Assessing Legacy Phosphorus Contributions and Management Strategies in Agricultural Watersheds with SWAT+

Ismail Jesna, Raj Cibin, Anthony Buda, Amy S. Collick

USDA Agricultural Research Service

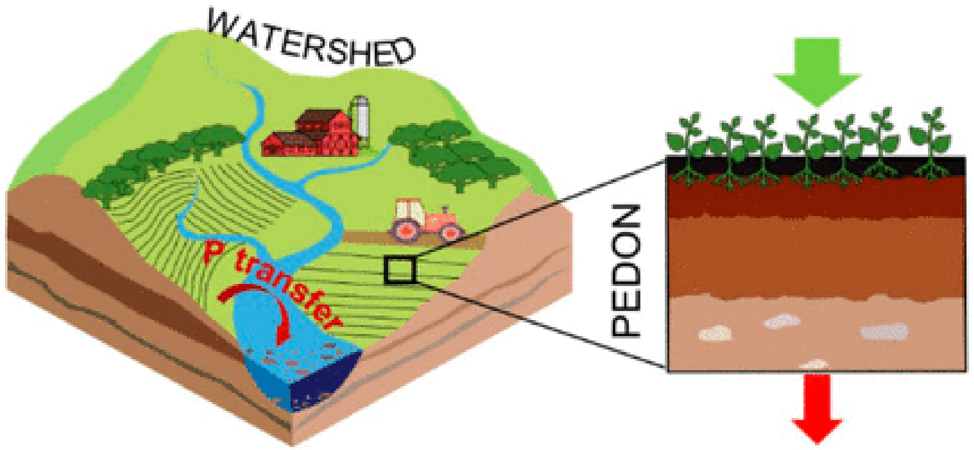
PennState

Legacy P: mechanism of P transfer across watershed and impact on water quality

ARISES FROM HISTORICAL AGRICULTURAL PRACTICES

ACCUMULATED PHOSPHORUS IN SOIL SURPASSING CROP NEEDS

MANURE OFTEN CONTAINS MORE P THAN CROPS CAN UTILIZE



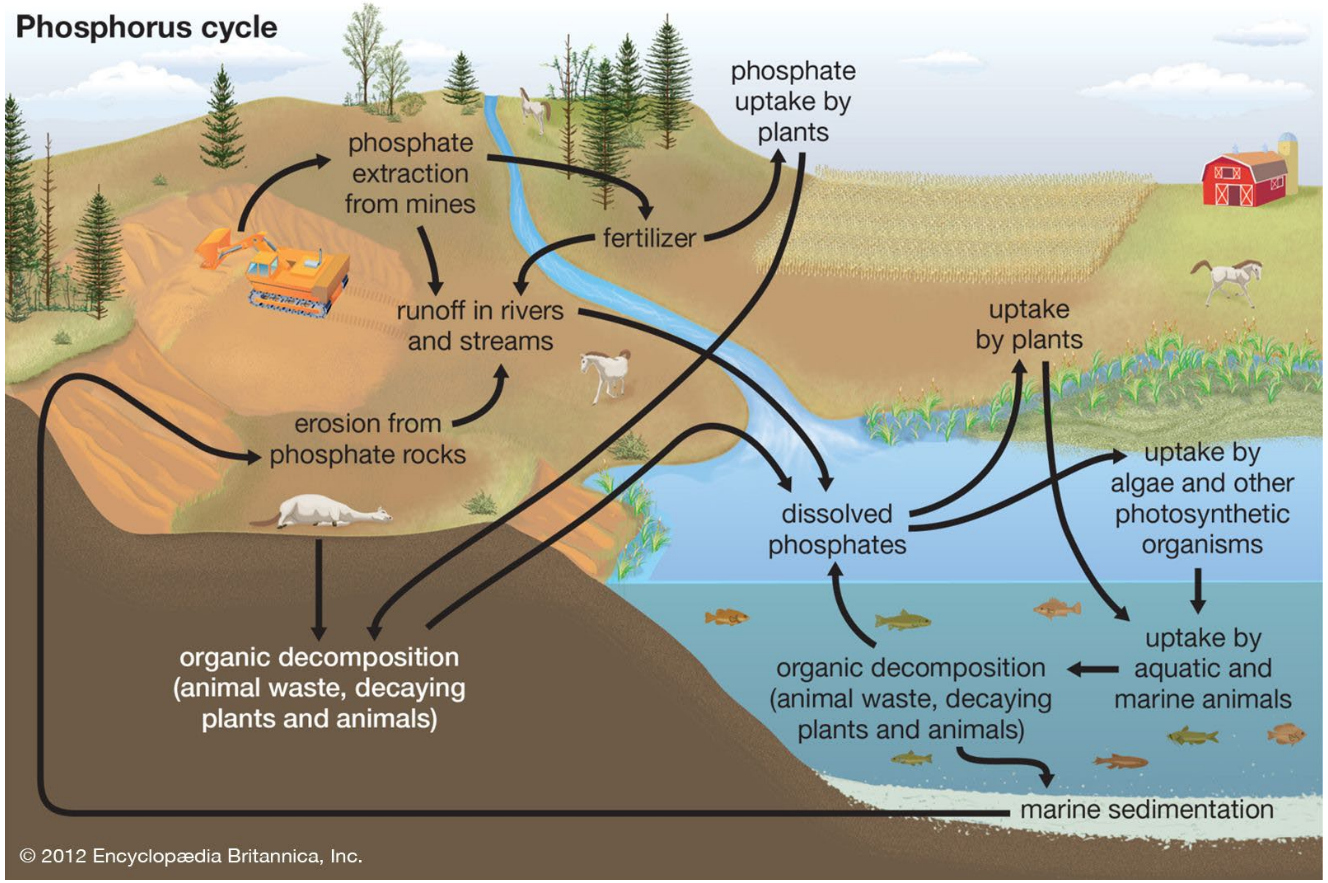
Residual P: magnitude of fertilizer P remains in soil
$+\Delta$ = P input – P output

The Hidden Cost of Phosphorus in Agriculture

Eutrophication in water bodies, harmful algal blooms and declining biodiversity

Challenges in meeting water quality targets

Declining biodiversity in Chesapeake Bay

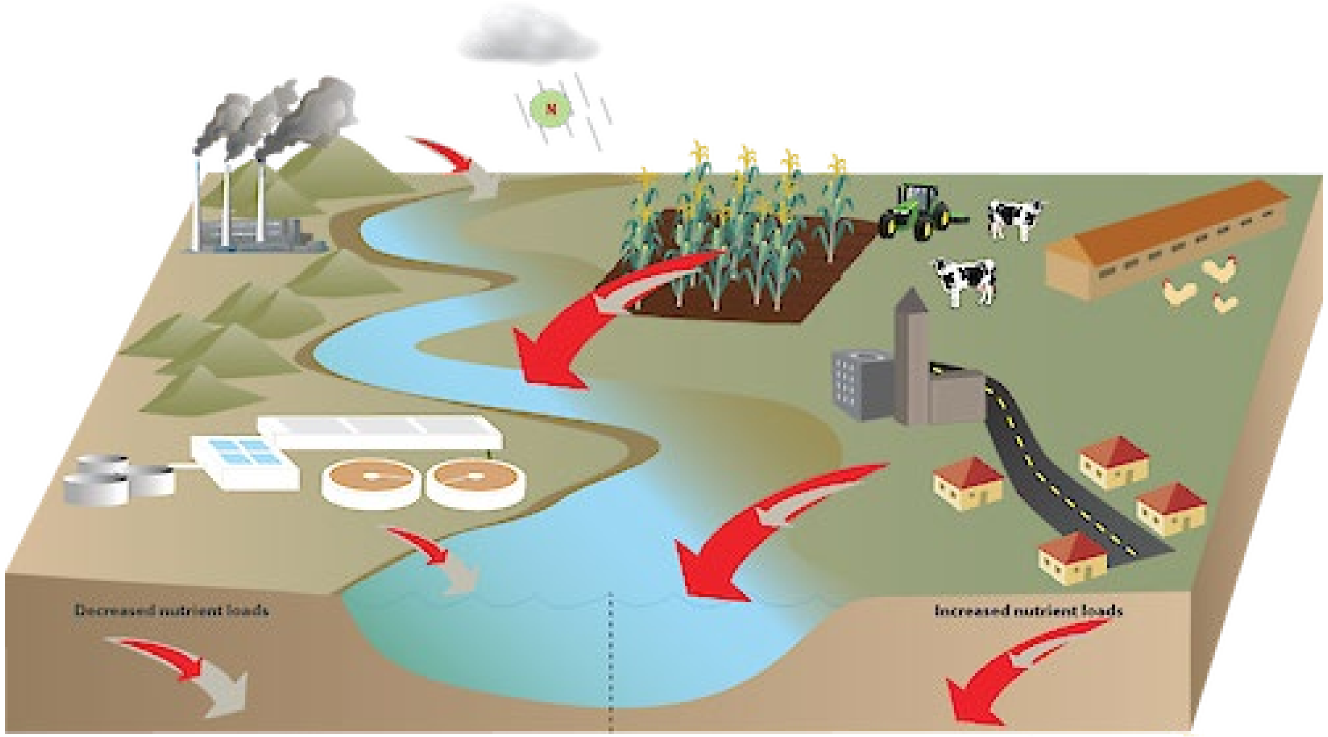


Barriers to meeting water quality goals

PENNSYLVANIA'S LAG IN MEETING CHESAPEAKE BAY TARGETS

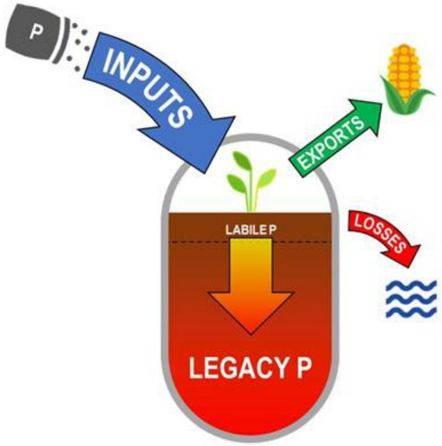
NEED FOR COST-EFFECTIVE STRATEGIES TO ADDRESS LEGACY P

ADOPTION OF BEST MANAGEMENT PRACTICES (BMPS)



Managing Legacy P: Are BMPs Enough?

Test how BMPs can reduce legacy phosphorus while maintaining yields



- Cover crops
- Buffer strips
- Manure management
- Reduced tillage
- Crop rotations
- Soil amendments

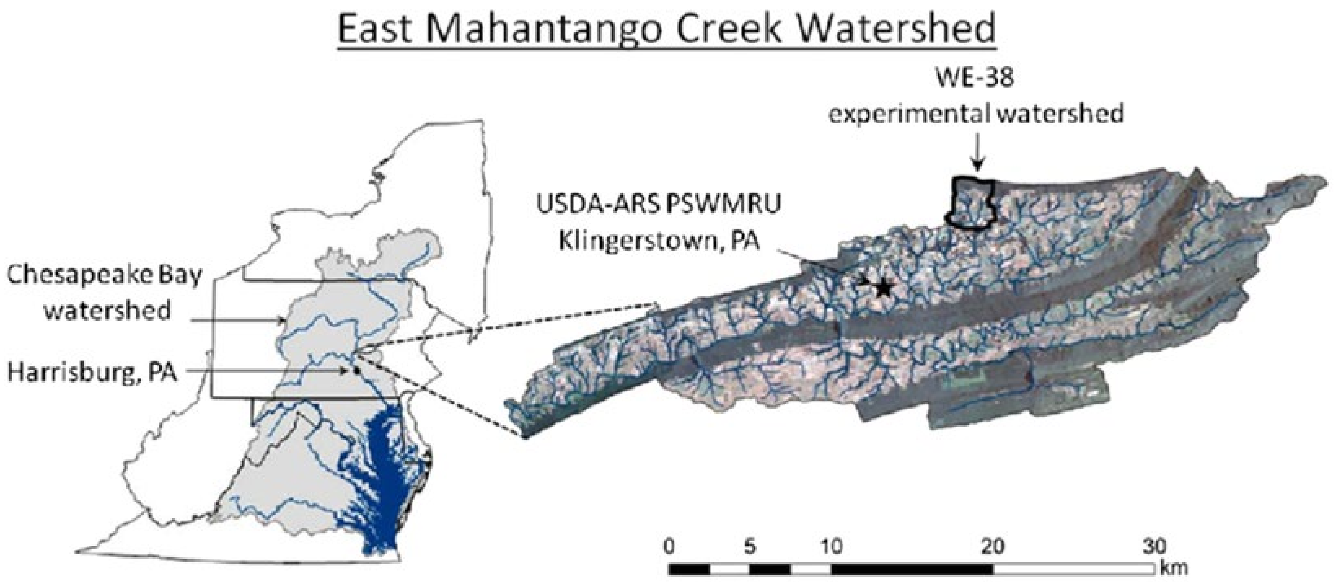
Study Site:

EAST MAHANTANGO CREEK WATERSHED

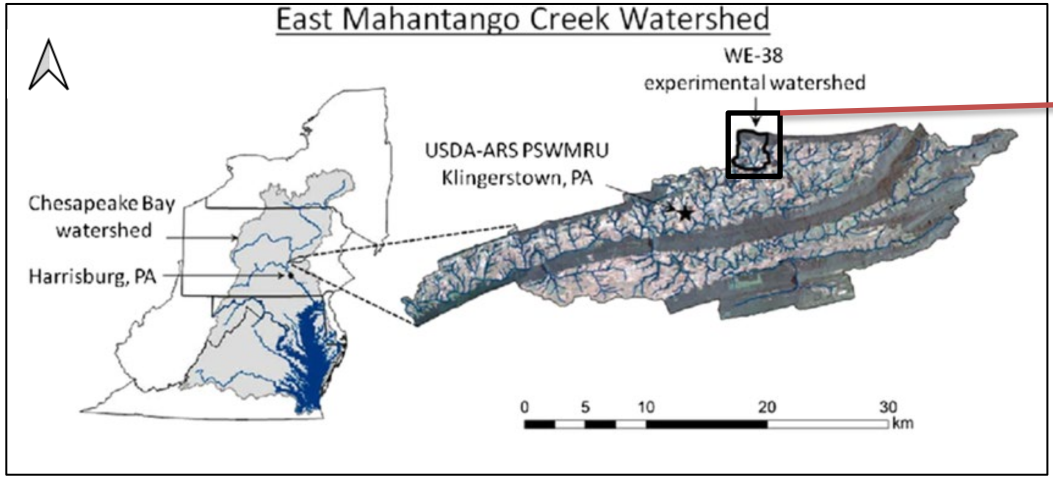
Location: Northumberland County, Pennsylvania

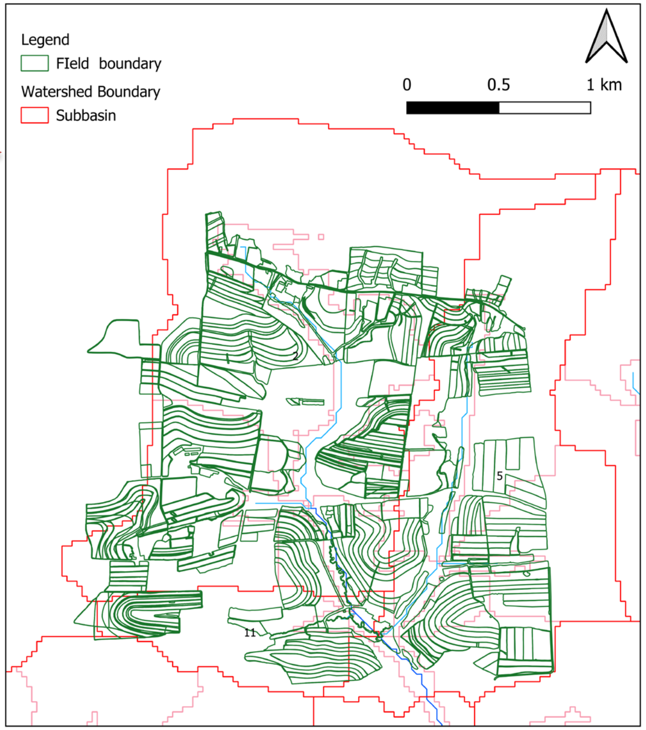
Drains into Chesapeake Bay.

Land use: 44% cropland and pasture, 55% forest.



Field-scale representation in SWAT+

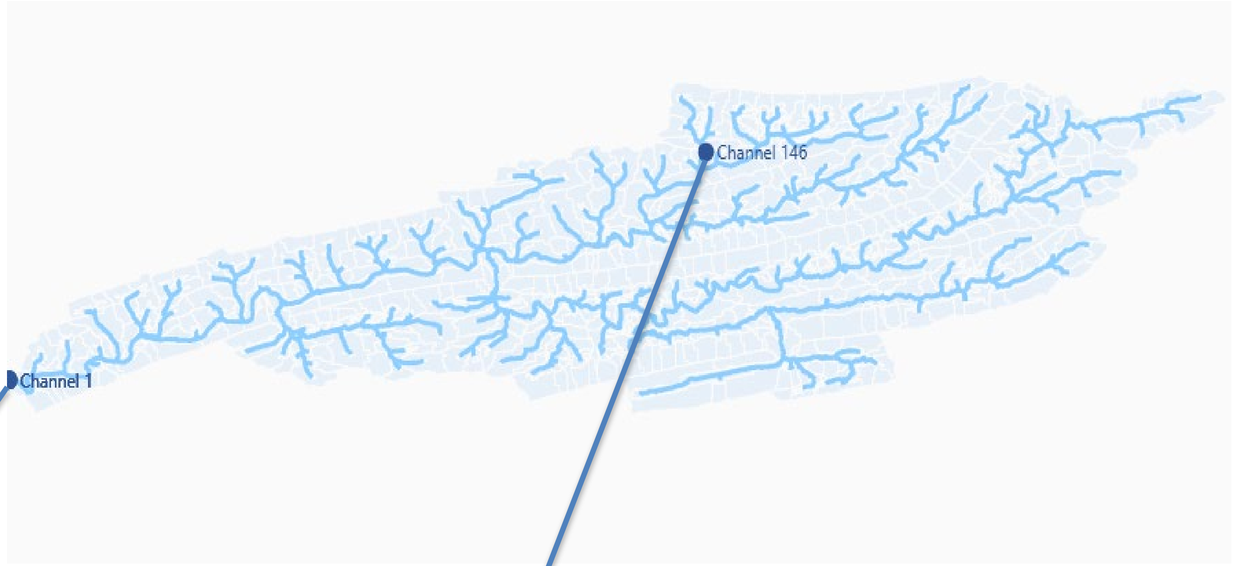


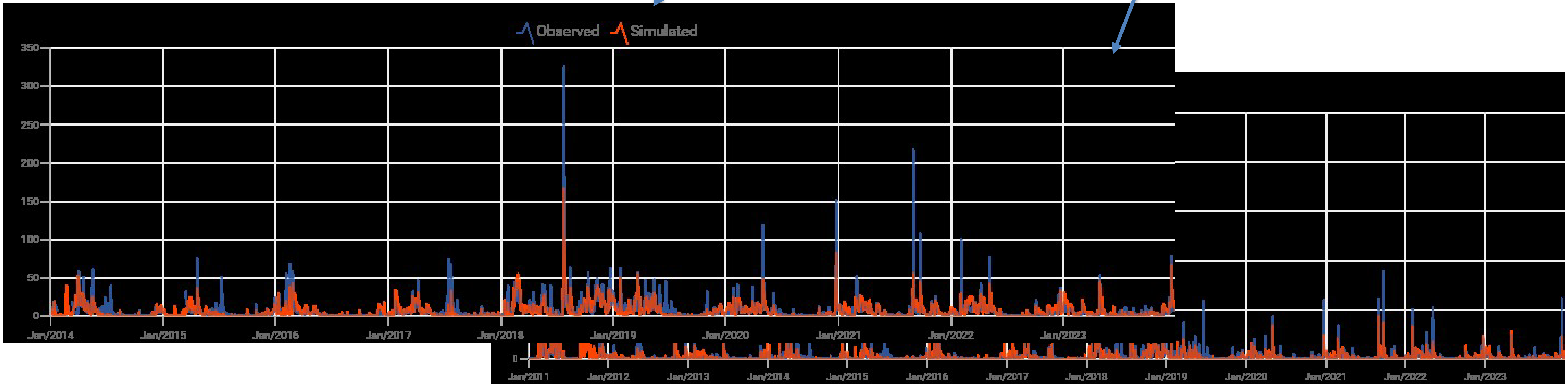


SWAT+ model incorporated with…

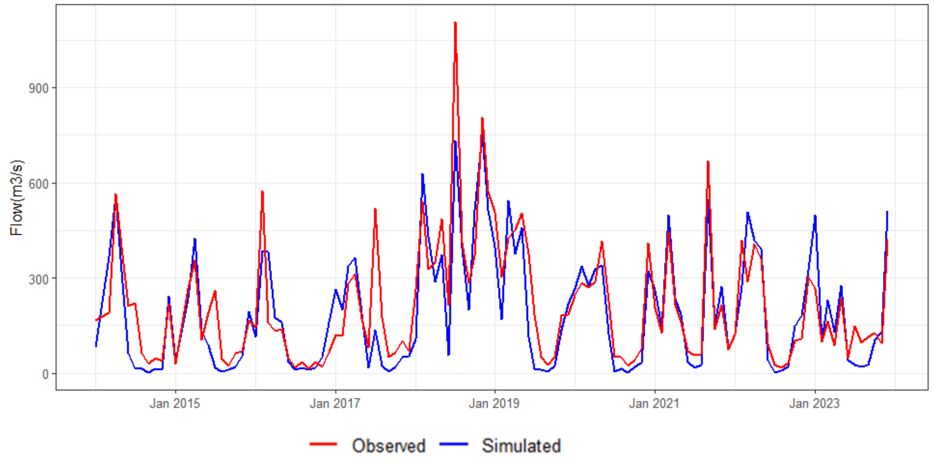
- **907 fields**
- **57k + field operations**

Calibration: Hydrology

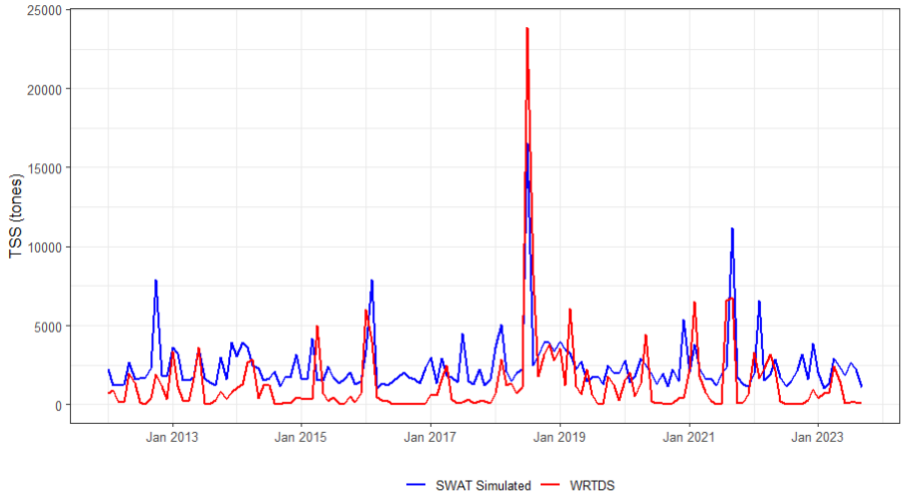




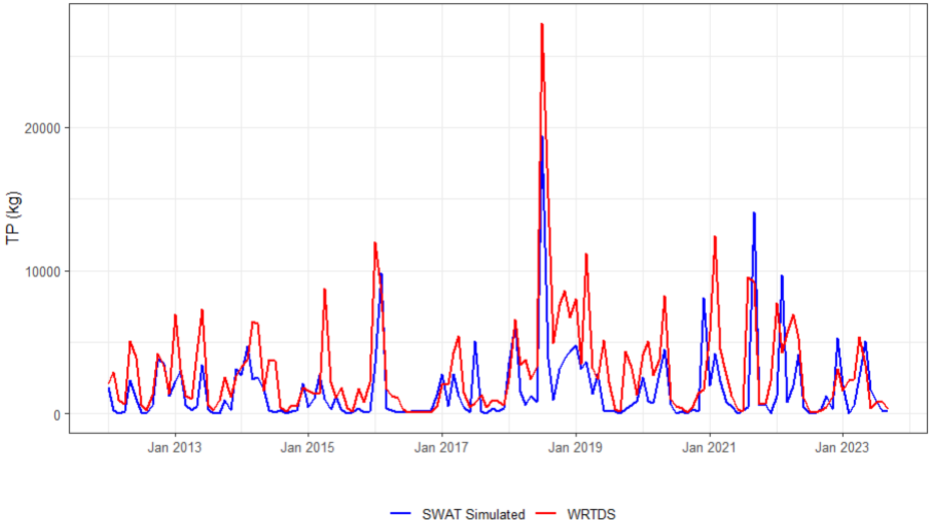
Hydrology and water quality calibration



Performance metrics	Value
NSE	0.72
KGE	0.83
MSE	73.81
RMSE	8.59
PBias	10.17
MARE	0.68

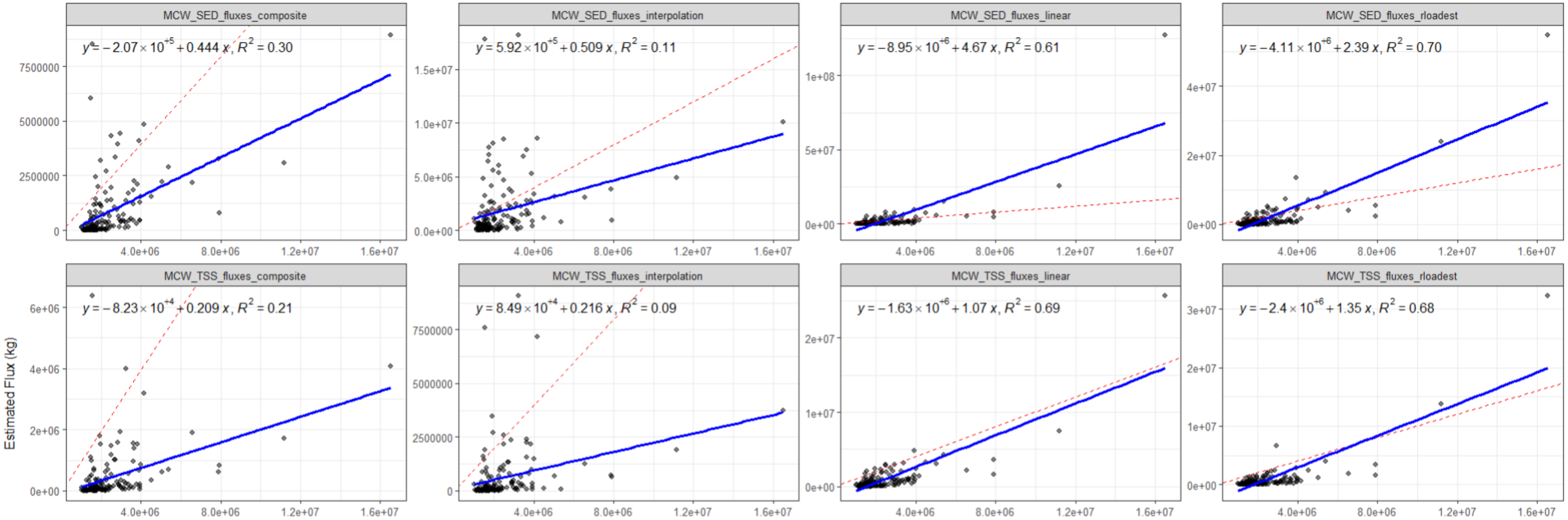


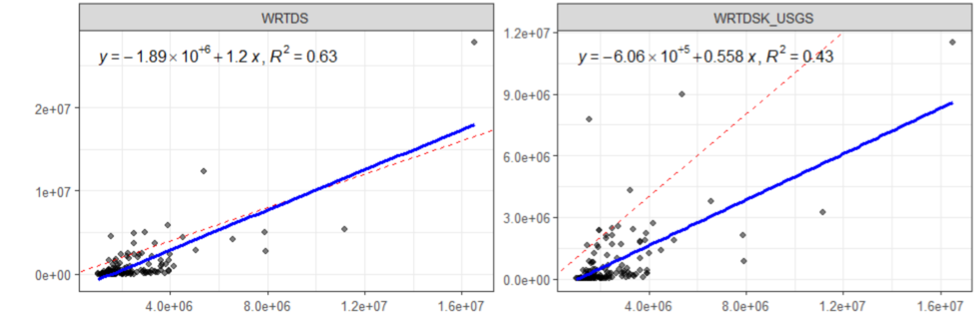
Performance metrics	Value
NSE	0.33
KGE	0.12
MSE	4972142
RMSE	2229
PBias	-76.53
MARE	19.30



Performance metrics	Value
NSE	0.44
KGE	0.40
MSE	8552
RMSE	92.48
PBias	47.25
MARE	0.66

Challenges in sediment flux estimation



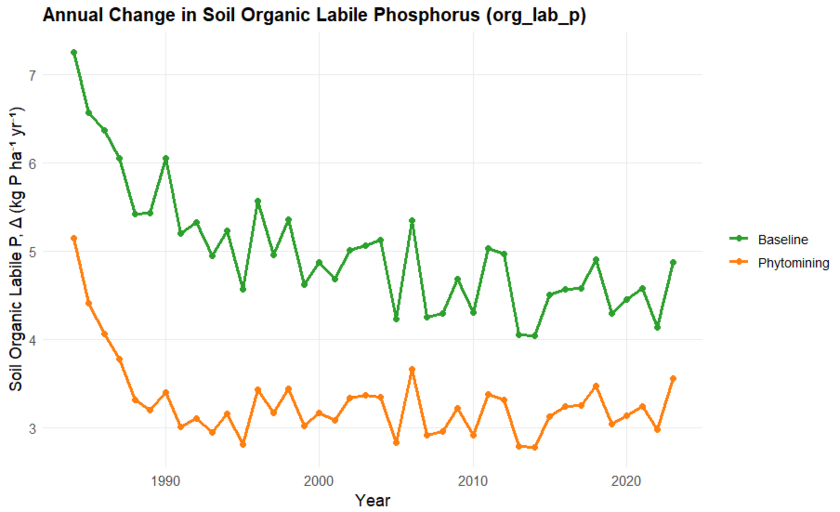


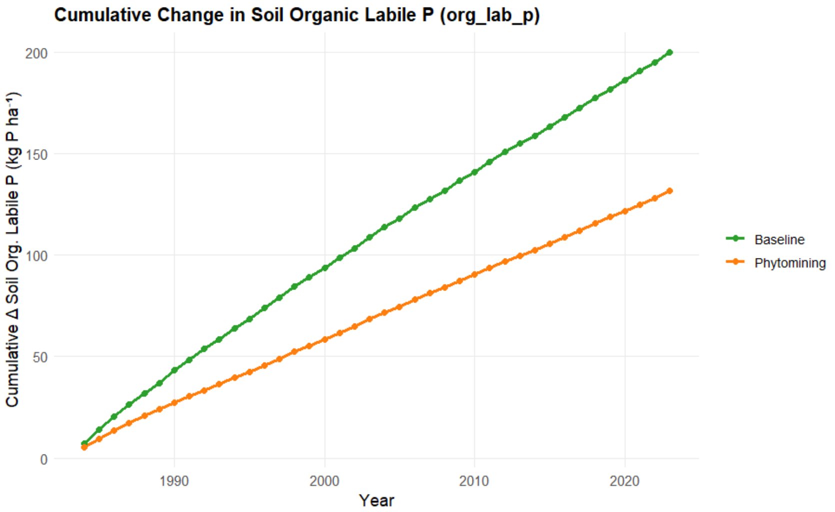
Model	NSE	RMSE	PBIAS	R²
MCW_SED_fluxes_composite	-1.32	2,223,168	178.45	0.30
MCW_SED_fluxes_interpolation	-0.04	2,897,981	33.07	0.11
MCW_SED_fluxes_rloadest	0.44	3,866,399	41.15	0.70
MCW_SED_fluxes_linear	0.23	9,505,239	-0.08	0.61
MCW_TSS_fluxes_composite	-8.60	2,581,318	471.05	0.21
MCW_TSS_fluxes_interpolation	-3.11	2,625,689	299.45	0.09
MCW_TSS_fluxes_rloadest	0.36	2,377,768	173.81	0.68
MCW_TSS_fluxes_linear	0.29	1,969,627	151.08	0.69
WRTDS	0.35	2,218,967	134.21	0.63
WRTDSK_USGS	-1.03	2,207,247	222.41	0.43

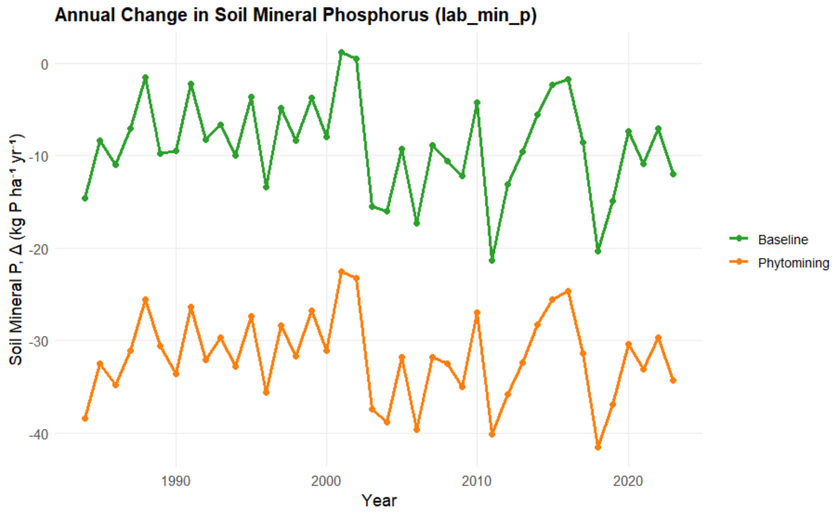
Best management practices: what is phytomining?

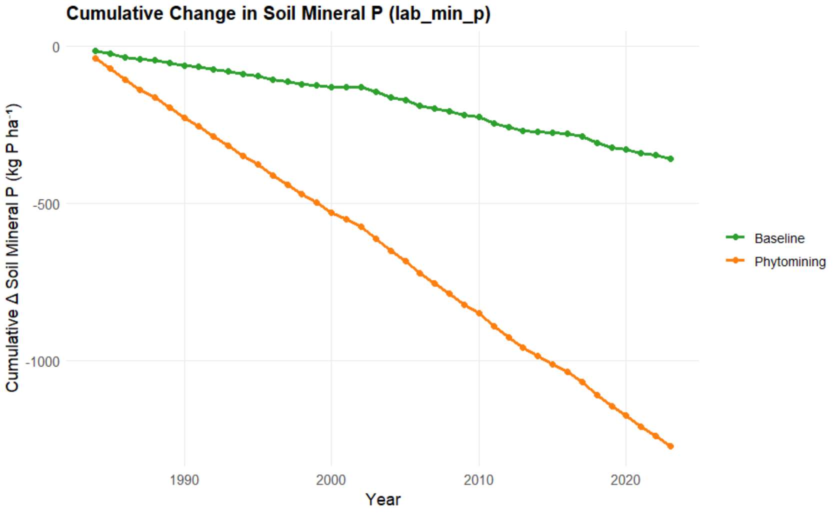
- ✓ **Remove all manure and phosphorus fertilizer applications** from the baseline management.
- ✓ No external phosphorus inputs → **negative P balance**, forcing the system to draw from soil reserves.
- ✓ Represents an **aggressive P drawdown strategy** for reducing legacy P in agricultural landscapes.
  - ✓ Initial conditions of labile P = 200ppm(average value from soil-p tests in WE38)

Long-term soil P dynamics: trade-offs under phytomining

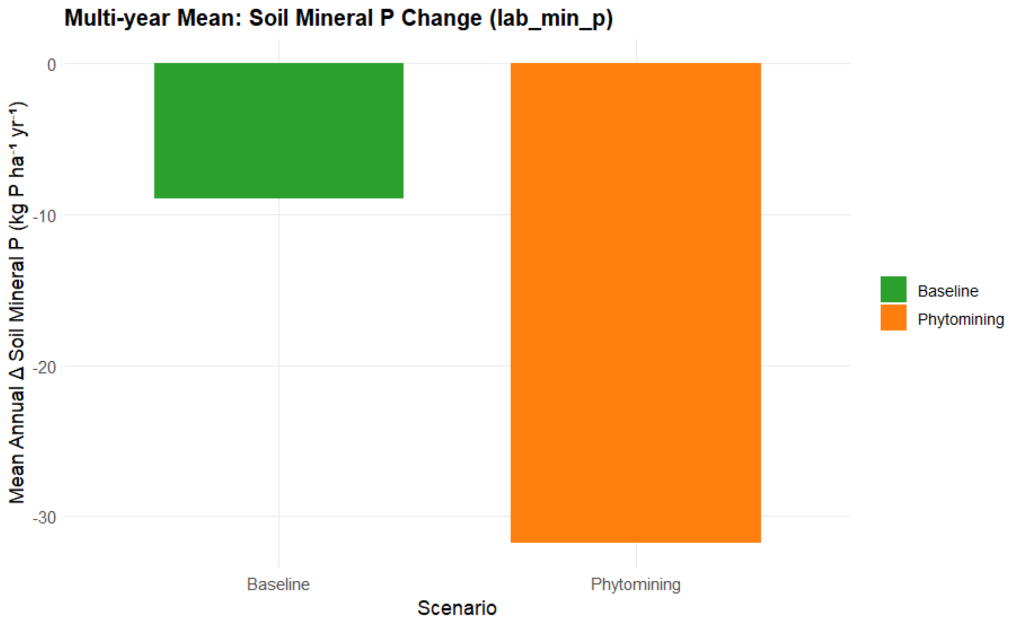


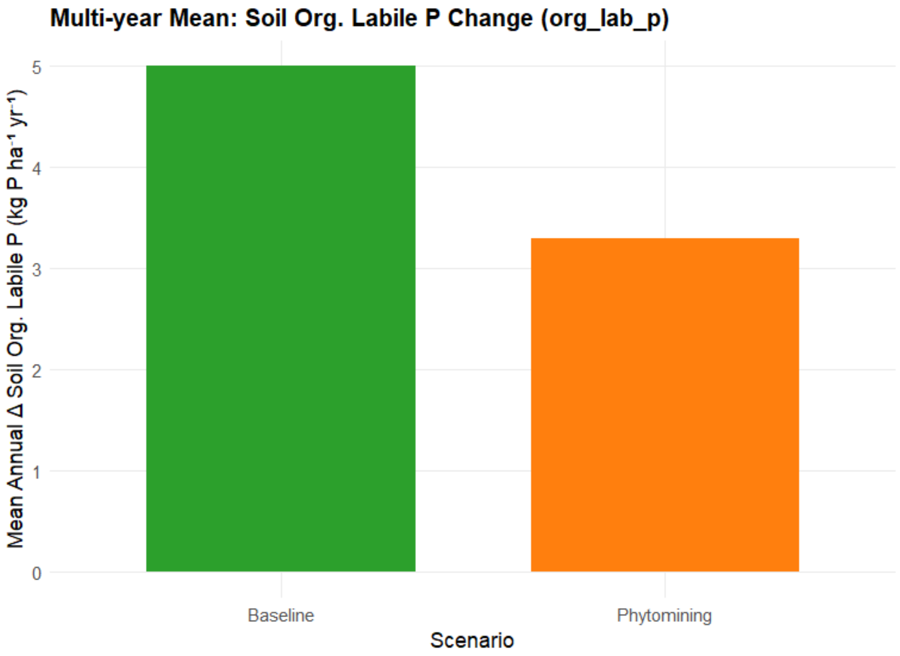




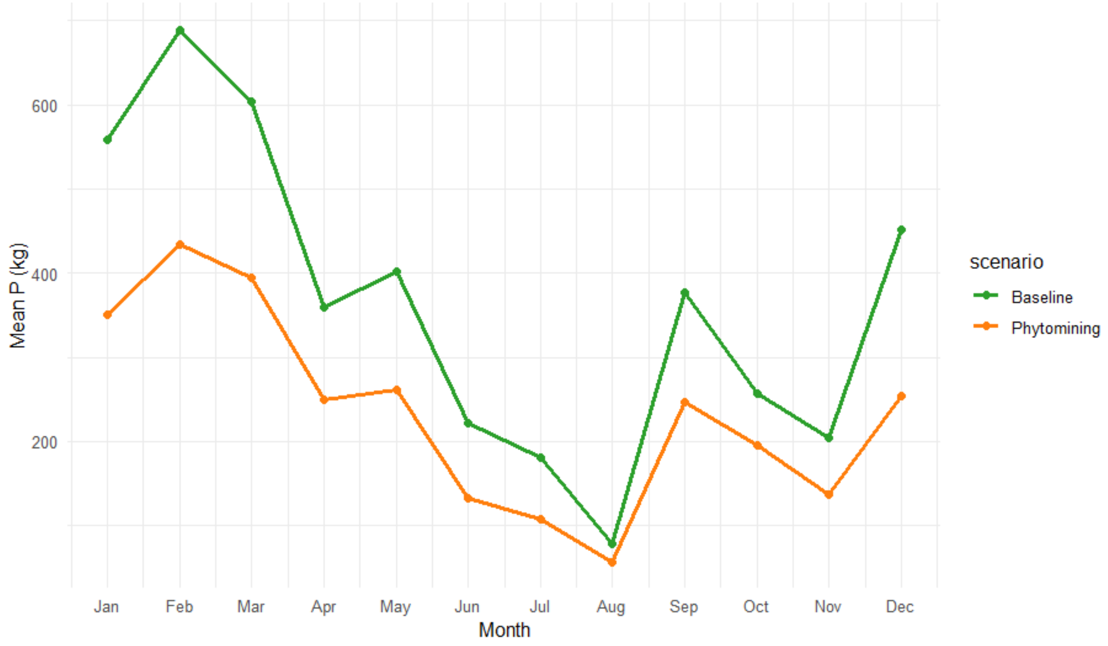


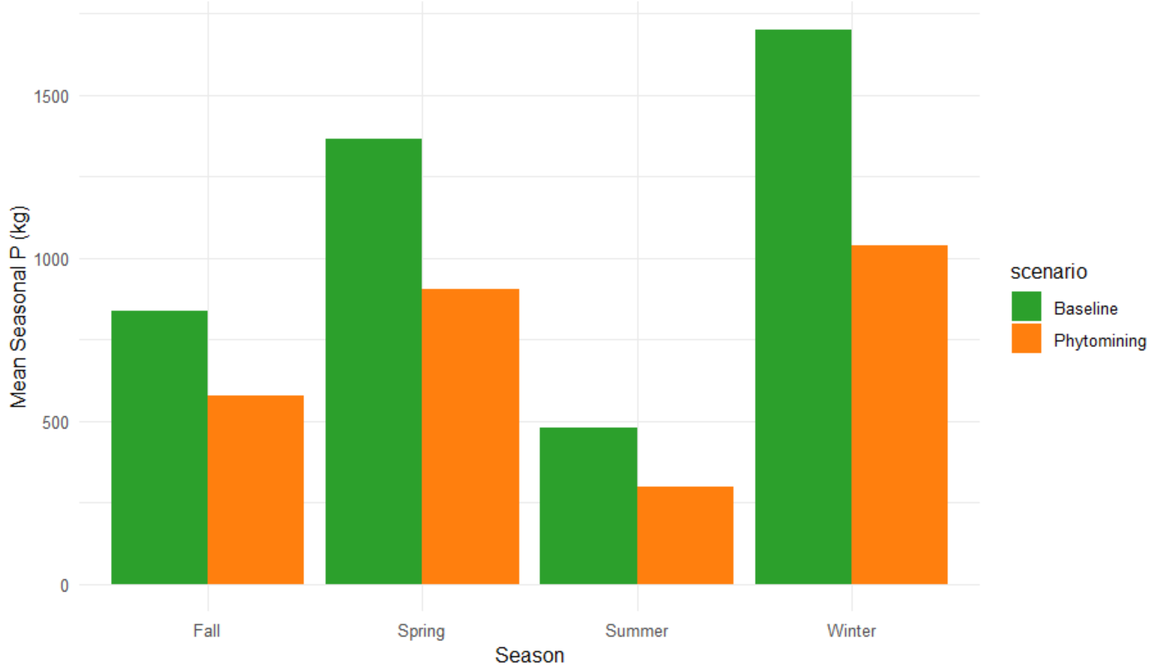
Less build-up, more extraction



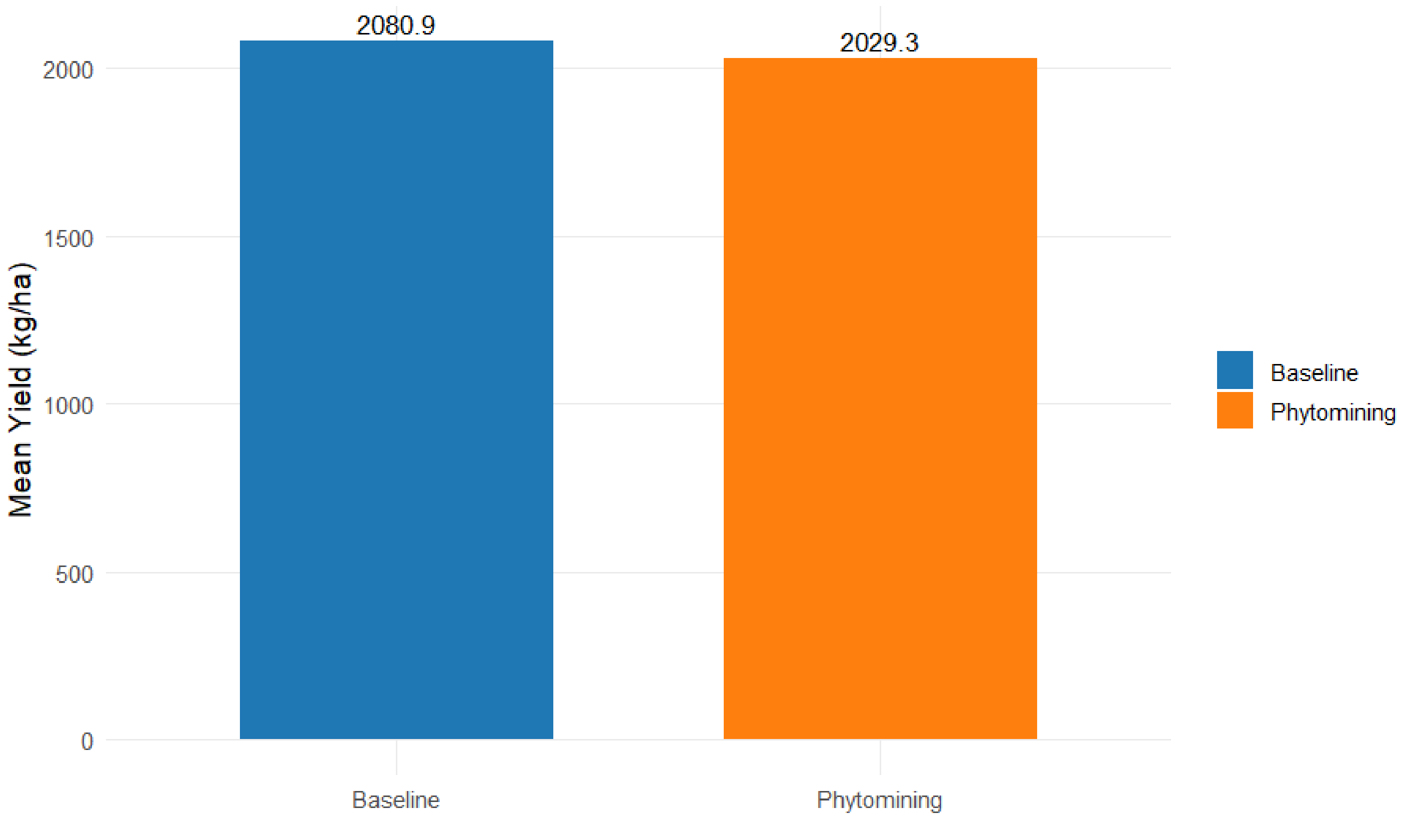


Consistent reduction in total P loss across months and seasons





Phytomining remove excess soil phosphorus with minimal impact on productivity



Legacy P mitigation practices: Way forward
🌱 Avoid ⚒️ Control 🌊 Trap

Practice	Effect on Legacy P
Cover Cropping	Scavenges residual soil P, reduces erosion and runoff losses.
Reduced Tillage / No-till	Lowers erosion-driven P loss; may increase surface soluble P due to stratification.
Riparian Buffers / Filter Strips	Trap sediment-bound legacy P before reaching streams.
Manure Injection	Reduces P losses in runoff; legacy P remains in deeper soil layers.
Irrigation Water Management	Reduces P mobilization by avoiding excess irrigation and leaching of legacy P.
Wetlands	Capture sediment-bound P; long-term saturation can recycle dissolved P.
Conservation Crop Rotation	Gradual drawdown of soil P via diverse crop uptake; reduces erosion/runoff that mobilize legacy P.
Nutrient Management	Prevents further soil P build-up; allows legacy P drawdown over time.