SWAT supporting cost-effectiveness of riparian forests for river water quality improvement

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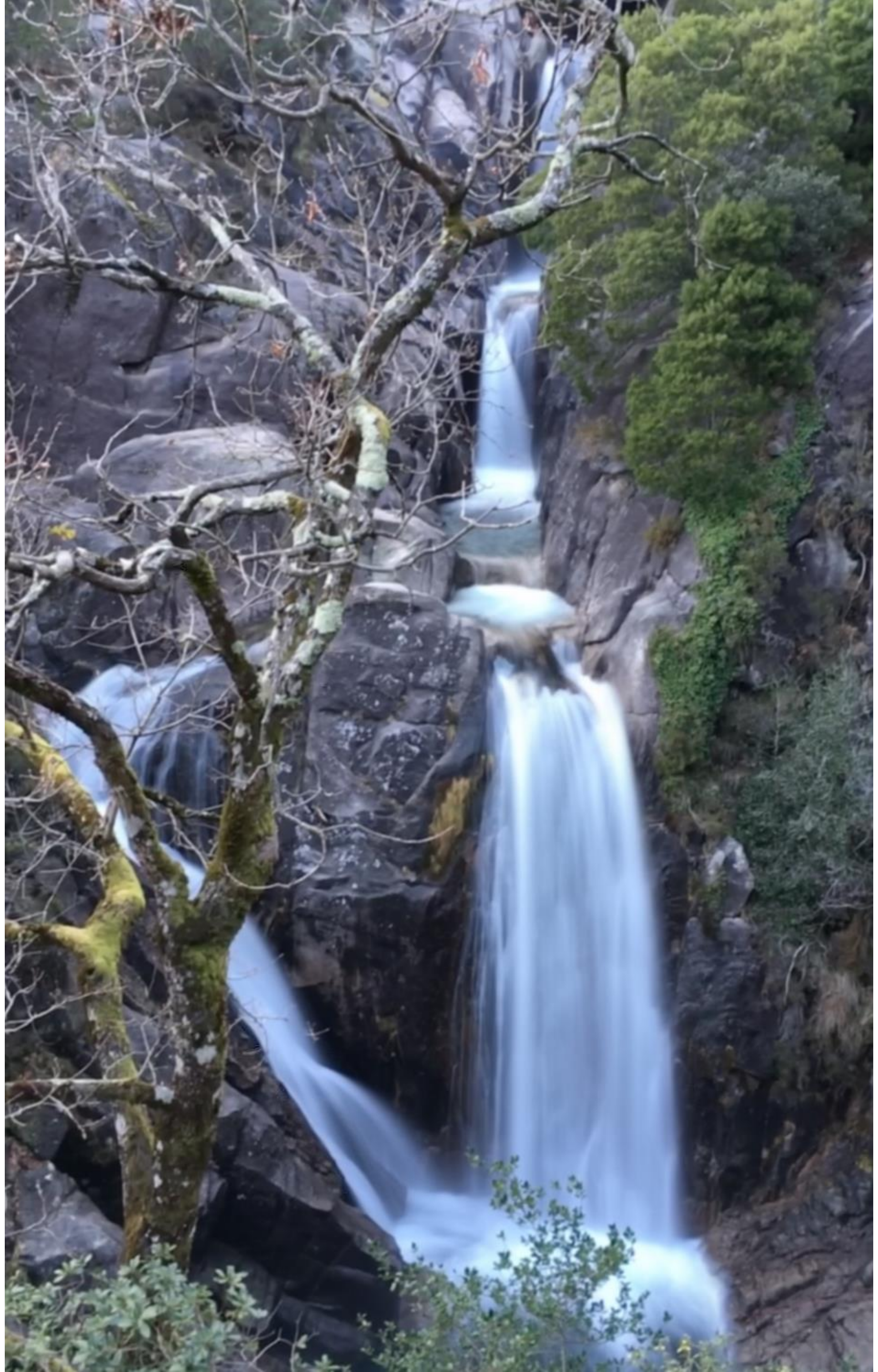

Universidade do Minho
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IB-S INSTITUTO DE CIÊNCIA E INOVAÇÃO PARA A BIO-SUSTENTABILIDADE

Trees4Water

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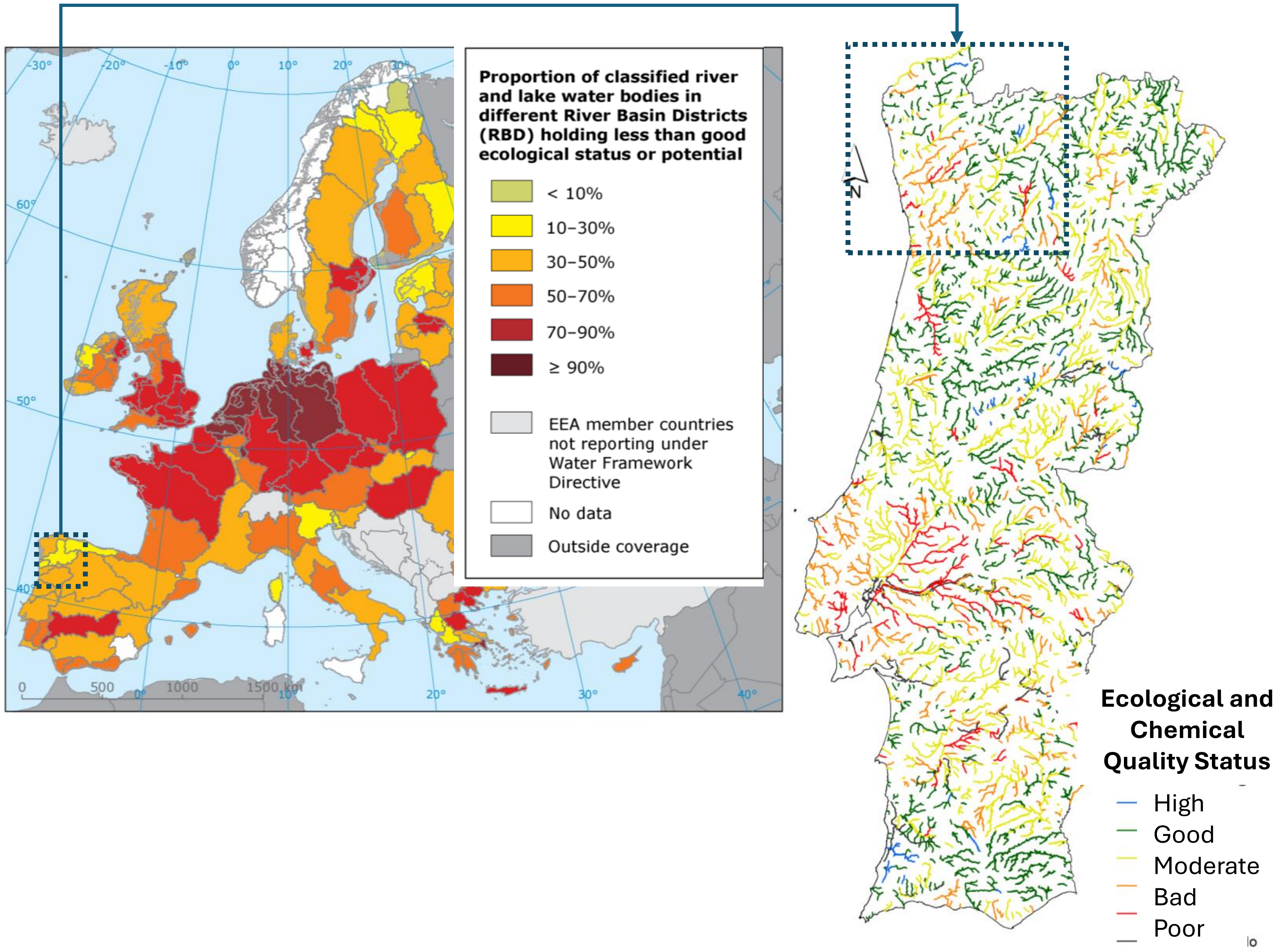
REPÚBLICA PORTUGUESA

12th July, 2024

1. Introduction

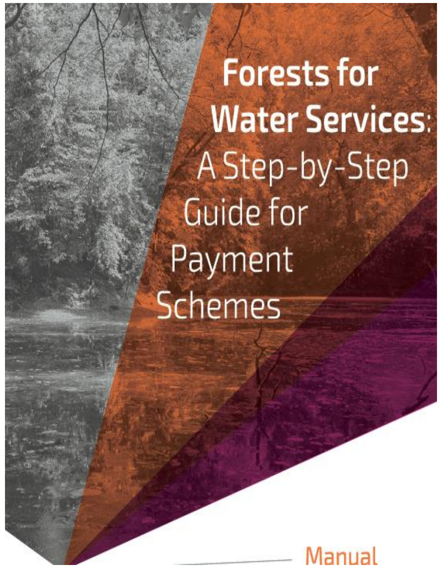


Environmental Effectiveness of schemes (based on meta-analysis)

Buffer width	5 m	10 m	20 m	50 m	100 m
Nitrate-N	20%	30%	40%	80%	90+%
Phosphate-P	10%	20%	30%	60%	90+%
Suspended Sediment	80%	90+%	90+%	90+%	90+%

Table 2

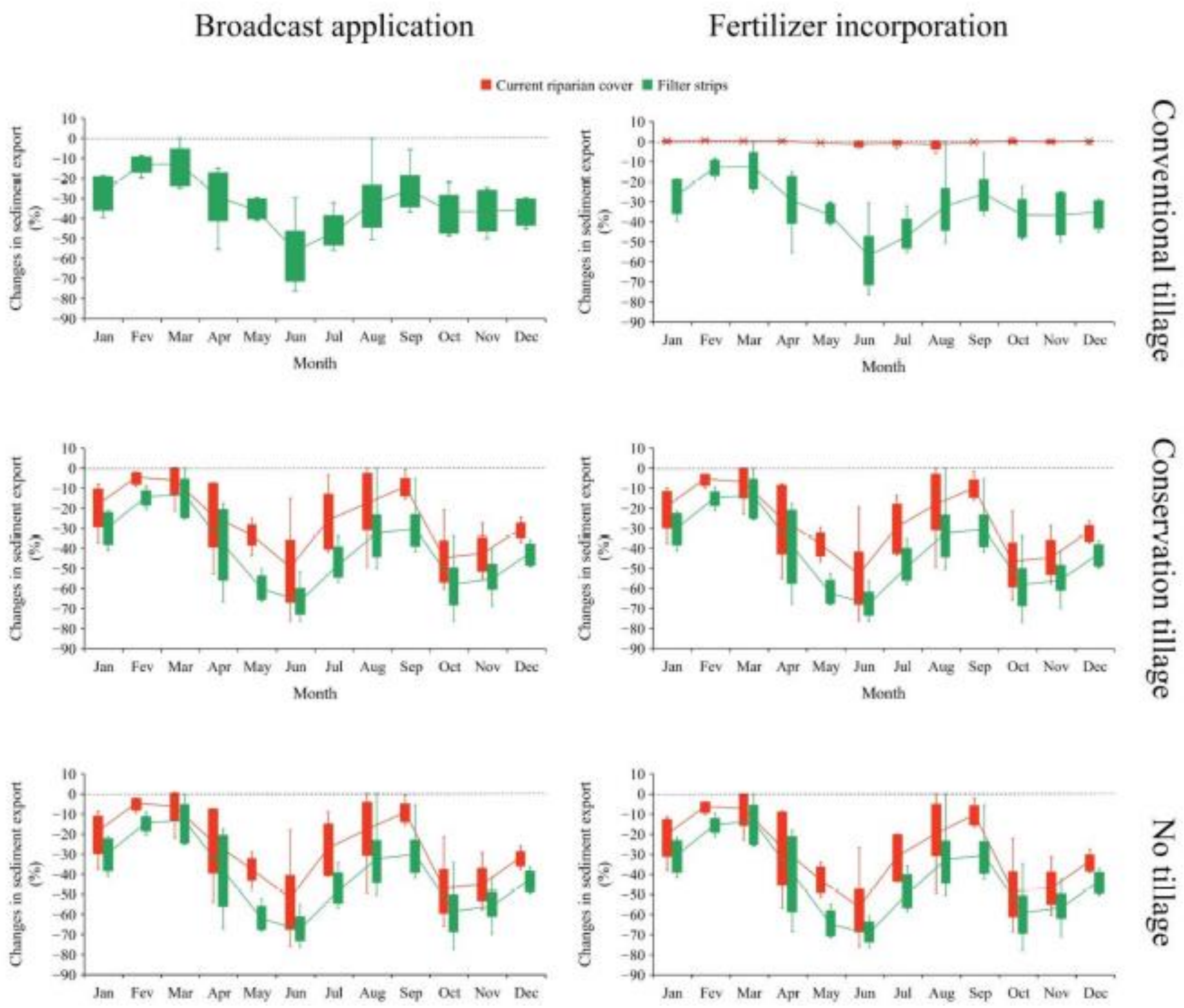
Percent reduction in diffuse pollutant concentration from upslope land to watercourses achievable from a well-designed and managed woodland buffer of variable width. Interpolated from relationships derived from review by Perez-Silos (2017).

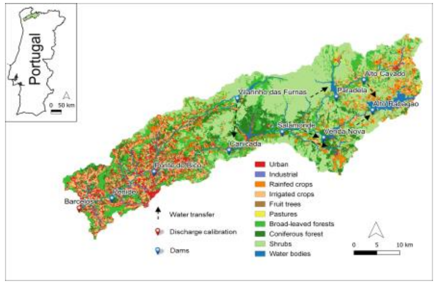


PESFOR-W Manual, 2021

Best agricultural practices on water quality

- Fertilizer incorporation, conservation tillage and Filter Strips
- 25% reduction in sediments and nutrient export





water

MDPI

Article

Modeling the Effectiveness of Sustainable Agricultural Practices in Reducing Sediments and Nutrient Export from a River Basin

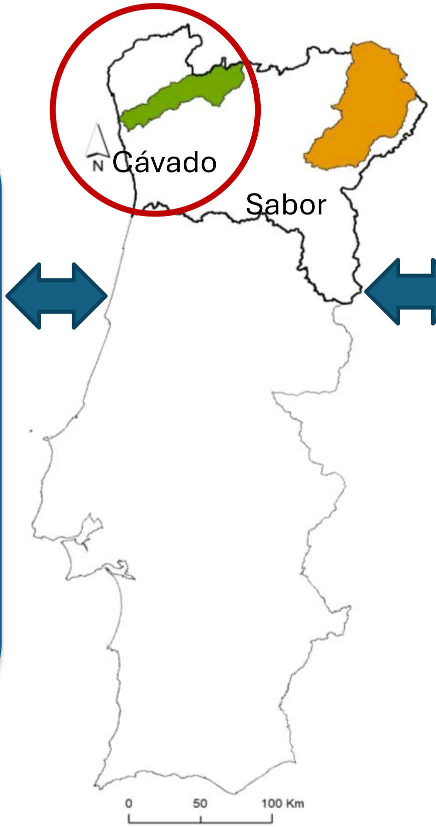
José Pedro Ramião [1,2,3,*], Cláudia Carvalho-Santos [1,2,3], Rute Pinto [4] and Cláudia Pascoal [1,2,3]

2. Project structure

Trees4Water - Tree-based solutions for water quality improvement

Trees4Water

1. Tree-based solutions: modelling (SWAT) with forestation scenarios for water quality improvement



2. Cost-effectiveness analysis of tree-based solutions

Improvement of river's ecological status

Universidade do Minho
Escola de Ciências

Center for Ocean and Society

C | A | U

Stakeholder involvement and co-design
Communication outreach

Águas do Norte
Grupo Águas de Portugal

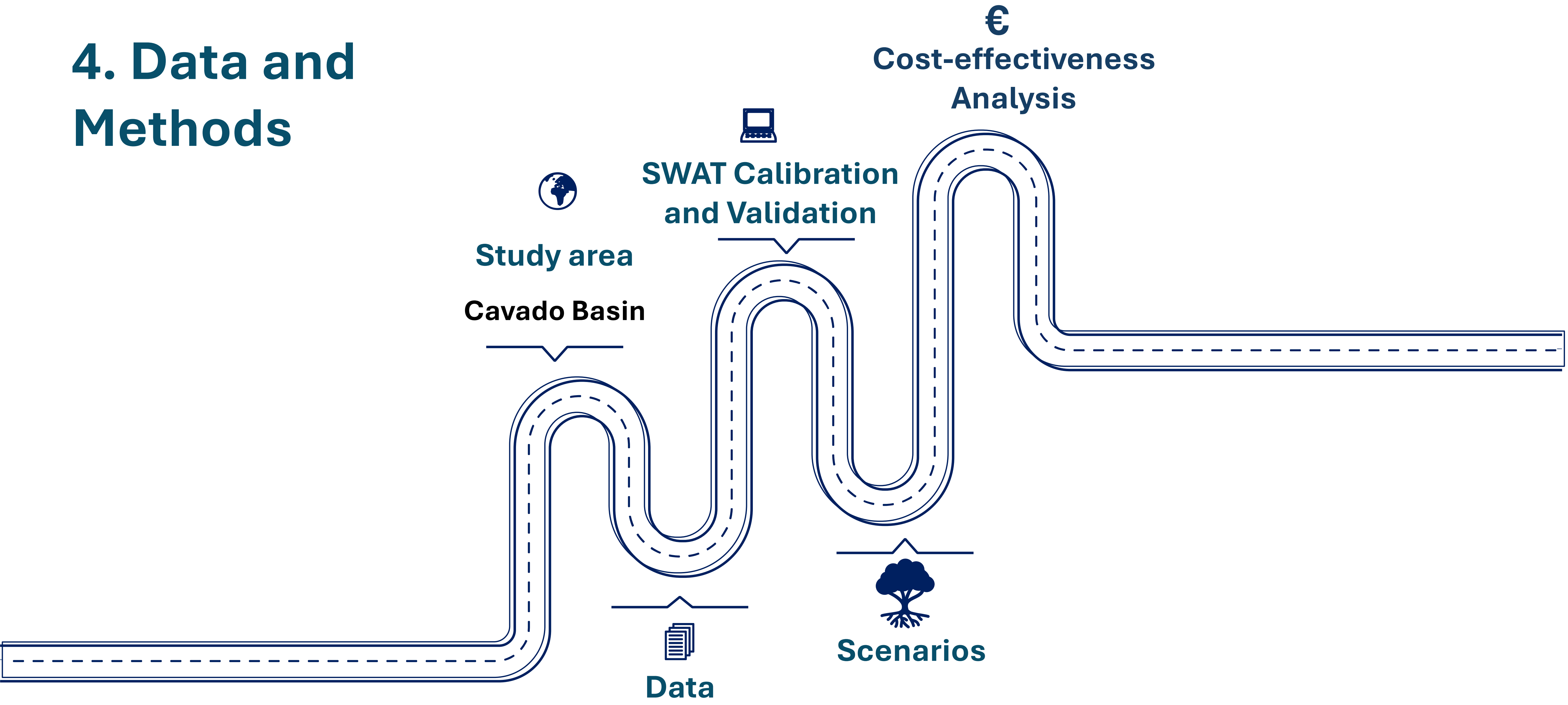
Tree-based solutions Hydrological modelling Water quality Cost-benefit analysis

3. Objectives

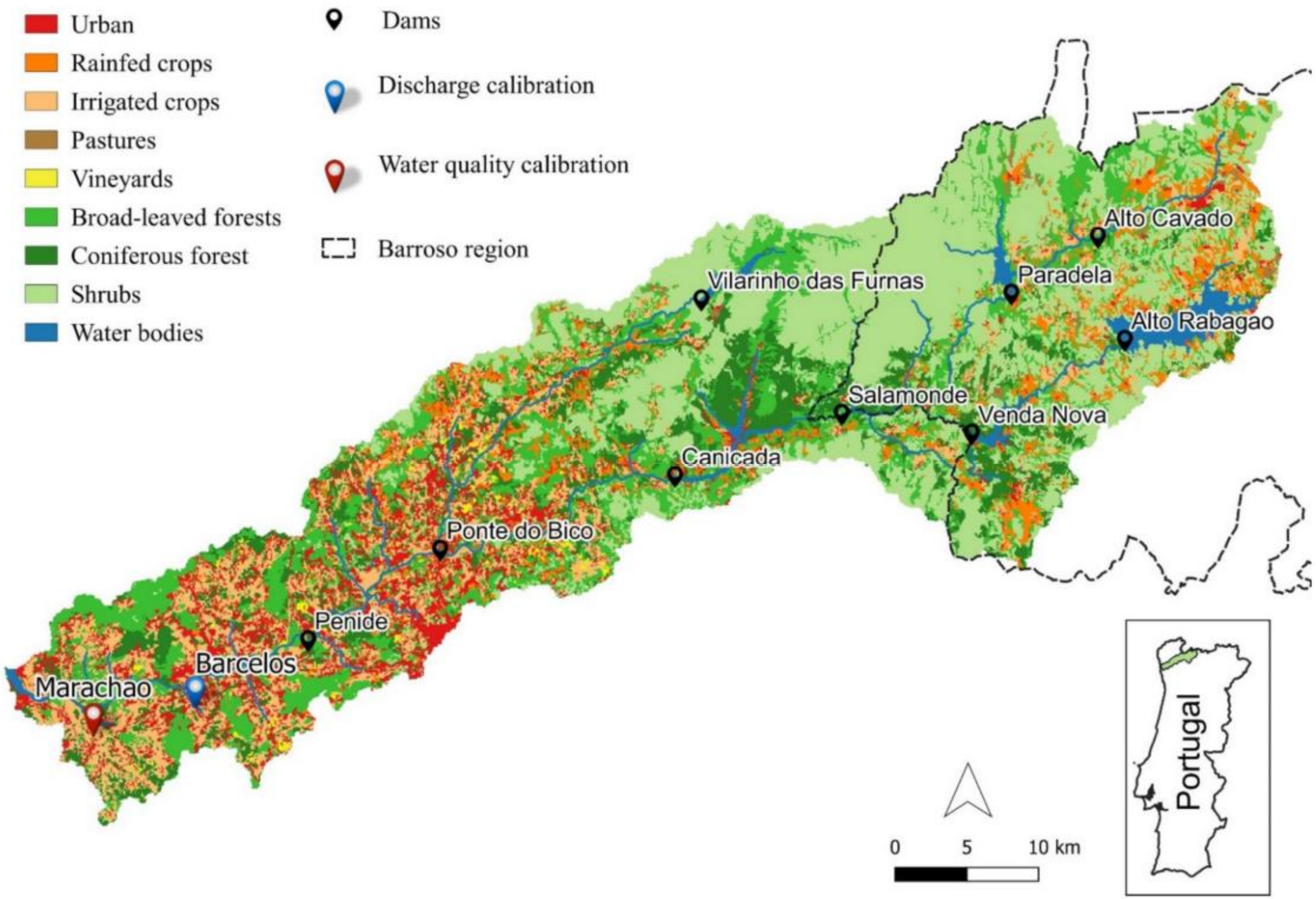
- To evaluate the **environmental effectiveness** of 2 riparian forest buffer scenarios in reducing sediments and nutrients to the rivers using **SWAT**

- To calculate the **cost-effectiveness** of the of 2 riparian forest buffer scenarios

4. Data and Methods



A) Study area



Cávado River Basin

- Area - 1581 km^2
- Annual precipitation is 1300 mm
- 9 dams located
- Soil classes were aggregated into 8 groups
- Land covers were aggregated into 16 groups
- Three classes of slope

B) Data

Variables	Source	Description
DEM	NASA Shuttle Radar Topography Mission (SRTM)	1 Arc-Second Global Land Elevation Map
Stream network	SNIAmb	Stream network according to the Water Framework Directive (WFD)
Land cover	DGT	COS 2010 (Land use map), 1 ha (minimum mapping unit). Classes were aggregated into seven main cover classes
Soil	Leitão et al. (2013)	Soil Ecological Value of Mainland Portugal, 1:50 000. Classes were aggregated into seven main soil classes
Precipitation and temperature	E-OBS	Mean daily precipitation (mm), maximum and minimum daily temperature (ºC) from E-OBS gridded dataset, from 1970 to 2018
Climate (other variables)	SNIRH	Hourly values from 2003 to 2017 were converted to daily values of solar radiation (MJ), relative humidity (%), and wind speed (m/s) from climate 3 climate stations
River discharge	SNIRH	Daily observations of river discharge ($m^3 s^{-1}$) at 1 hydrometric station. Calibration period: 1980–1982; Validation: 1983–1985
Water flow-in to reservoirs	SNIRH	Daily observations of water flow-in ($m^3 s^{-1}$) to 6 reservoirs. Calibration period: 2004–2006; Validation: 2015–2017
Reservoirs	SNIRH, EDP	Location and input data for reservoirs
Water abstraction	SNIG, APA	Location of surface water abstractions and volume of water abstracted

C) Calibration and Validation

Modified SWAT general parameters for Cávado basin during calibration and validation period (1995-2001) with 3-year period of warm-up

Parameters	Description in SWAT	Initial value	Calibration
Groundwater			
Cn2	Curve number for moisture condition II	Various	-10
Reservoir			
RES_D50	Grain size of sediments	0	20
RES_NSED	Equilibrium sediment concentration	1	0.9
Sediments			
USLE_K	Erodibility factor	0.23	0.02
Nitrates			
NPERCO	Nitrate percolation coefficient	0.20	0.97
Phosphorus			
ERORGP	Phosphorus enrichment ratio	0	1.14

water MDPI

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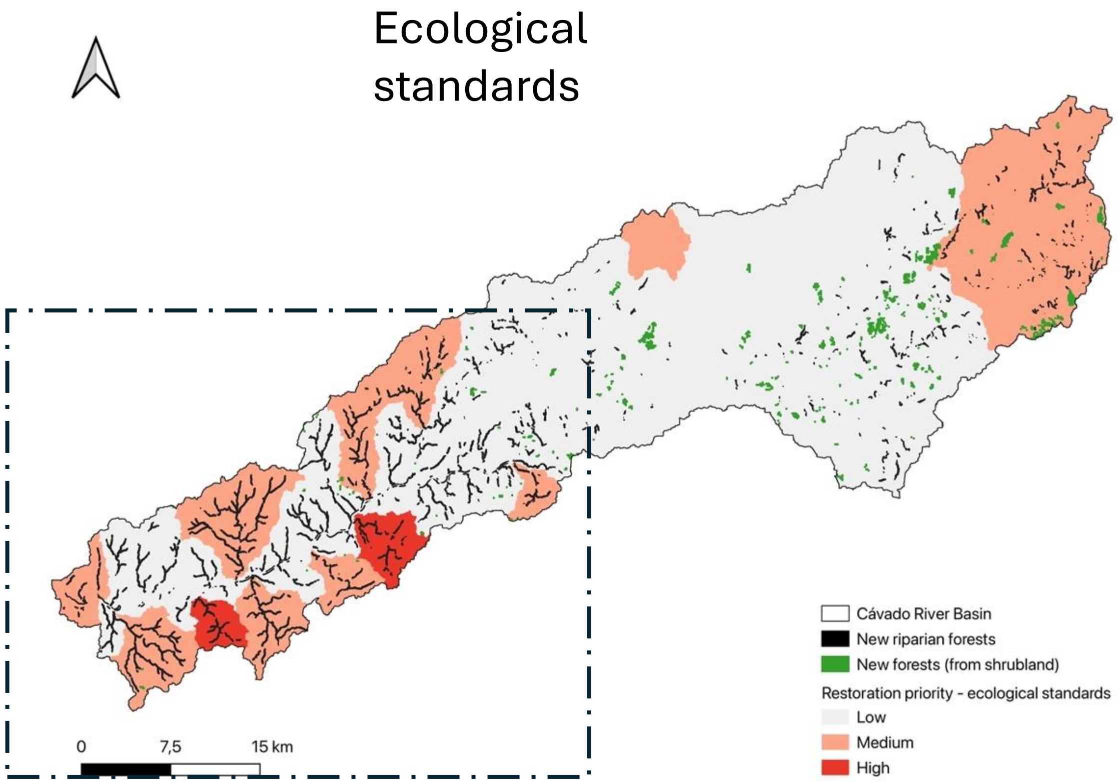
D) Riparian Forest scenarios development

D1) Opportunity Mapping



Lowlands with intensive dairy farming

D2) Creation of new land cover

- Two scenarios of 2.5 and 5 m of riparian forest buffer
- Applied only in 10 subbasins
- Create one more land cover class (SALG)
- Add SALG class that intersects in the Agriculture lands (areas more than 2 ha)

Riparian Buffer Scenario	Area
2.5 m	29 ha
5 m	57 ha

Species of riparian forest (SALG): Willow, Oak and native forest

E) Cost-Effectiveness Analysis

i) Total cost equation

$$TC_{PV} = (C_{plant.})_{t=0} + \sum_{t=1}^{T} \frac{(C_{maint.} + C_{opp.})}{(1+d)^t}$$

TCpv= Total cost
Cplant = cost of planting the forest
Cmaint = cost of forest maintenance
Copp = opportunity cost
d = 3.24 interest rate of 10-year government bonds

ii) Environmental effectiveness

$$EE^j = \sum_{t=1}^{T} p_{st} - p_{bt} \leftrightarrow p_{st} < p_{bt}$$

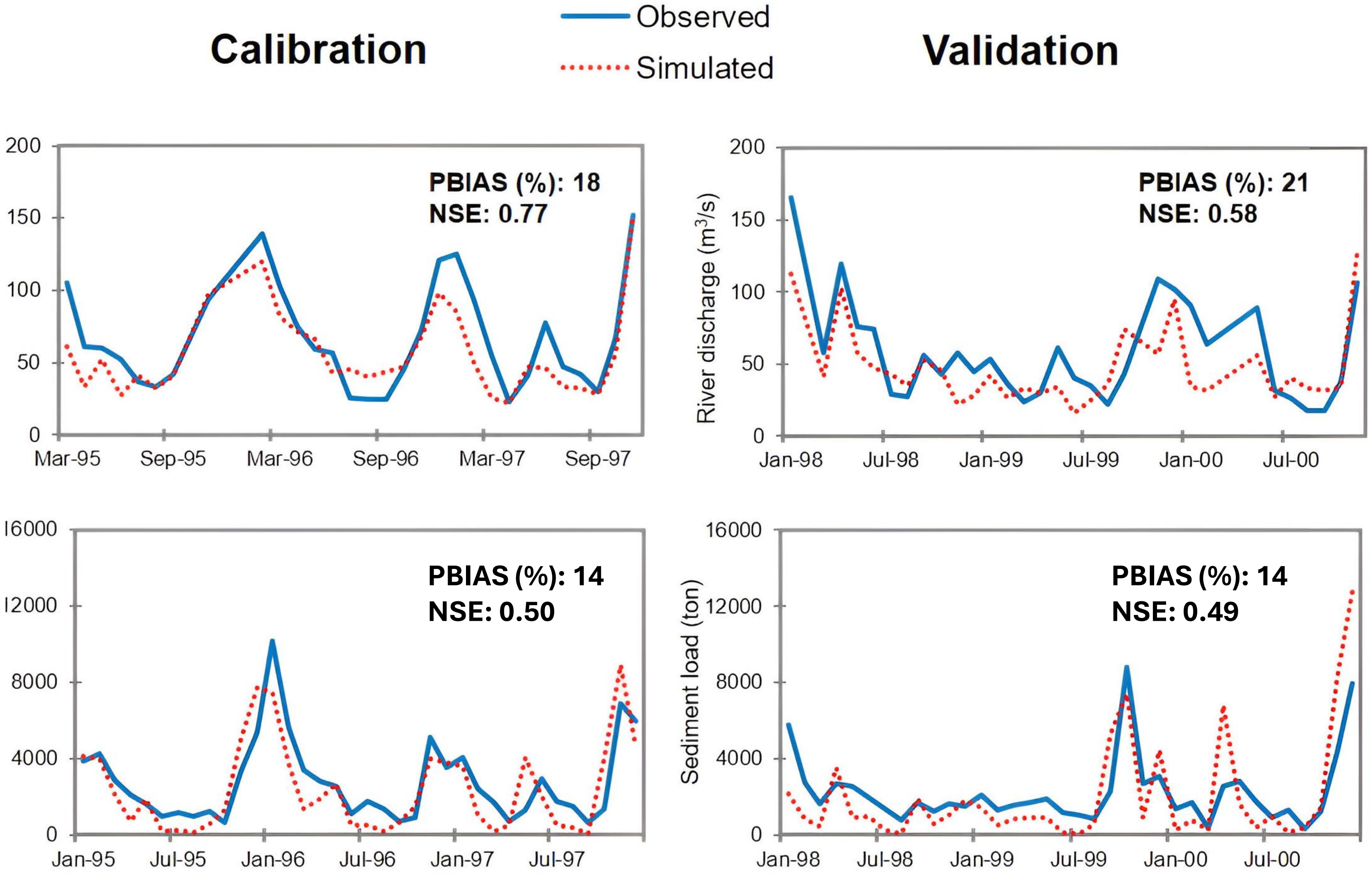
EEj = environmental effectiveness or water quality improvement for pollutant j,
Pbt = pollution level in the water at time t in the baseline scenario (i.e. no forestation)
Pst = is the pollution level after the forestation scenario
T = lifespan considered for the scenarios.

iii) Cost-effectiveness ratio

$$CE_j = \frac{-(TC_{PV})/n_P}{EE^j}$$

Cej =cost-effectiveness ratio for pollutant j
TCPV = present value of the total cost
nP = number of pollutants
Eej = environmental effectiveness of the forestation scenario for pollutant j

5. Results

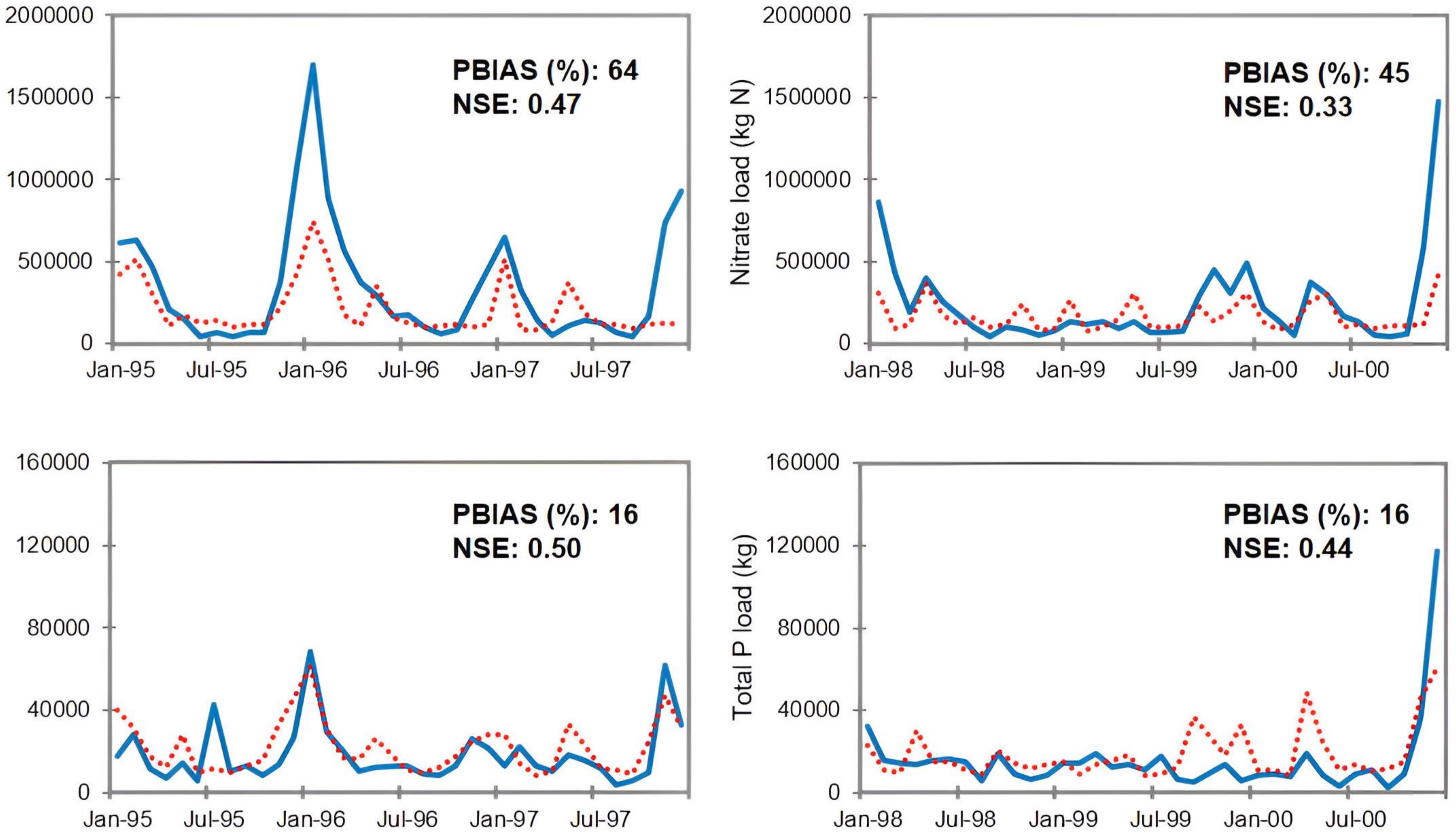


	Performance rating
Discharge (m^3/s)	Good
Sediments (Ton)	Satisfactory

Calibration | Observed / Simulated | **Validation** | **Performance** rating

Nitrates (kg) — Satisfactory

Phosphorus (kg) — Satisfactory



5. Results

Environmental effectiveness

Scenario	Total suspended sediments	NO_3	P
2.5 m	⬇ 5.3%	⬇2.4%	⬇1.8%
5 m	⬇32.9%	⬇ 4%	⬇3.3%

5. Results

Total costs

2.5m buffer (29 ha)

Item	Cost(€) (min)	Cost(€) (max)	Cost(€) (average)
1. Forest Plantation	17,680.13	265,202.01	61,880.46
2. Maintenance	363,017.58	499,149.17	431,083.38
3. Opportunity cost	0	2,414,072.63	1,207,036.31
Total cost	380,697.71	3,178,423.81	1,700,000.16

5m buffer (57 ha)

Item	Cost(€) (min)	Cost(€) (max)	Cost(€) (average)
1. Forest Plantation	34,052.01	510,780.01	119,182.01
2. Maintenance	699,173.15	961,363.09	830,268.12
3.Opportunity cost	0	4,573,263.66	2,286,631.83
Total cost	733,225.16	6,045,406.78	3,236,081.96

5. Results

Cost-effectiveness Ratios (€/mg)

2.5m buffer

CE	Nitrates ($N - NO_3$)	Phosphorus (P)	Sediments (TSS)
Cost Min	13,631.83	196,913.31	398.25
Cost Max	113,811.41	1,644,018.11	3,325.02
Cost Average	60,872.75	879,313.52	1,778.41

5m buffer

CE	Nitrates ($N - NO_3$)	Phosphorus (P)	Sediments (TSS)
Cost Min	16,950.55	209,328.24	123.53
Cost Max	139,756.5 5	1,725,901.45	1,018.52
Cost Average	74,811.12	923,868.12	545.21

Least costly pollutant is sediment in both scenarios

Phosphorus is the most expensive

6. Conclusions

SWAT was able to capture the hydrology of Cávado basin and support **economic analysis**

Riparian forest buffers demonstrate their ability to regulate pollutants

Sediments were the least costly pollutant to reduce in both scenarios

The **cost-effectiveness** analysis is important to support the implementation of **environmental financial schemes** to protect the water bodies

THANK YOU!!!

Trees4Water

2022.06375.PTDC

https://trees4waterpt.wixsite.com/trees-4-water/

Acknowledgments:

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