International Institute for
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Linking watershed phosphorus management to eutrophication responses in European lakes

25 June 2025

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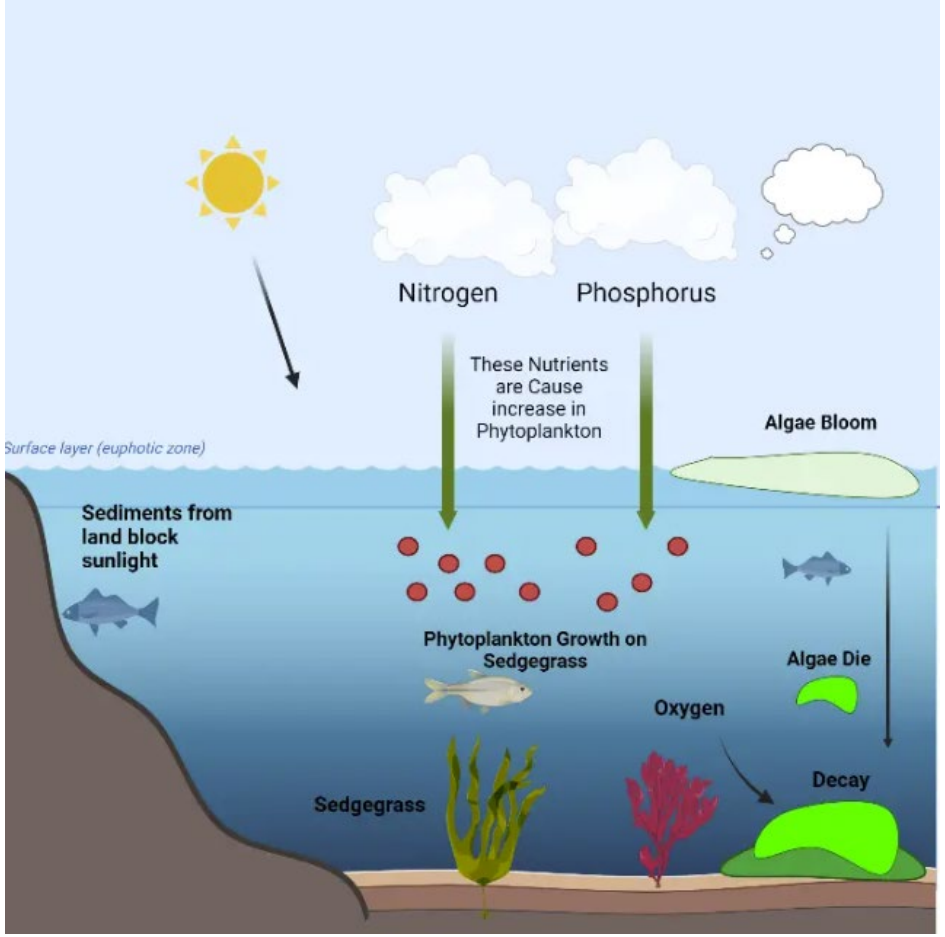
Context

EUROLakes

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)



EUROLakes

Context – EUROLakes project

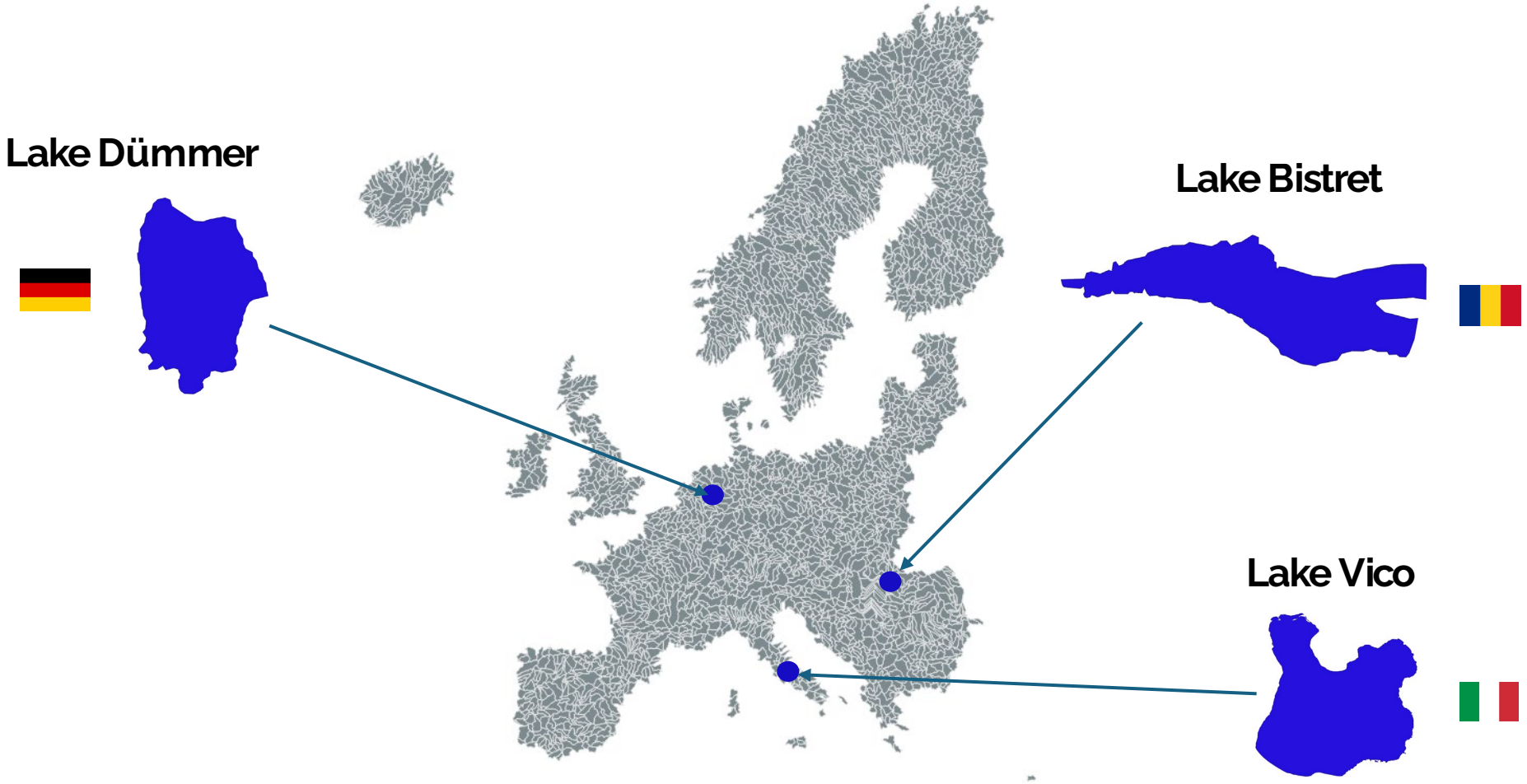
INTEGRATED PROTECTION AND RESTORATION APPROACHES FOR NATURAL LAKE ECOYSTEMS

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



EUROLakes

Highlighted losses/challenges

Soil erosion -> sediments, nutrients

Nutrient input -> Biodiversity

Dykes -> Disconnectivity

Nutrient input -> Biodiversity

Eutrophication

1. Lake Vico

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)

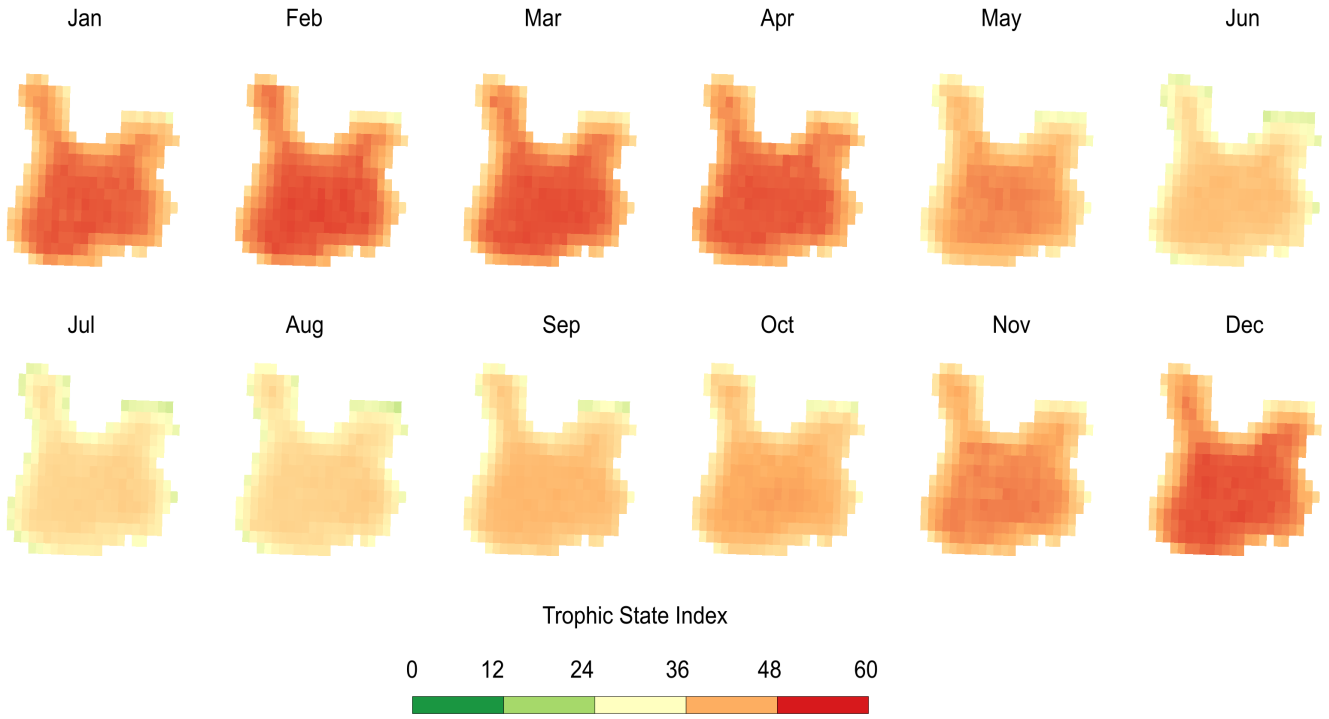
TSI is a classification system used to describe the **nutrient status** and **biological productivity** of a water body, typically lakes or reservoirs

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

EUROLakes

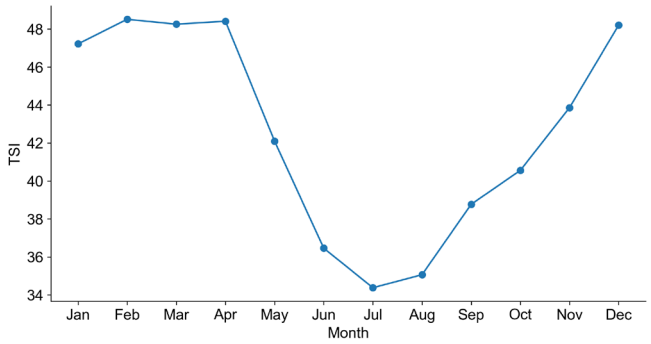
Lake Vico - TSI

(2002 – 2024)

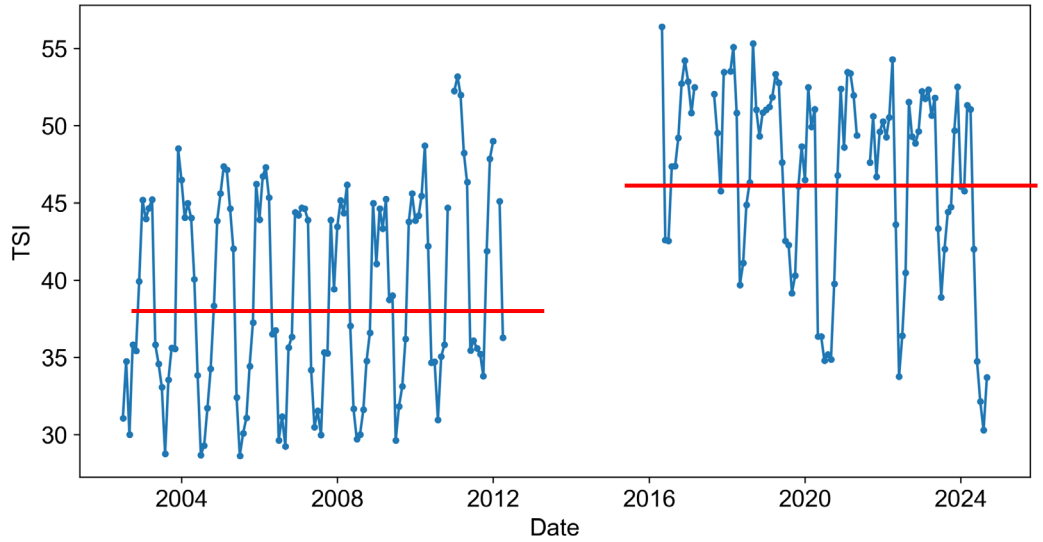


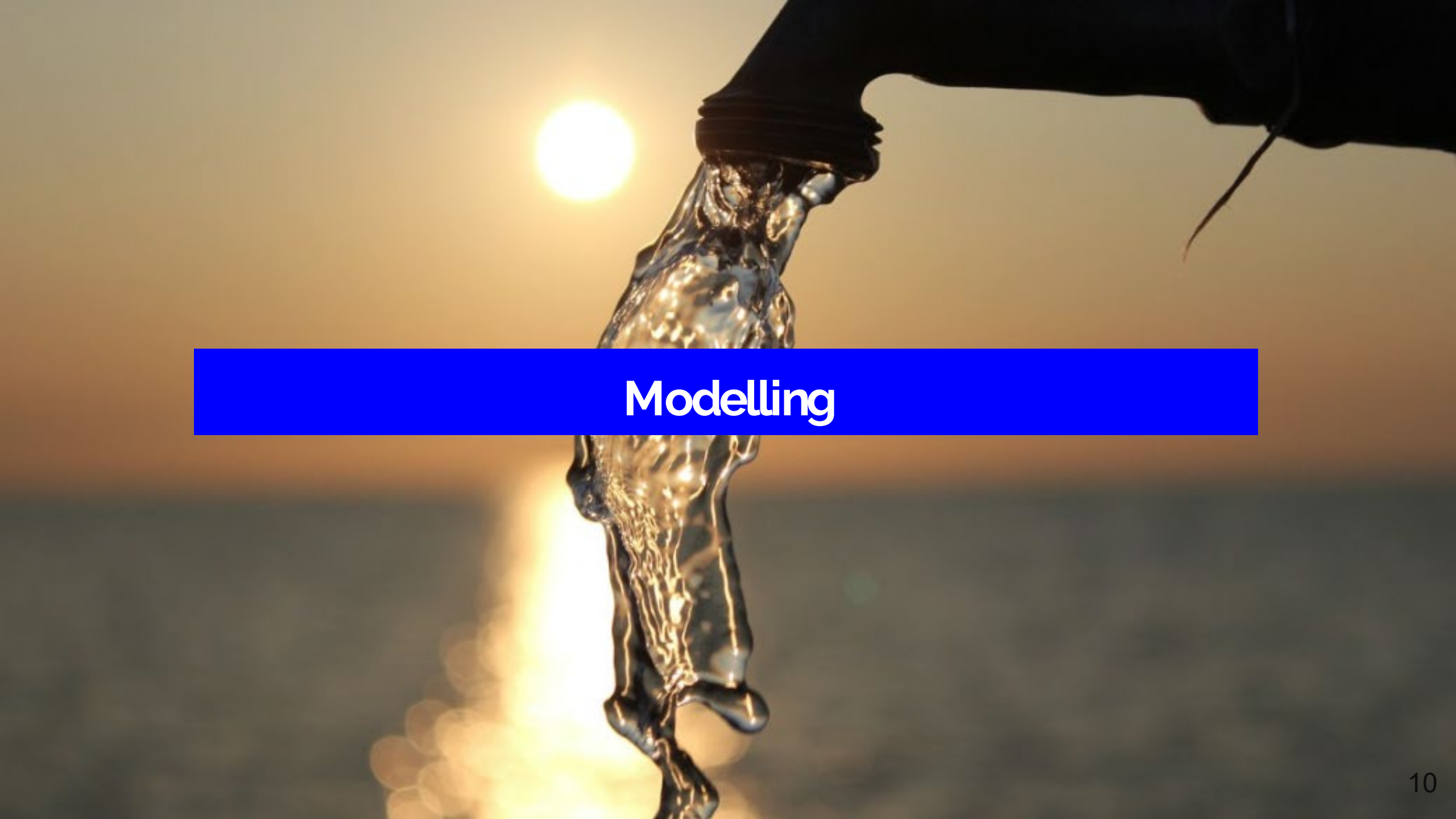
100 m - Copernicus Global Land Service (CGLS

Seasonal



Long term trend

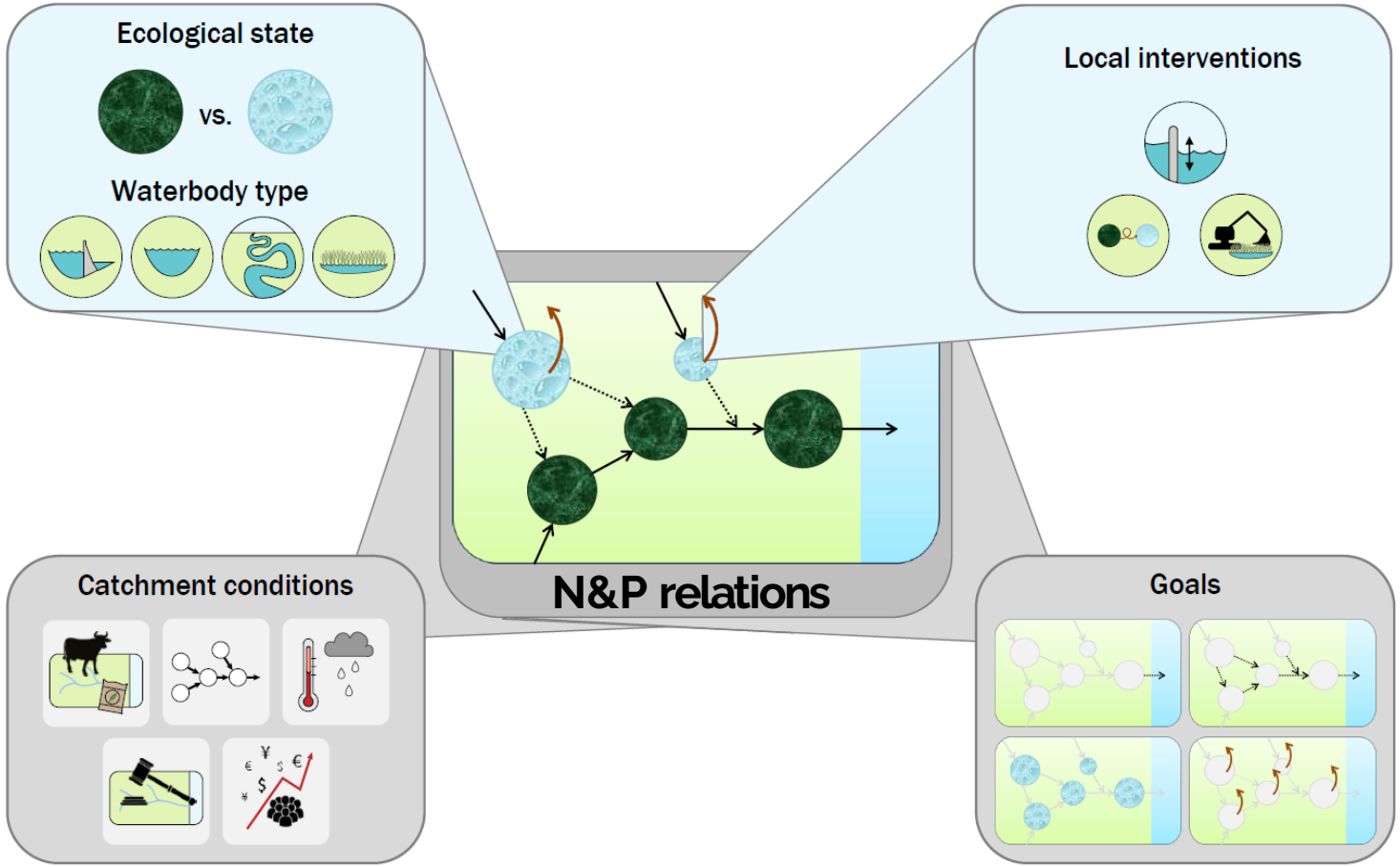




Modelling

Modelling approach

Lake



Protection & Restoration scenarios

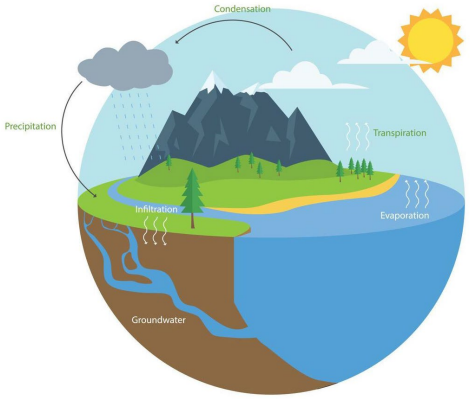
Land & river phase

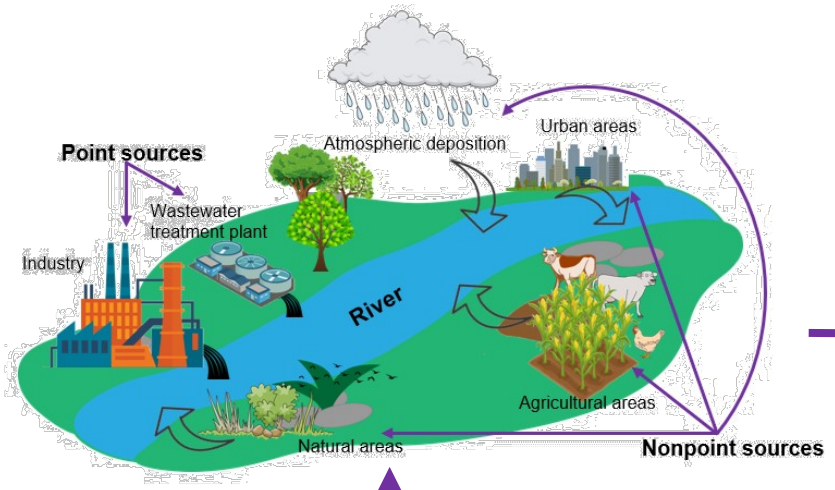
Target objectives

Adapted from van Wijk, et al. (2023)

Modelling approach

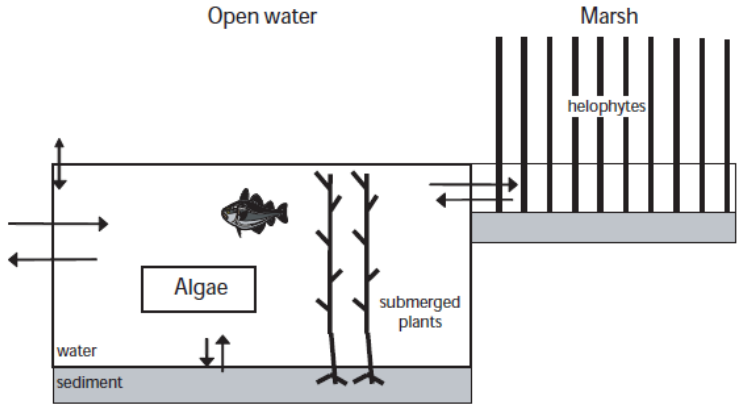
Hydrological setup (SWAT+)





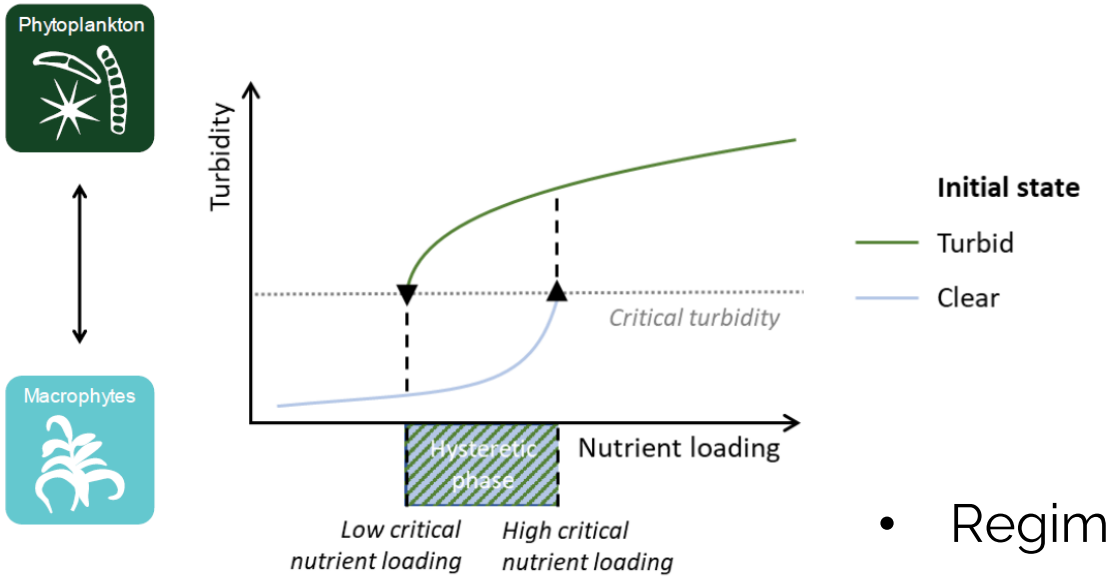
Add pollution sources (SWAT+)

P&R scenarios



Couple with GPLake-M

Modelling approach – GPLake-M

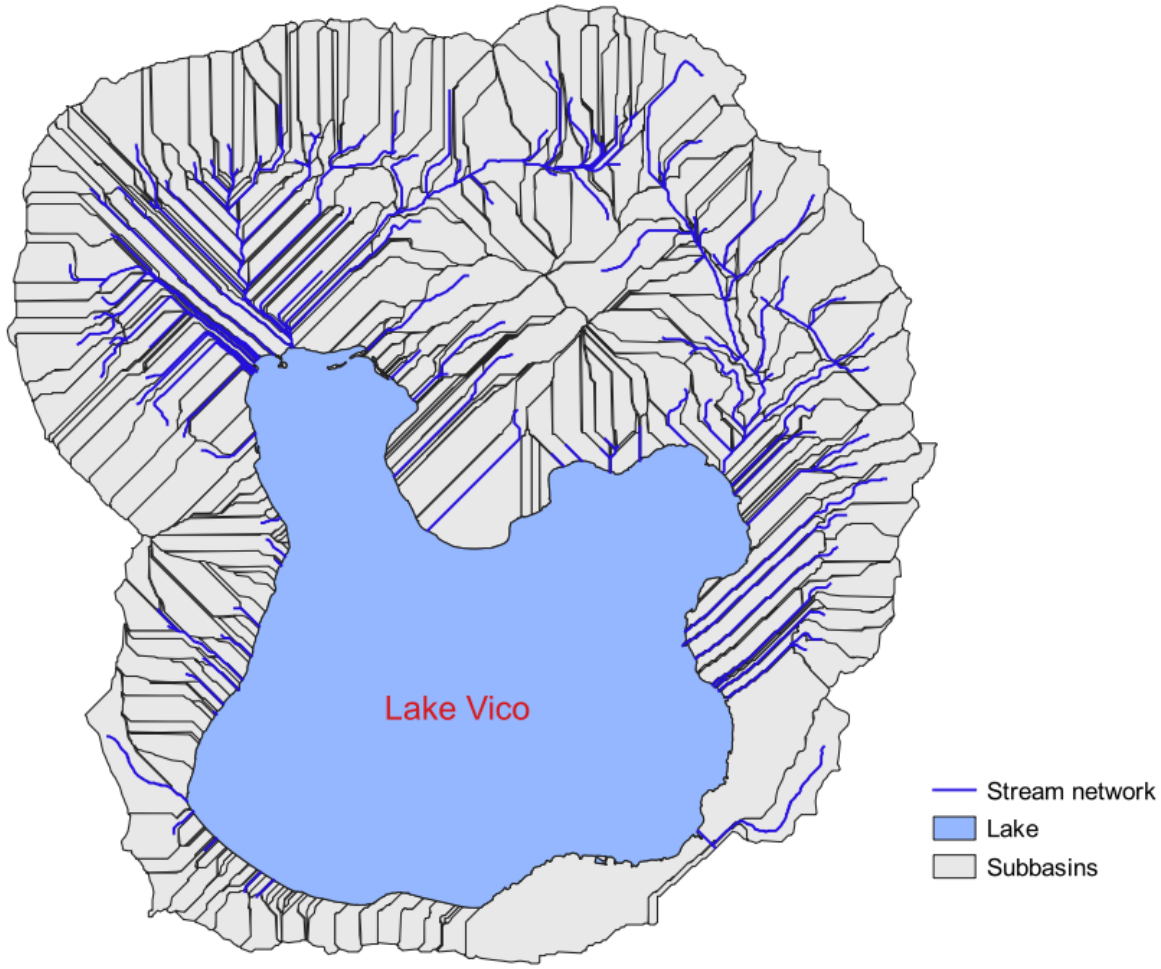


Key input: Initial state, P-loading, residence time, lake depth

(van Wijk, et al., 2023)

- 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 mech**anisms leading to alternative stable states in shallow lakes

Model setup (SWAT+)

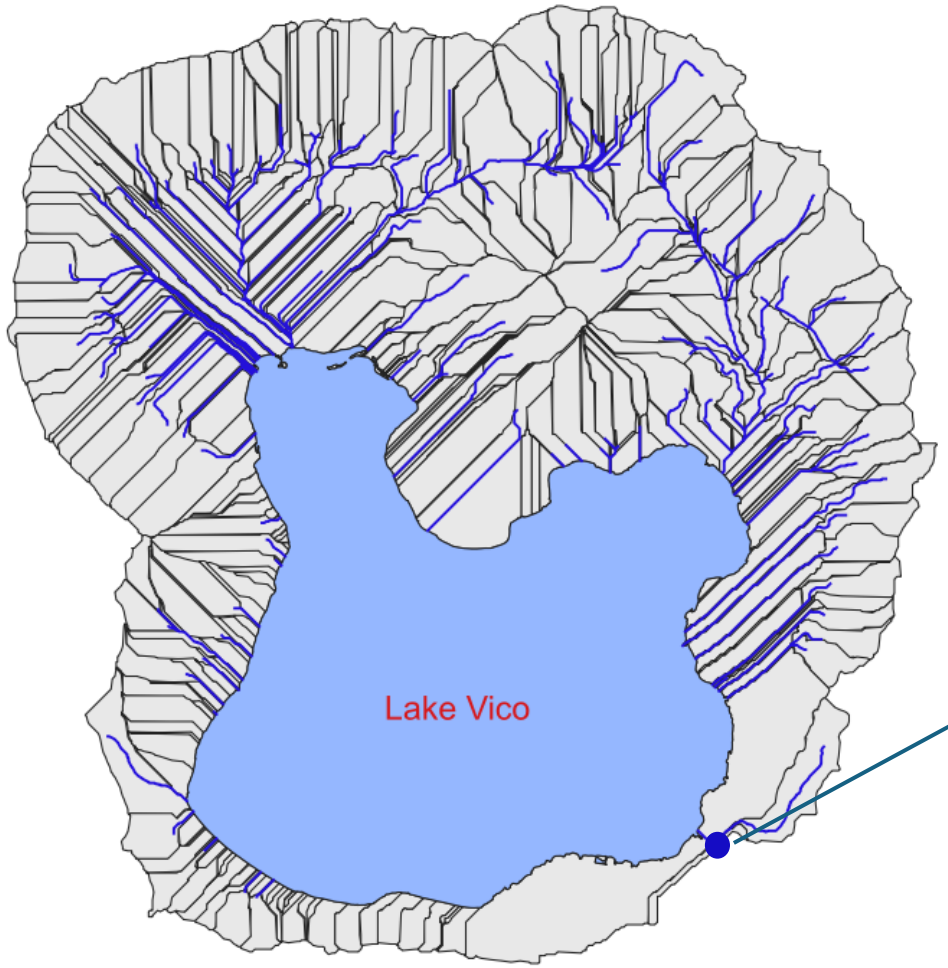


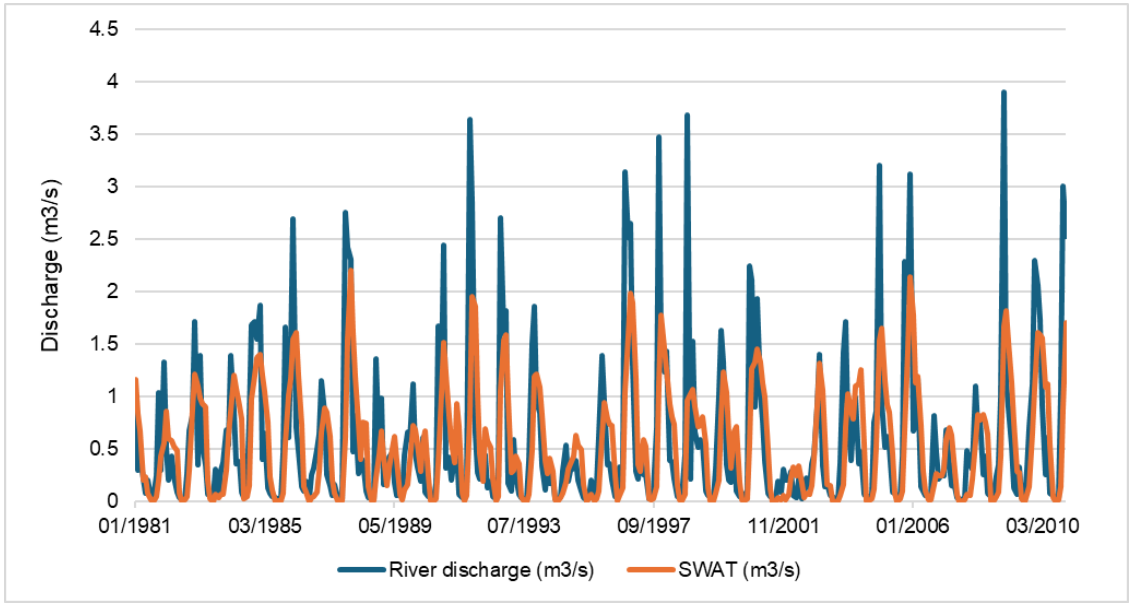
Input data

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



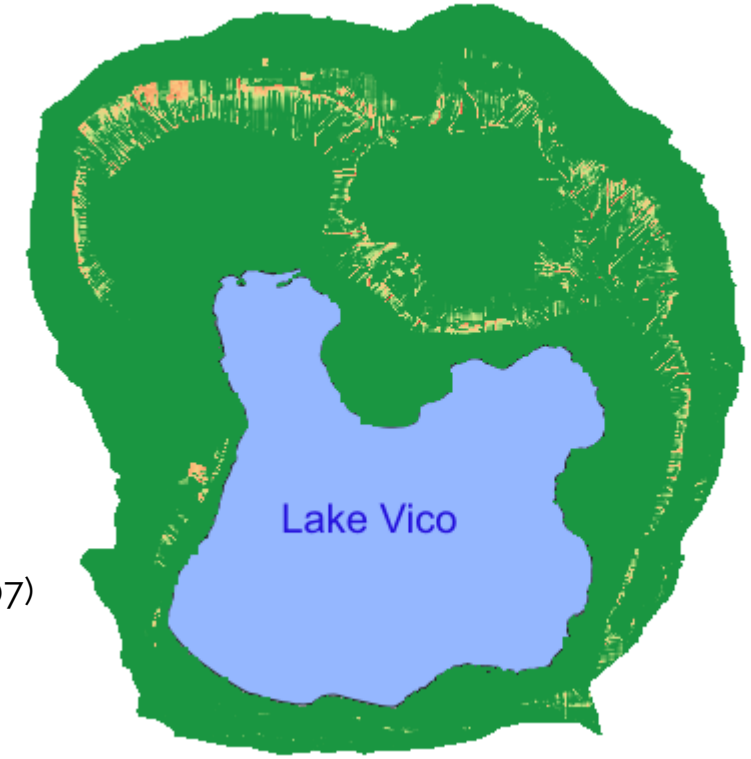


NSE = 0.56
R^2 = 0.67

(Uncalibrated SWAT+ model)

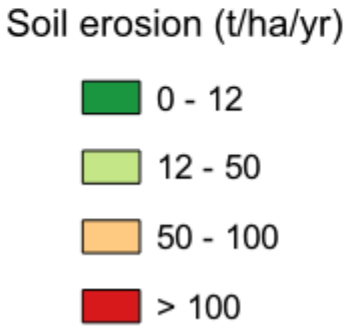
Soil erosion evaluation

(a) RUSLE estimate

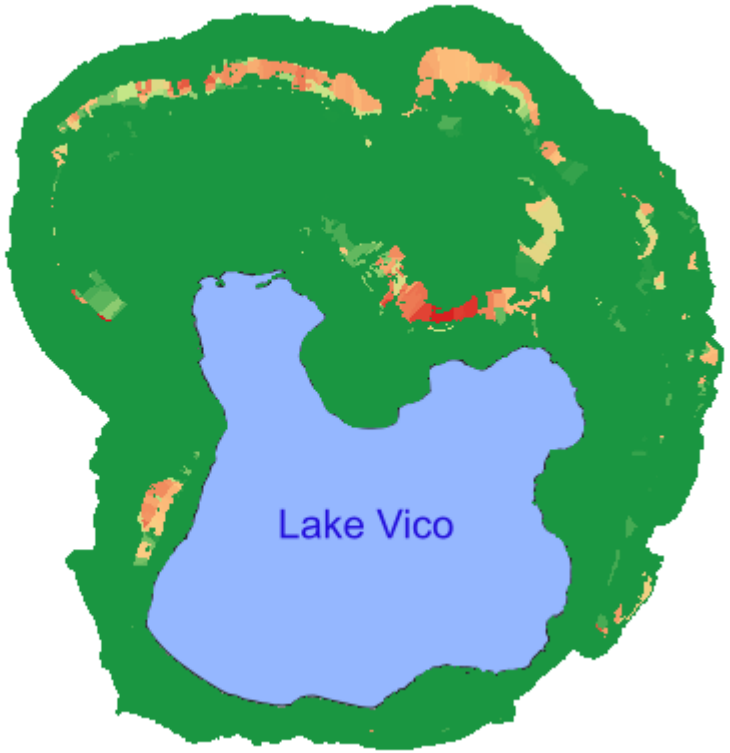


(Strauss et al. 2007)

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

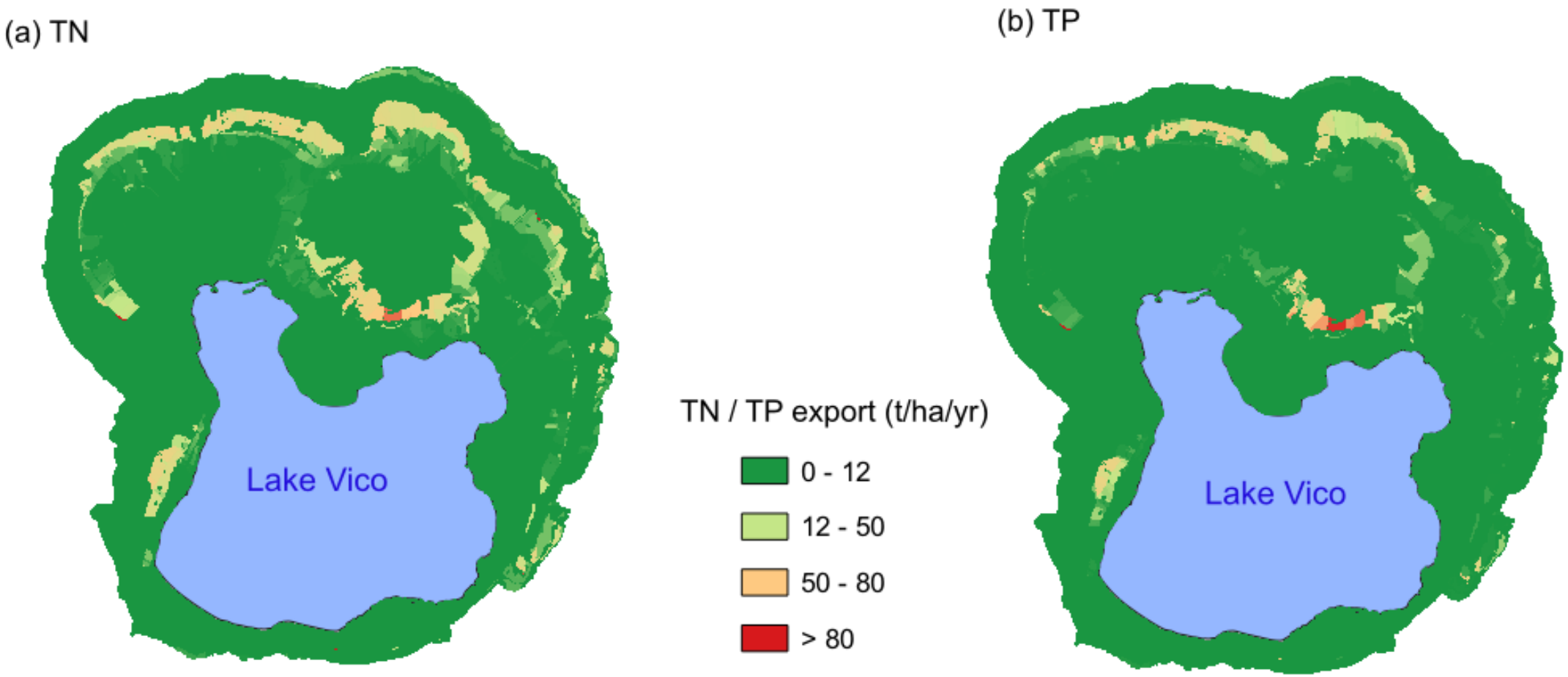


(b) This study (MUSLE)



Mean basin value = 13.6 t/ha/yr

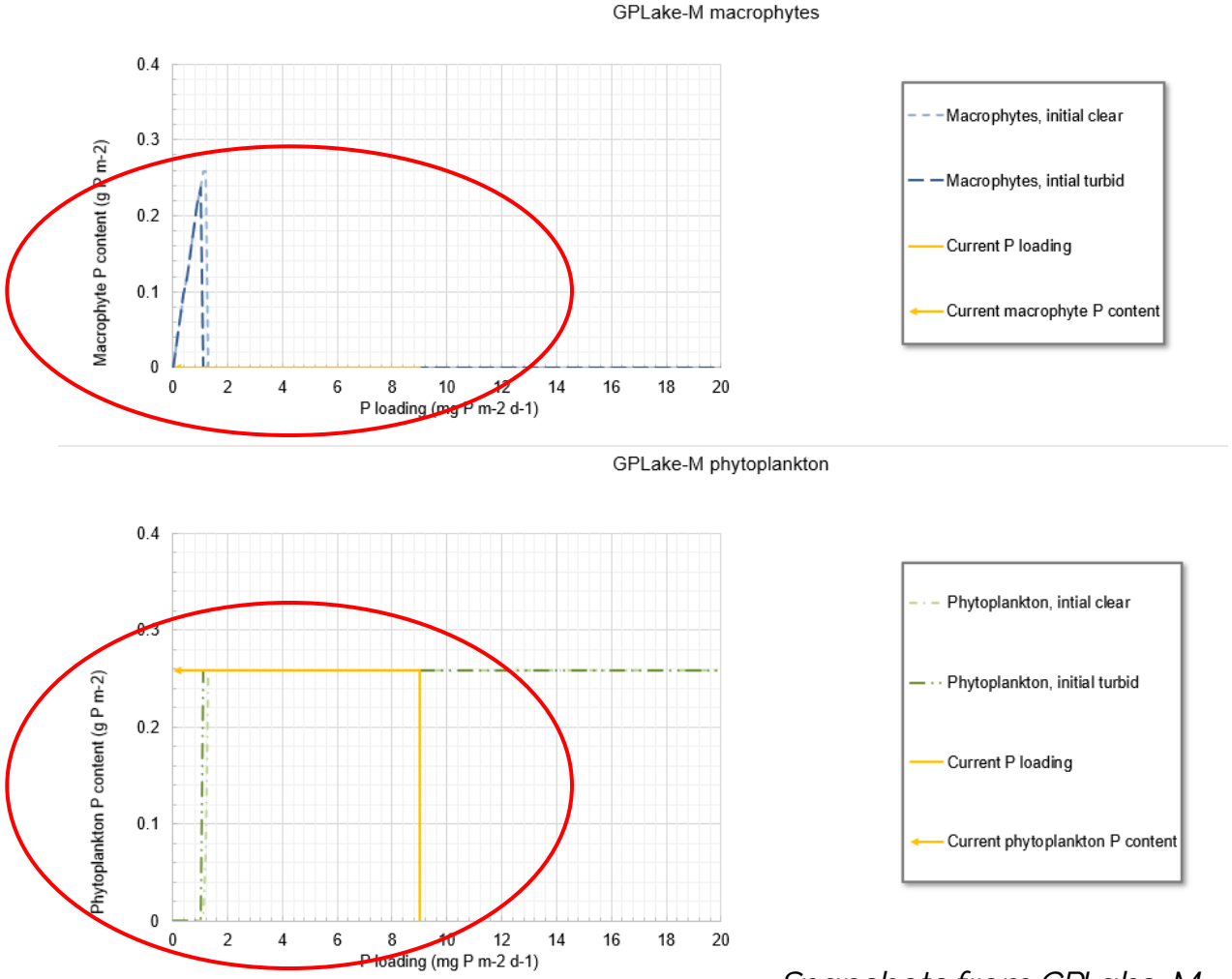
TN & TP simulations



Current Lake status

- With the current Phosphorus (P) loading (**41 ton/yr**), the lake is phytoplankton dominant with zero macrophytes.

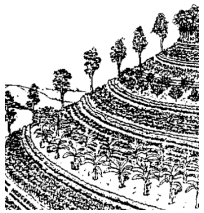
- By back-casting. a reduction **(89 %)** in P loading is required to reverse a shift from dominance of phytoplankton to macrophyte dominance.



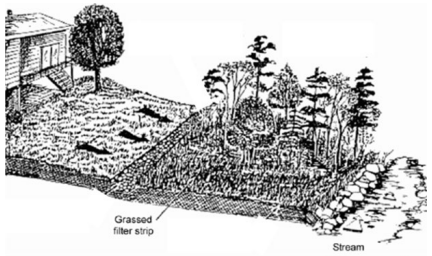
Snapshots from GPLake-M

Selected Management practices

Contour farming



Filter strips

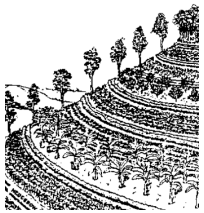


Fertilizer (P) reduction

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



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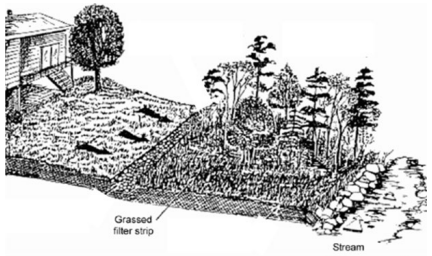
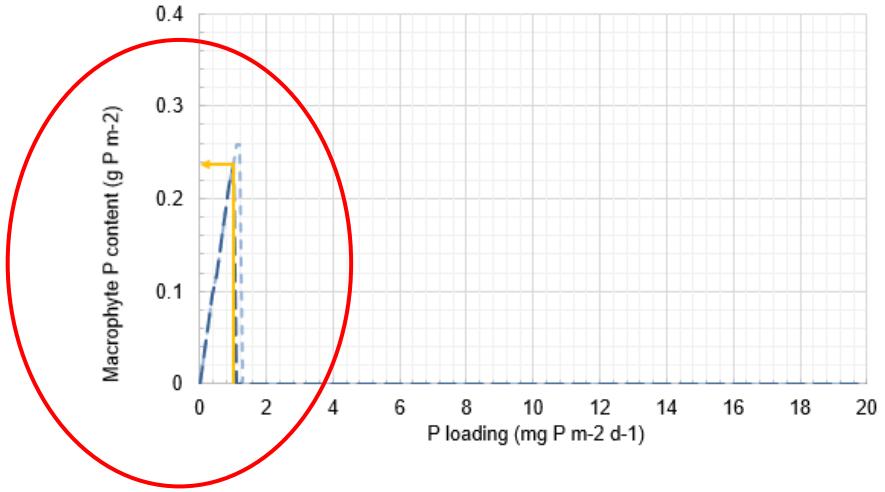
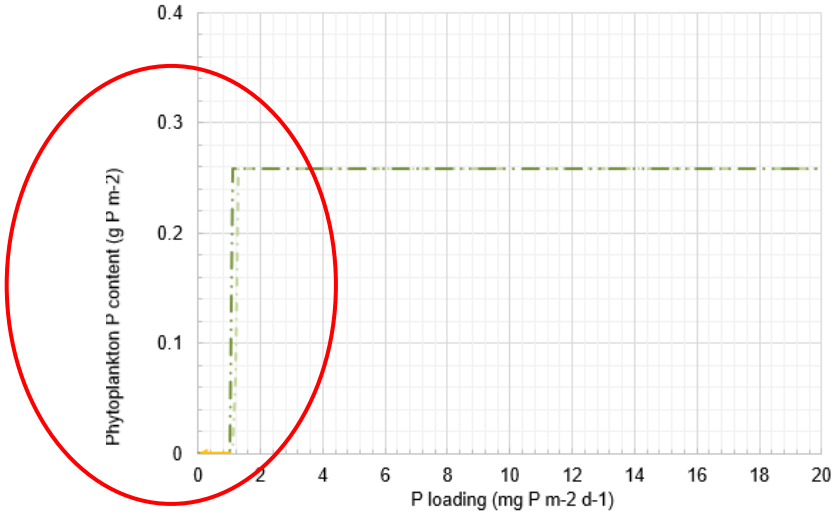


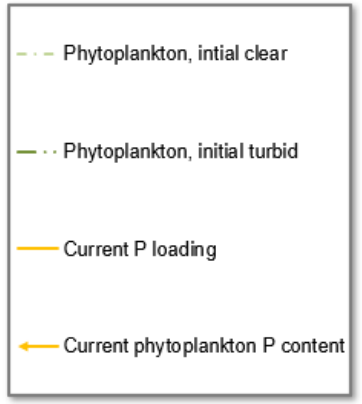
Fertilizer (P) reduction

GPLake-M macrophytes



GPLake-M phytoplankton





Take-aways

- 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 lake**s (around 2 meters deep).
- Still, it's a **simple and clear** way to help understand and manage lake ecosystems.

Thank you!

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