R) approaches on lake ecosystems**



Co-funded by  
the European Union

# Selected European lakes



# Highlighted losses/challenges



Soil erosion -> sediments, nutrients



Nutrient input -> Biodiversity



Dykes -> Disconnectivity

Nutrient input -> Biodiversity

Eutrophication

# 1. Lake Vico

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## Major problem is **Lake Eutrophication**

(a) Agriculture (Intensive cultivation of hazelnut orchards) is leading;

- to **excessive nutrient** (Nitrogen & Phosphorous) export from land to lake
- to increased **soil erosion risk** due to the bare soil required to optimize mechanical harvesting

(b) Lake has very minor tributaries, thus a **long residence time** (17 years)

(c) **Water stratification** according to temperature, impedes efficient vertical water mixing





# Eutrophication & Trophic State Index (TSI)

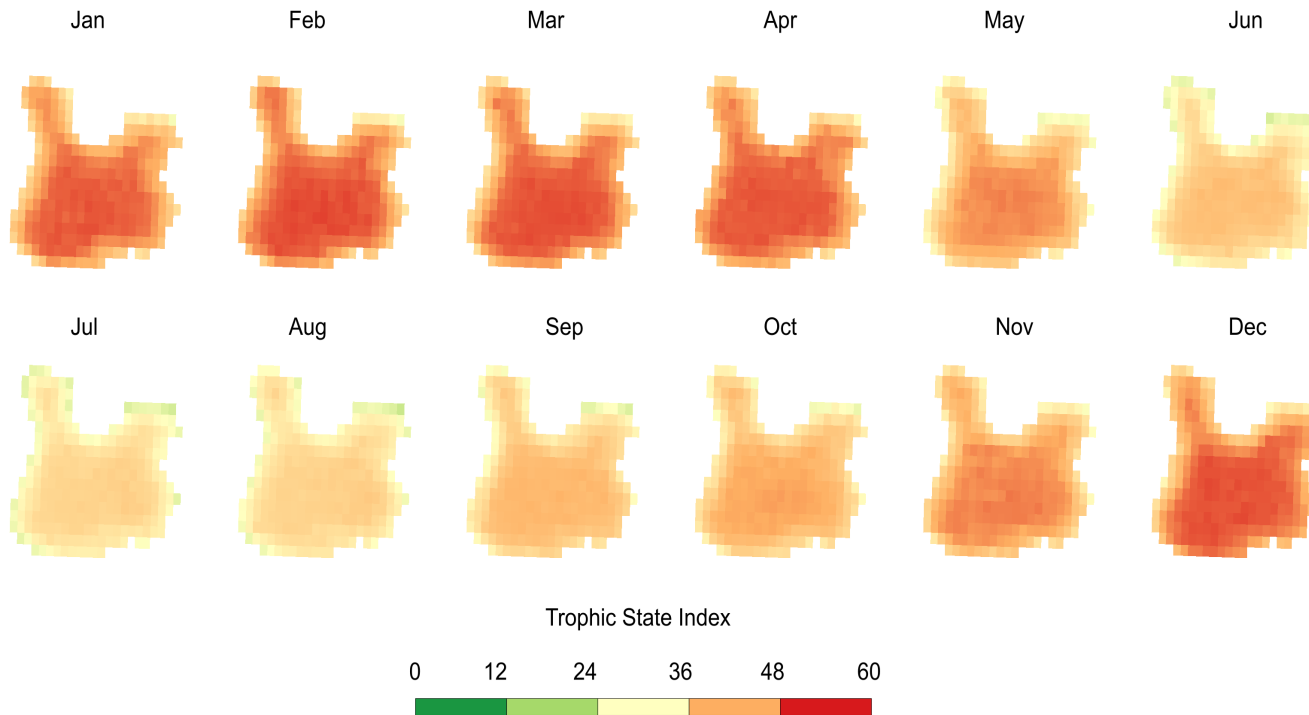
**TSI** is a classification system used to describe the **nutrient status** and **biological productivity** of a water body, typically lakes or reservoirs

TSI Value	Trophic Status	General Characteristics
0–40	<b>Oligotrophic</b>	Clear water, low productivity, low nutrients
41–50	<b>Mesotrophic</b>	Moderate productivity, average nutrient levels
51–70	<b>Eutrophic</b>	High productivity, possible algae blooms, high nutrients
71+	<b>Hypereutrophic</b>	Very high productivity, frequent algal blooms, poor water quality



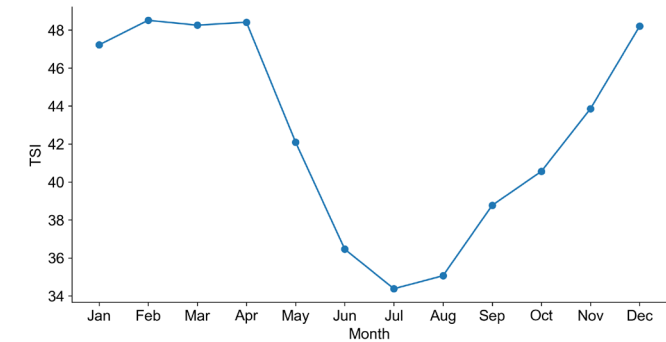
# Lake Vico - TSI

(2002 – 2024)

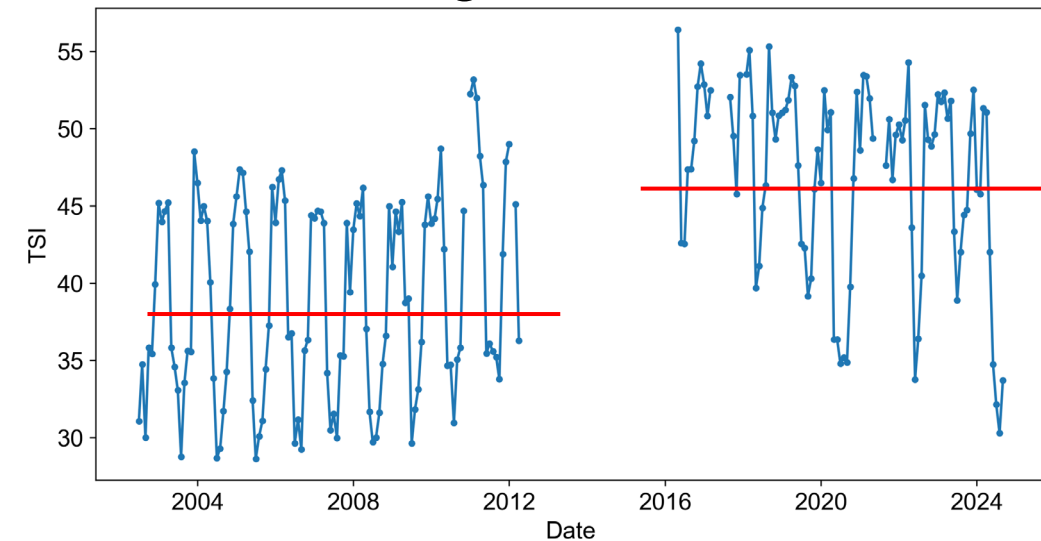


100 m - Copernicus Global Land Service (CGLS)

## Seasonal



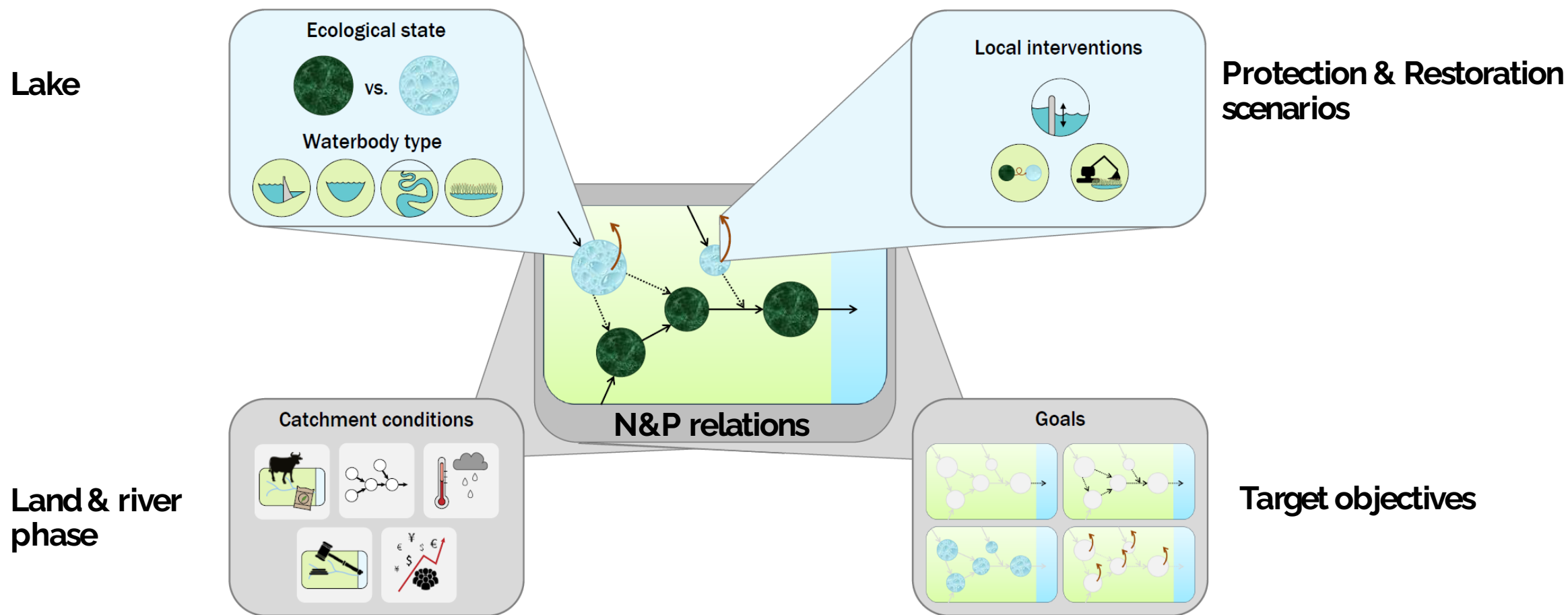
## Long term trend



A close-up photograph of water being poured from a dark bottle. The water is captured in mid-pour, creating a dynamic, textured stream. The background is a soft-focus sunset or sunrise, with a bright sun low on the horizon, casting a warm, golden glow. The water reflects this light, giving it a shimmering appearance. A solid blue horizontal bar is superimposed over the middle of the image, containing the word 'Modelling' in white text.

# Modelling

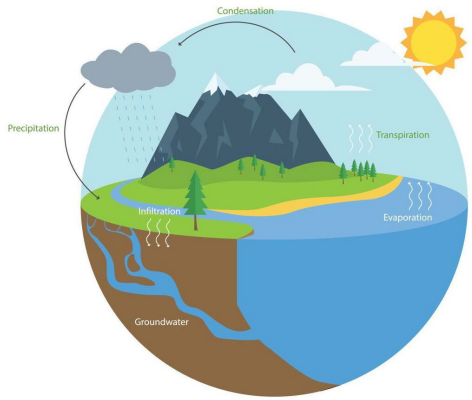
# Modelling approach



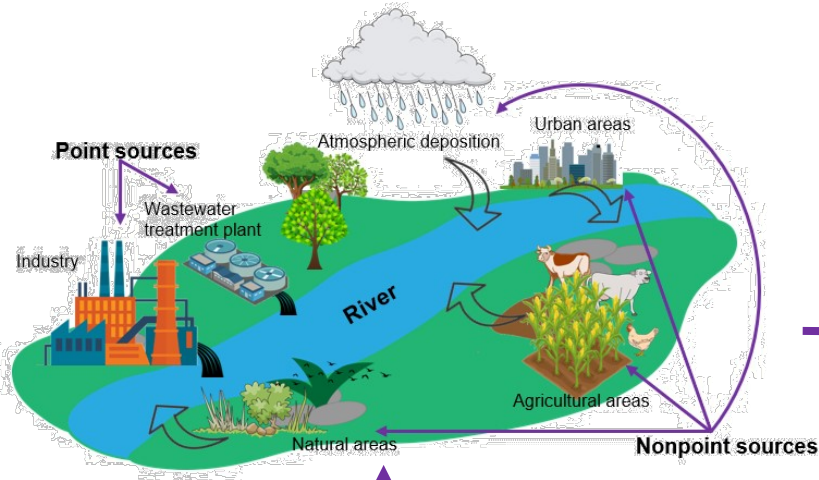
*Adapted from van Wijk, et al. (2023)*

# Modelling approach

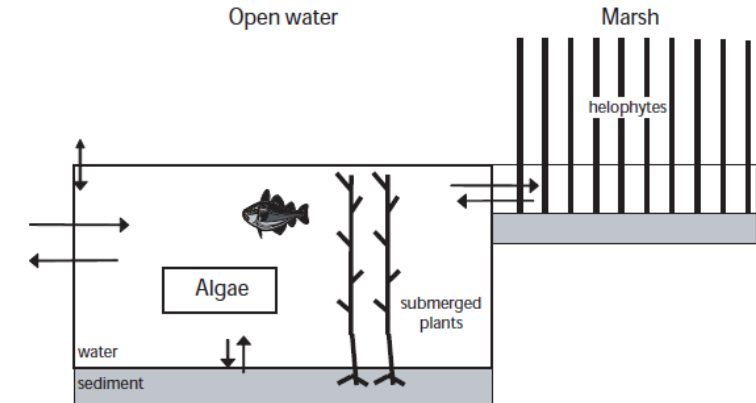
## Hydrological setup (SWAT+)



## Add pollution sources (SWAT+)



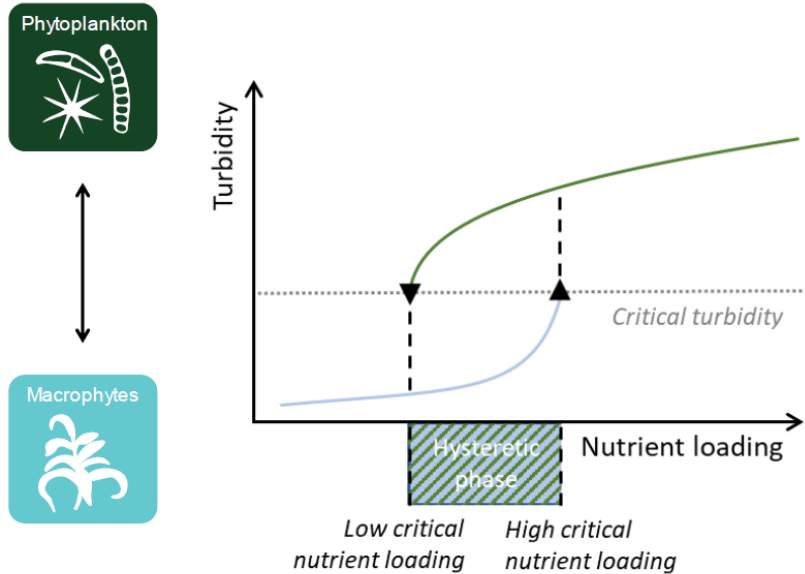
**P&R scenarios**



## Couple with GPLake-M



# Modelling approach – GPLake-M

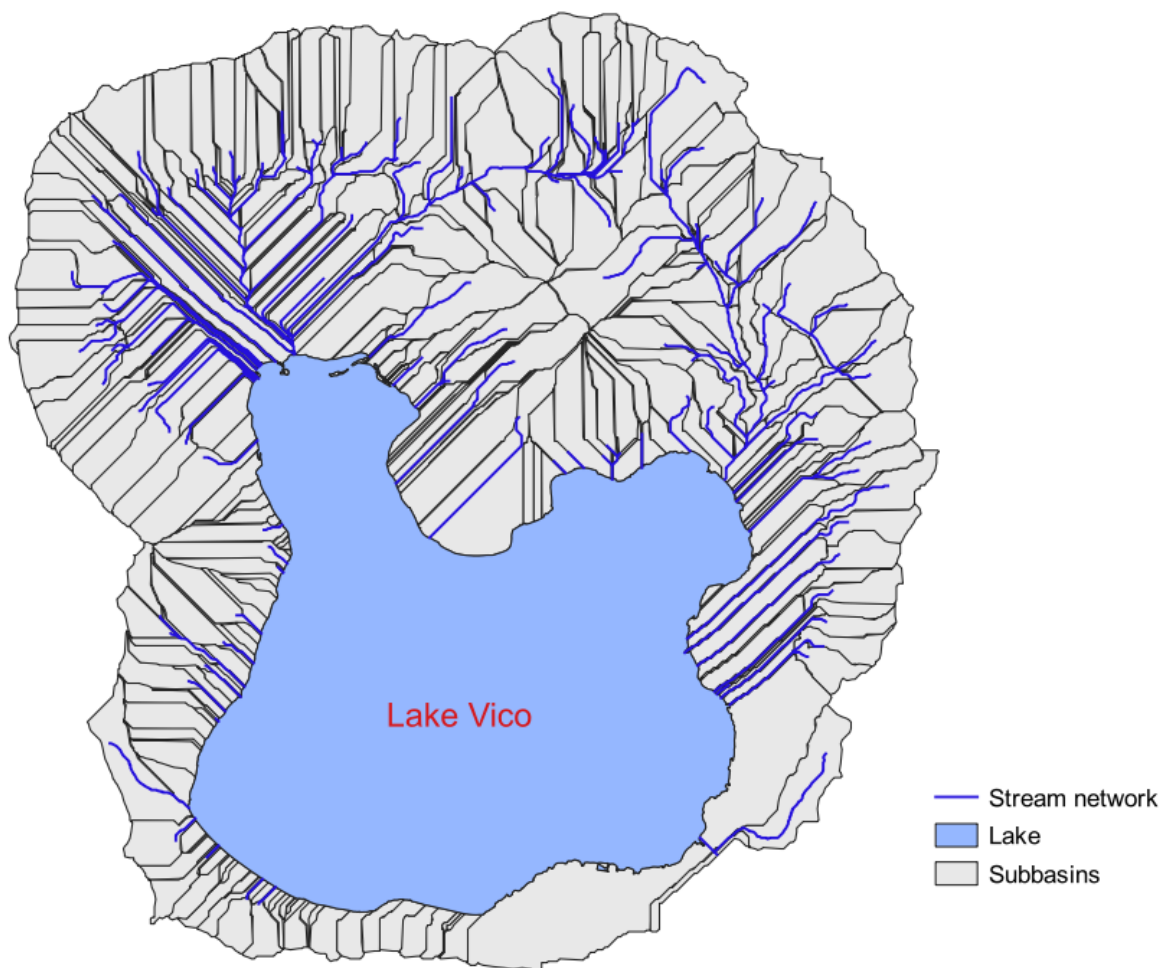


**Key input:** Initial state, P-loading, residence time, lake depth

- Regime shifts in lakes are explained by **critical turbidity**
- Critical turbidity (black dashed line) indicates the **phytoplankton nutrient content** at which **regime shifts occur**.
- Captures the **essential mechanisms** leading to alternative stable states in shallow lakes

(van Wijk, et al., 2023)

# Model setup (SWAT+)

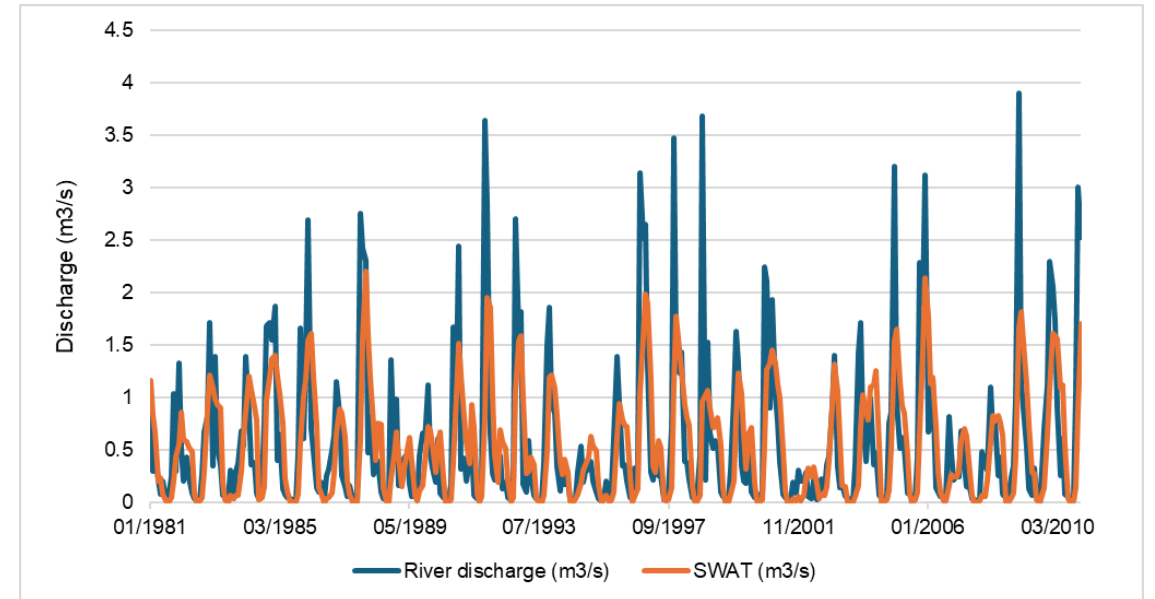
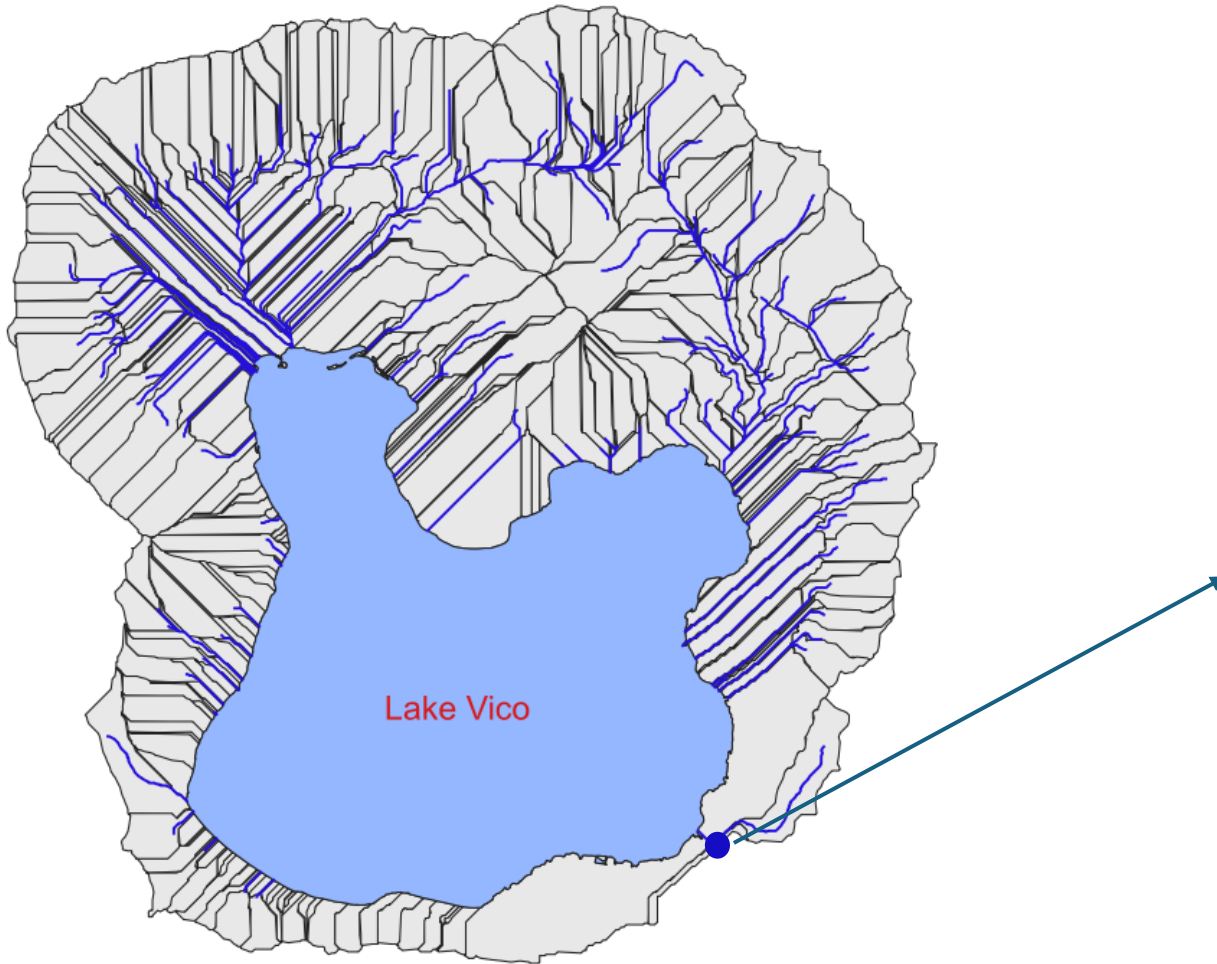


## Input data

Data variable	Spatial Resolution (m)	Time period
Digital Elevation Model (DEM)	10 m	
Landuse	10m	2020
Soil map	1:20000	1985
Crop areas	10m	2020
Fertilizer application (Nitrogen)	180 kg/ha/yr	
Fertilizer application (Phosphorus)	80 kg/ha/yr	
Climate (Precipitation & Temperature)		Daily (2011 – 2017)

264 subbasins, 3618 HRUs

# River flow evaluation



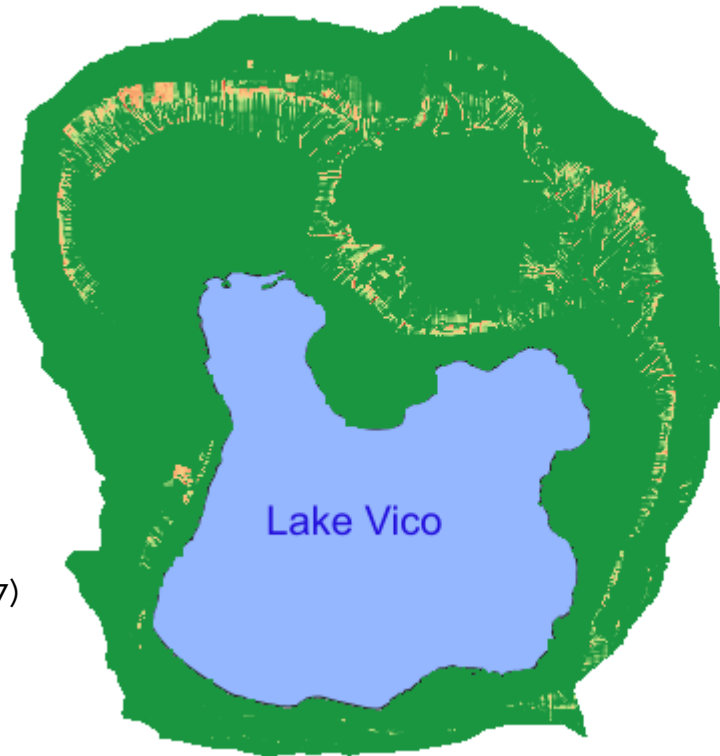
NSE = 0.56

$R^2 = 0.67$

(Uncalibrated SWAT+ model)

# Soil erosion evaluation

(a) RUSLE estimate



(Strauss et al. 2007)

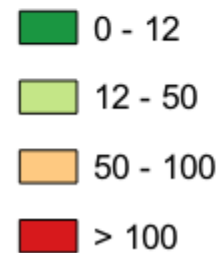
Mean basin value = 14.5 – 17.5 t/ha/yr

(b) This study (MUSLE)



Mean basin value = 13.6 t/ha/yr

Soil erosion (t/ha/yr)



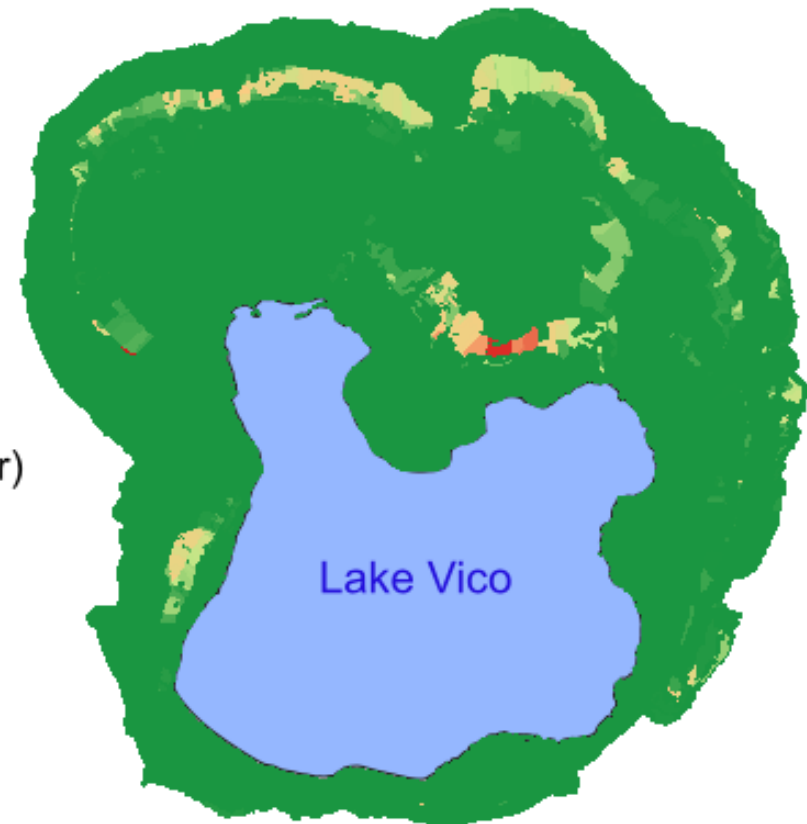


# TN & TP simulations

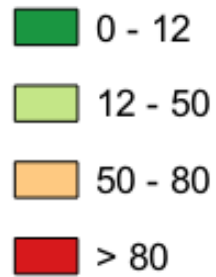
(a) TN



(b) TP



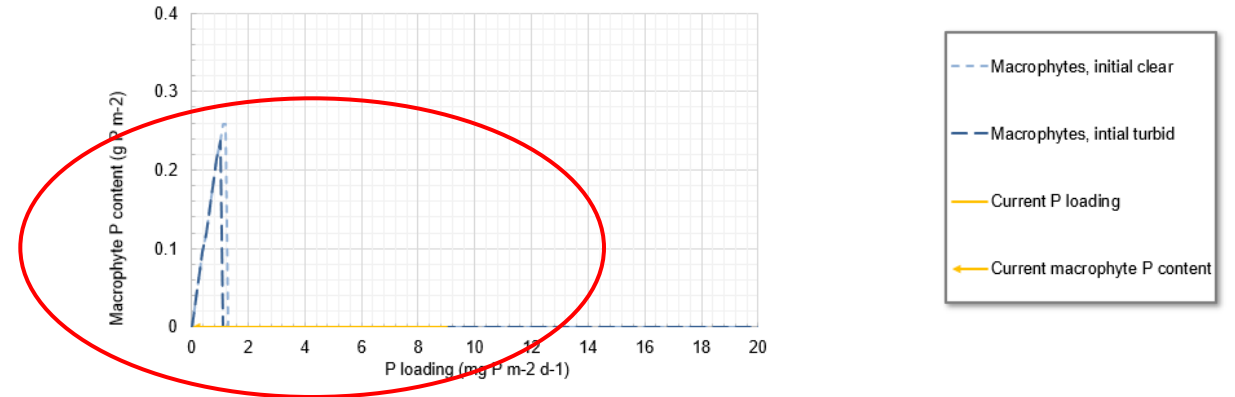
TN / TP export (t/ha/yr)



# Current Lake status

- With the current Phosphorus (P) loading (**41 ton/yr**), the lake is phytoplankton dominant with zero macrophytes.
- By back-casting, a reduction (**89 %**) in P loading is required to reverse a shift from dominance of phytoplankton to macrophyte dominance.

GPLake-M macrophytes



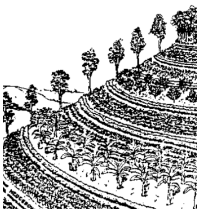
GPLake-M phytoplankton



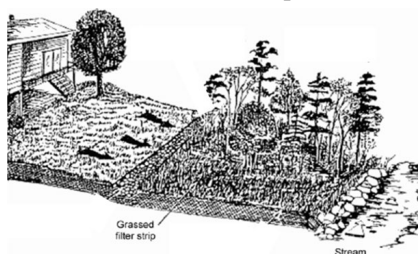
Snapshots from GPLake-M

# Selected Management practices

## Contour farming



## Filter strips



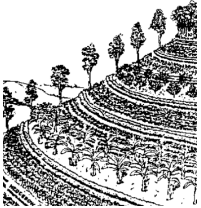
## Fertilizer (P) reduction



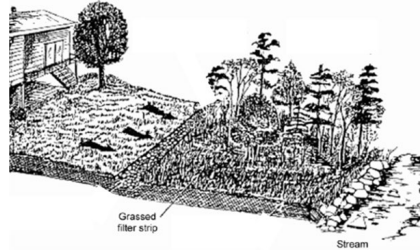
Pathway	TP (Kg/yr)	Reduction(%)
Baseline (180kg/ha -N and 150Kg -P)	41125	
Fertilizer reduction (-40%)	28697	30.22
Fertilizer reduction (-80%)	13434	67.33
Filter strip	17008	58.64
Contour	23180	43.64
Filter strip + Contour	6565	84.04
Filter strip + Contour + 50% reduction	4026	90.21

# Selected Management practices

## Contour farming



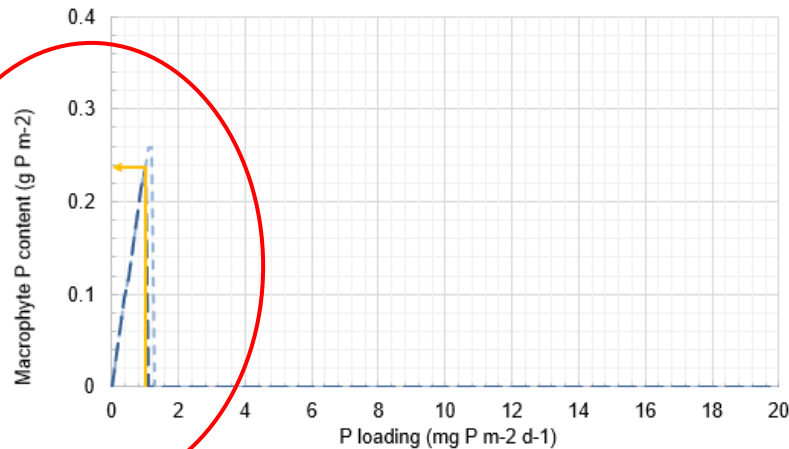
## Filter strips



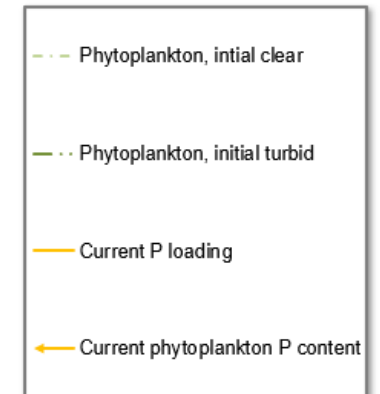
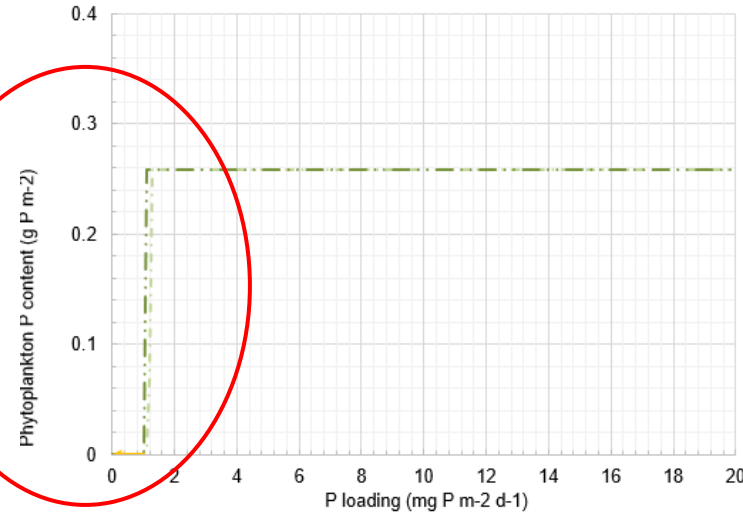
## Fertilizer (P) reduction



GPLake-M macrophytes



GPLake-M phytoplankton





# Take-aways

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- Combining **all management practices** is the most **effective approach**.
- One challenge is that the current model has **one-way** coupling.
- Focus is mainly on phosphorus and phytoplankton
- The model applies mainly to **shallow lakes** (around 2 meters deep).
- Still, it's a **simple and clear** way to help understand and manage lake ecosystems.

An aerial photograph showing a coastal region. The land on the left is a patchwork of agricultural fields in various shades of brown, tan, and green, with some urban development visible. A large, irregular area of the water is covered in a bright green algal bloom, extending from the shoreline into the open water. The water outside the bloom is a deep blue-green. The text "Thank you!" is overlaid in white on the blue water.

Thank you!

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