# WaterProof: A Rapid Return on Investment Tool for Nature-Based Solutions

17/05/2023

inspiring change

# WEBINAR INFORMATION

- This webinar will be **recorded and made available "on-demand"** on the IWA Connect Plus platform, with presentation slides, and other information.
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# WEBINAR INFORMATION


- **‘Chat’ box**: please use this for general requests and for interactive activities.
- **‘Q&A’ box**: please use this to send questions to the panelists.

**(We will answer these during the discussions and in post-webinar materials.)**

***Please Note:*** *Attendees’ microphones are muted. We cannot respond to ‘Raise Hand’.*

# AGENDA

- **Introduction, housekeeping rules & 1st Poll (5 min)**
*Brooke Atwell*

- **Introduction to Nature based solutions (NBS) & accounting for their benefits (10 min)**
*Kari Vigerstol*

- **WaterProof conceptual presentation & 2nd Poll (30 min)**
*Carlos A. Rogéliz*

- **WaterProof live demonstration (30 min)**
*Carlos A. Rogéliz*

- **Q&A Discussion (12 min)**
*Moderator and speakers*

- **Final remarks and conclusion (3 min)**

# MODERATOR AND SPEAKERS

Brooke Atwell
Associate Director, Resilient Watersheds, TNC Global
(Moderator)

Kari Vigerstol
Director of Water Security Science, TNC Global

Carlos A. Rogéliz
Integrated Water Resource Management Program Leader, TNC Colombia

# Poll 1

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# Introduction to Nature based solutions (NBS) & accounting for their benefits

KARI VIGERSTOL, TNC GLOBAL

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# NATURE-BASED SOLUTIONS (NBS)

Actions to **protect, conserve, restore, sustainably use** and **manage** natural or modified terrestrial, freshwater, coastal and marine **ecosystems**, which address **social, economic and environmental challenges** effectively and adaptively, while simultaneously providing human well-being, ecosystem services and resilience and biodiversity **benefits**. – UN Environmental Assembly, 2022

# WHICH WATER SECURITY CHALLENGES CAN NBS HELP WITH?

| WATER SECURITY CHALLENGE | WATER AVAILABILITY | | DISASTER RISK | WATER QUALITY | | Potential for multiple co-benefits |
|---|---|---|---|---|---|---|
| Ecosystem benefit | Dry season flows | Groundwater recharge | Flood risk | Erosion & sediment | Nutrients & pollutants | |
| ***Protection*** | | | | | | |
| 1 *Targeted habitat protection* | ✓ | ✓ | ✓✓ | ✓✓ | ✓ | |
| ***Restoration*** | | | | | | |
| 2 *Revegetation* | ✓ | ✓ | ✓✓ | ✓✓ | ✓ | |
| 3 *Riparian restoration* | ✓ | ✓ | ✓ | ✓✓ | ✓✓ | |
| 4 *Wetlands restoration* | ✓ | ✓ | ✓✓ | ✓ | ✓✓ | |
| 5 *Floodplain restoration* | ✓ | ✓ | ✓✓ | ✓✓ | ✓ | |
| ***Management*** | | | | | | |
| 6 *Agricultural BMPs* | | ✓ | | ✓✓ | ✓✓ | |
| 7 *Ranching BMPs* | ✓ | ✓ | | ✓ | ✓ | |
| 8 *Forestry BMPs* | ✓ | | | ✓ | ✓ | |
| 9 *Fire Management* | | | ✓✓ | ✓✓ | ✓ | |
| ***Created Habitats*** | | | | | | |
| 10 *Artificial wetlands* | ✓ | ✓ | ✓ | ✓ | ✓✓ | |
| 11 *Sustainable Urban Drainage Systems (SuDS)* | ✓✓ | ✓ | ✓✓ | ✓ | ✓✓ | |

| LEGEND | LOW | MEDIUM | HIGH |
|---|---|---|---|
| *Magnitude of water security benefit* | | | |
| *Depth of evidence* | | ✓ | ✓✓ |
| *Potential for multiple co-benefits* | | | |

How to Guide to Watershed Investments (TNC & AFD)

# NATURE-BASED SOLUTIONS: SHIFTING THE WATER PARADIGM


# MULTIPLE BENEFITS FOR PEOPLE AND NATURE

**Water security**. Maintaining or improving water quality and dry season flows.

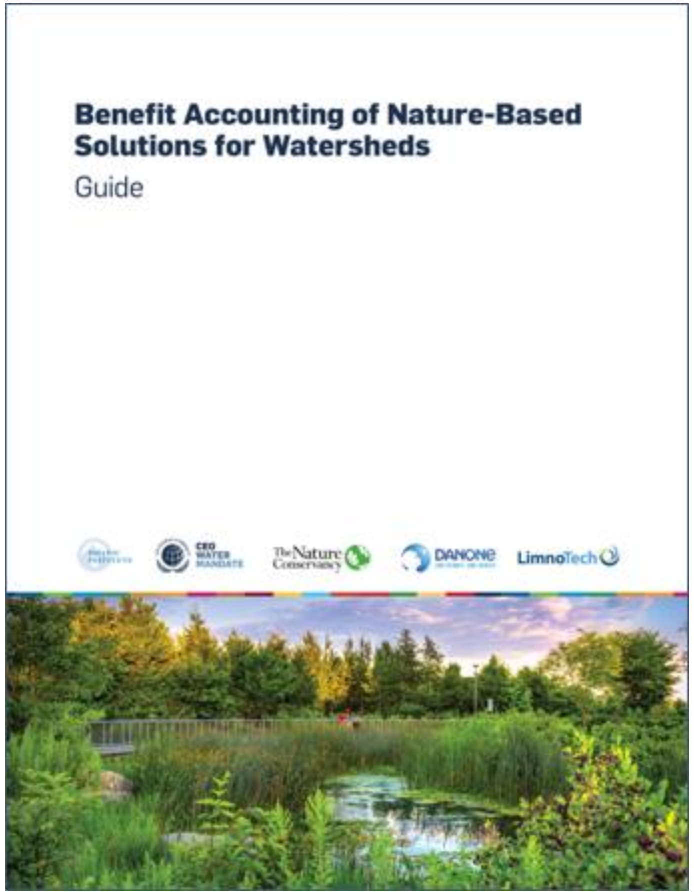
**Climate change mitigation.** Avoiding greenhouse gas emissions and increasing carbon sequestration.

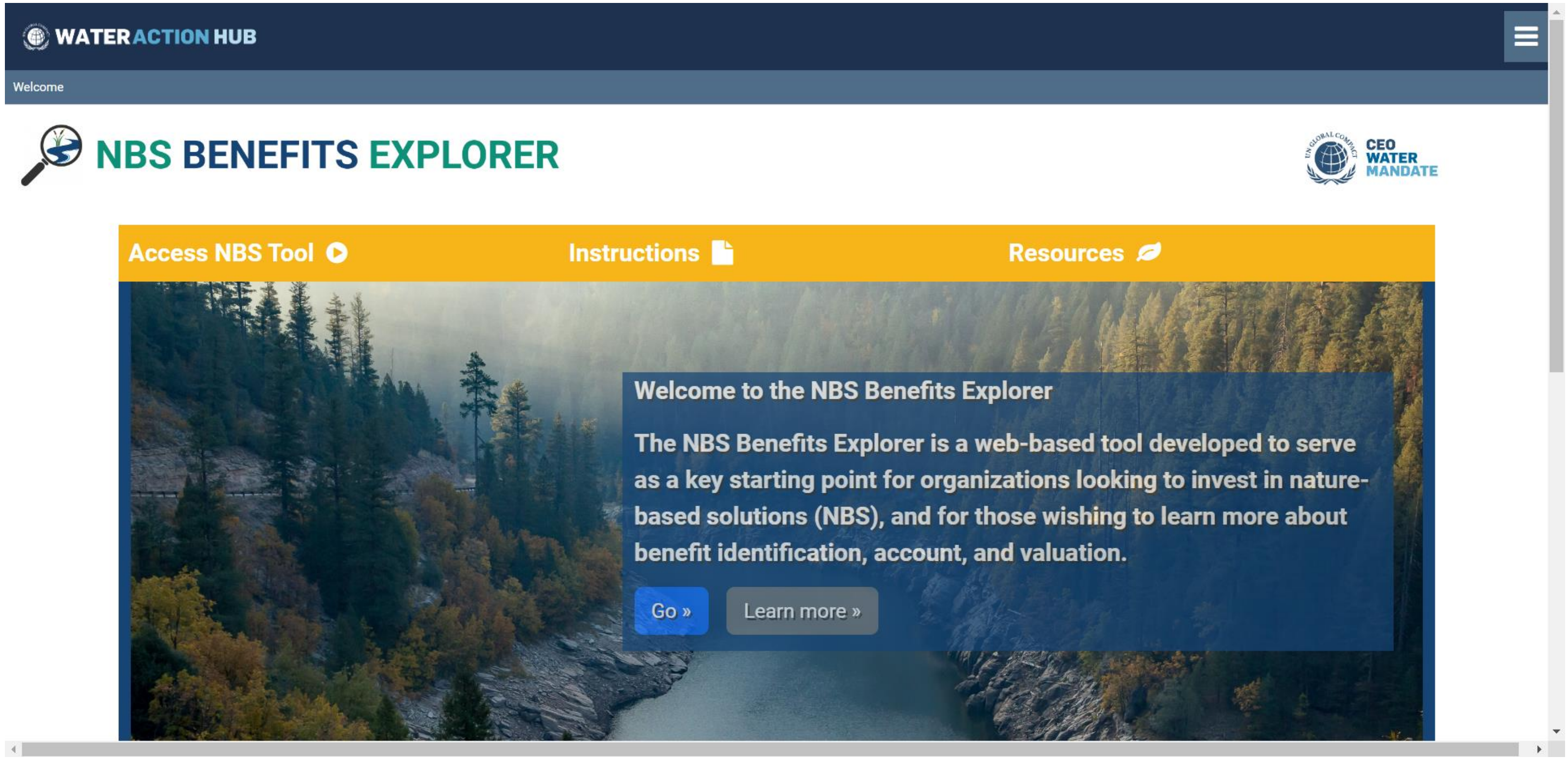
**Climate change adaptation.** Using nature to mitigate climate change impacts and build resilient communities.

**Human health and well-being.** Supporting and improving physical and mental health, food security, livelihoods and social cohesion.

**Biodiversity conservation.** Protecting and improving the status of terrestrial and freshwater species and the ecosystems in which they live.

# Benefit Accounting of NBS for Watersheds

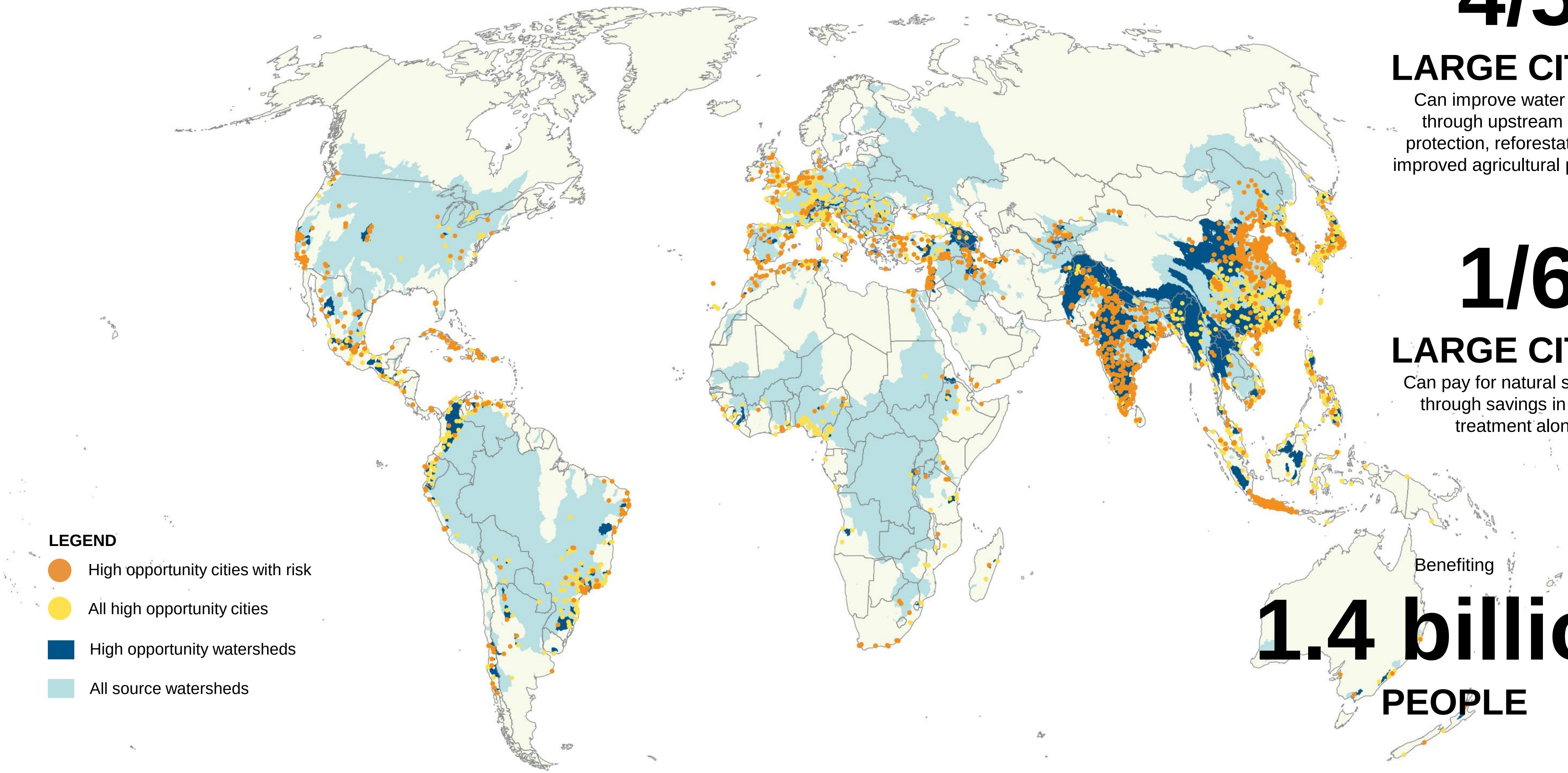



https://ceowatermandate.org/nbs/

CEO WATER MANDATE | PACIFIC INSTITUTE | The Nature Conservancy | DANONE ONE PLANET. ONE HEALTH | LimnoTech

# Nature-based solutions | SCALE OF THE OPPORTUNITY




**4/5**

**LARGE CITIES**

Can improve water quality through upstream forest protection, reforestation and improved agricultural practices.

**1/6**

**LARGE CITIES**

Can pay for natural solutions through savings in water treatment alone

Benefiting

**1.4 billion**

**PEOPLE**

The Nature Conservancy

the international water association

# WaterProof conceptual presentation

PART 2

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# WaterProof: A web based system to provide rapid ROI calculation, and early indication of a preferred portfolio of nbs for watersheds in the world

CARLOS A. ROGÉLIZ, TNC COLOMBIA

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Results in your basin
NbS
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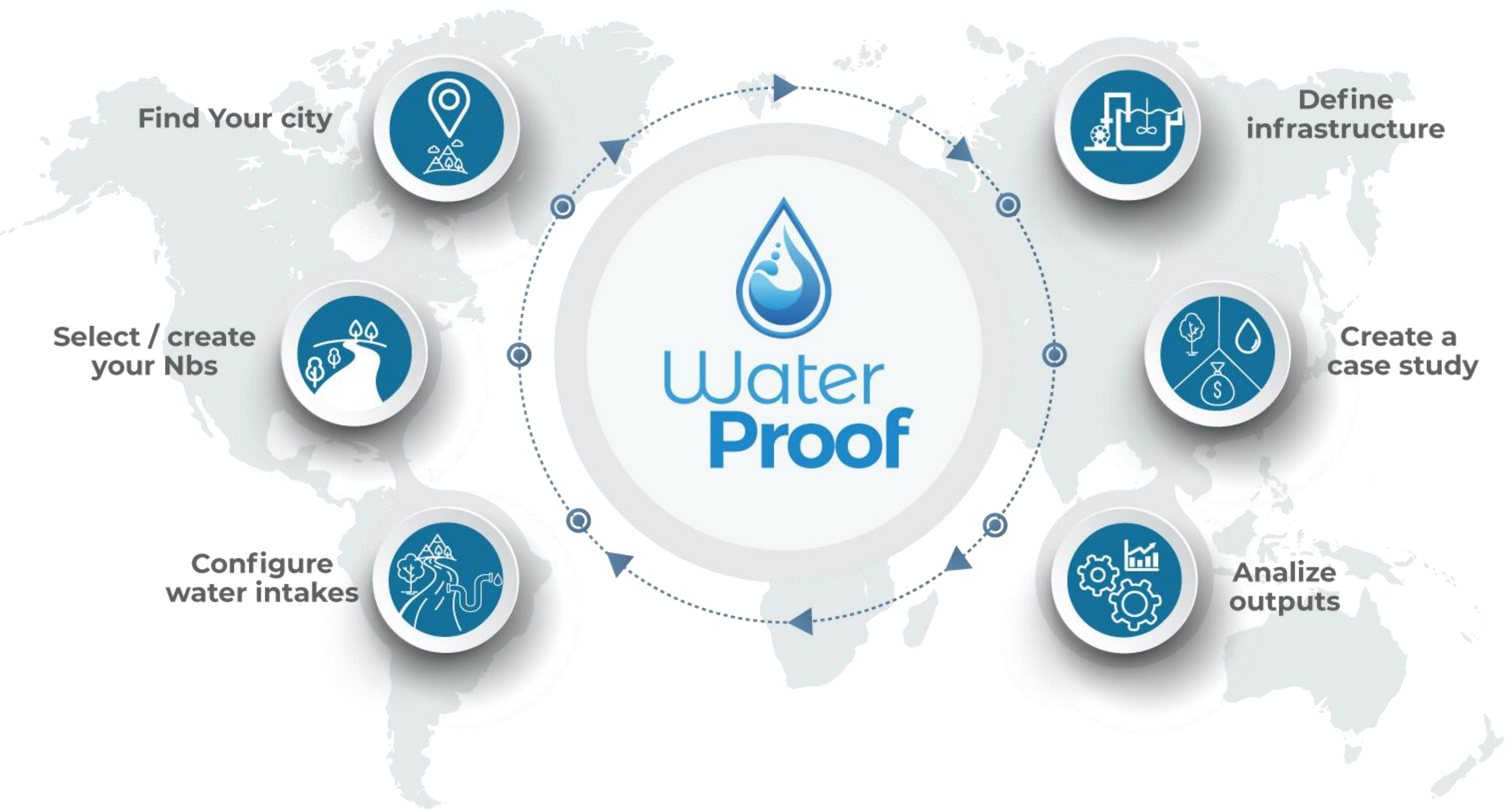
# WaterProof

WaterProof is a **high-level ROI assessment tool**, designed to provide stakeholders interested in Nature-based Solutions with a **pre-feasibility / indicative assessment regarding NbS potential**



# The challenge

Watersheds Degradation

NbS

ROI

Complexity and time required to demonstrate an NbS portfolio's positive Return on Investment for water security outcomes

# WaterProof

## -A PRE-FEASIBILITY SOLUTION

**Fast**

**Compelling**

**Customizable**

**Multi-Currency**

**Free**

the international water association

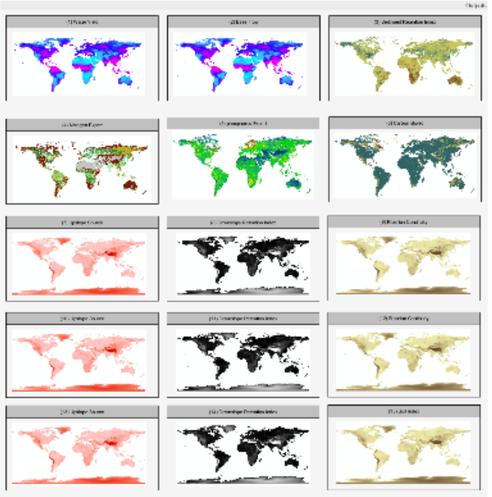
# WaterProof – Concept

the international water association

## 1

Global

Databases



## 2

Benefits in Ecosystem Services

InVEST

integrated valuation of ecosystem services and tradeoffs

RIOS

NbS Porfolio

## 3

Global Cost Functions

Custom Cost Functions


## 4

ROI

Calculation


**Climates available in version 1.0:**

Historic
RCP-4.5-BCC-CSM2-MR
RCP-4.5-CNRM-ESM2-1
RCP4.5-MIROC6

RCP-8.5-BCC-CSM2-MR
RCP-8.5-CNRM-ESM2-1
RCP8.5-MIROC6

# Peer-Reviewed

water MDPI

*Article*

## WaterProof—A Web-Based System to Provide Rapid ROI Calculation and Early Indication of a Preferred Portfolio of Nature-Based Solutions in Watersheds

**Carlos A. Rogéliz [1,*], Kari Vigerstol [2], Pilar Galindo [1], Jonathan Nogales [1], Justus Raepple [2], Juliana Delgado [1], Edwin Piragauta [3] and Laura González [3]**

[1] The Nature Conservancy, Bogotá 110231, Colombia
[2] The Nature Conservancy, Arlington, VA 22203, USA
[3] Skaphe Tecnología SAS, Bogotá 110231, Colombia
* Correspondence: carlos.rogeliz@tnc.org

**Abstract:** Watersheds are being degraded around the world, with dire impacts on water security. Nature-based solutions (NbS) can preserve or restore degraded watersheds, thereby addressing critical water security issues; however, there is a lack of NbS uptake and investment. This is in part due to the complexity and time required to demonstrate an NbS portfolio's positive return on investment (ROI) for desired water security outcomes. *WaterProof* is a web-based decision support tool to provide a rapid ROI calculation and early indication of a preferred portfolio of NbS for any watershed in the world using Natural Capital ecosystem service models (InVEST and RiOS). *WaterProof* is intended to engage stakeholders interested in exploring green infrastructure solutions for local water challenges and for prioritization of locations of possible NbS water security programs. *WaterProof* version 1.0 is freely available and open-sourced, with clear methodology and metadata, with a user-friendly interface suitable for a wide range of potential audiences.

**Keywords:** nature-based solutions; return on investment; watershed conservation; water security

**Citation:** Rogéliz, C.A.; Vigerstol, K.; Galindo, P.; Nogales, J.; Raepple, J.; Delgado, J.; Piragauta, E.; González, L. WaterProof—A Web-Based System to Provide Rapid ROI Calculation and Early Indication of a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NbS

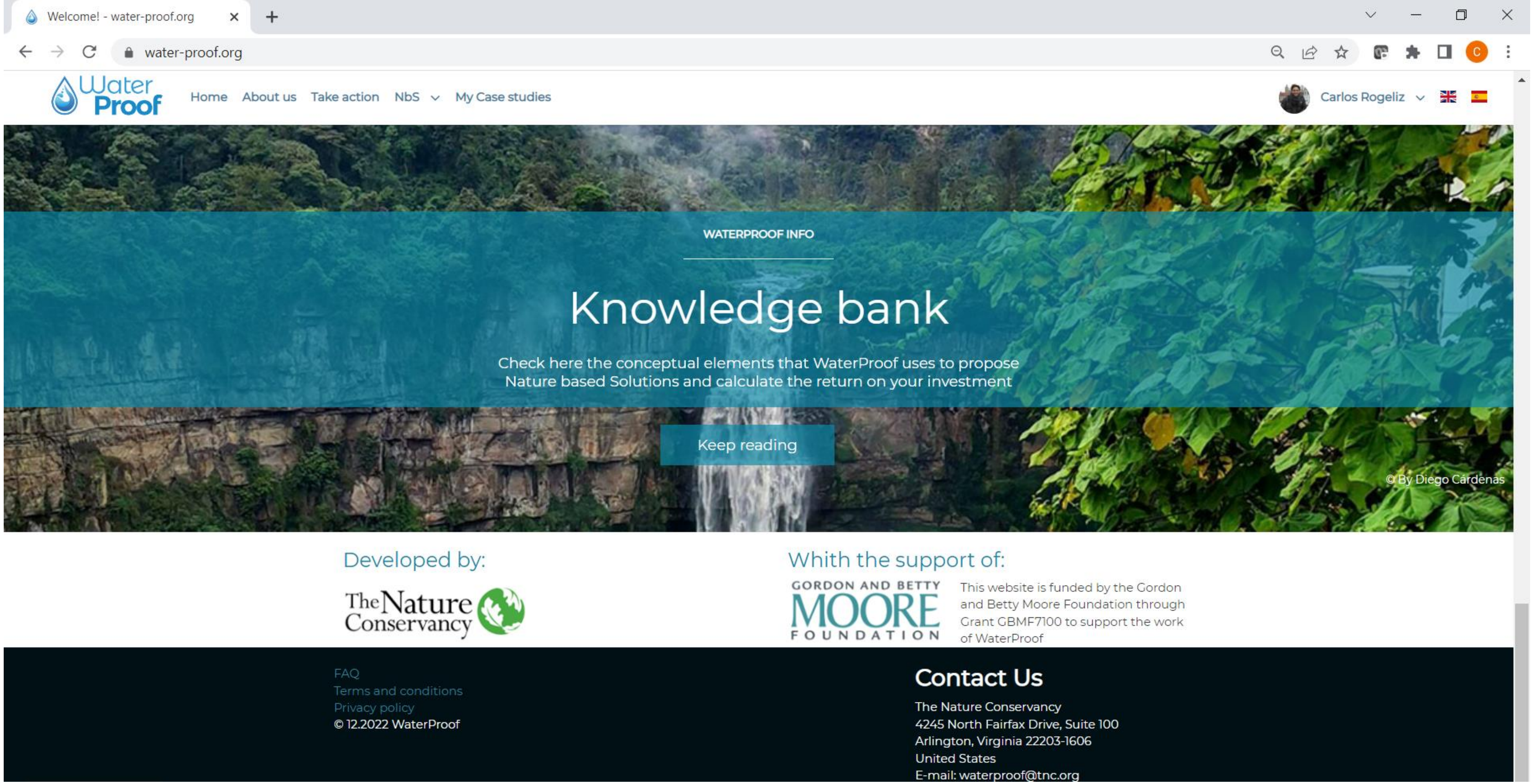
# WaterProof

- A web based system to provide rapid ROI calculation, and early indication of a preferred portfolio of NbS for watersheds in the world

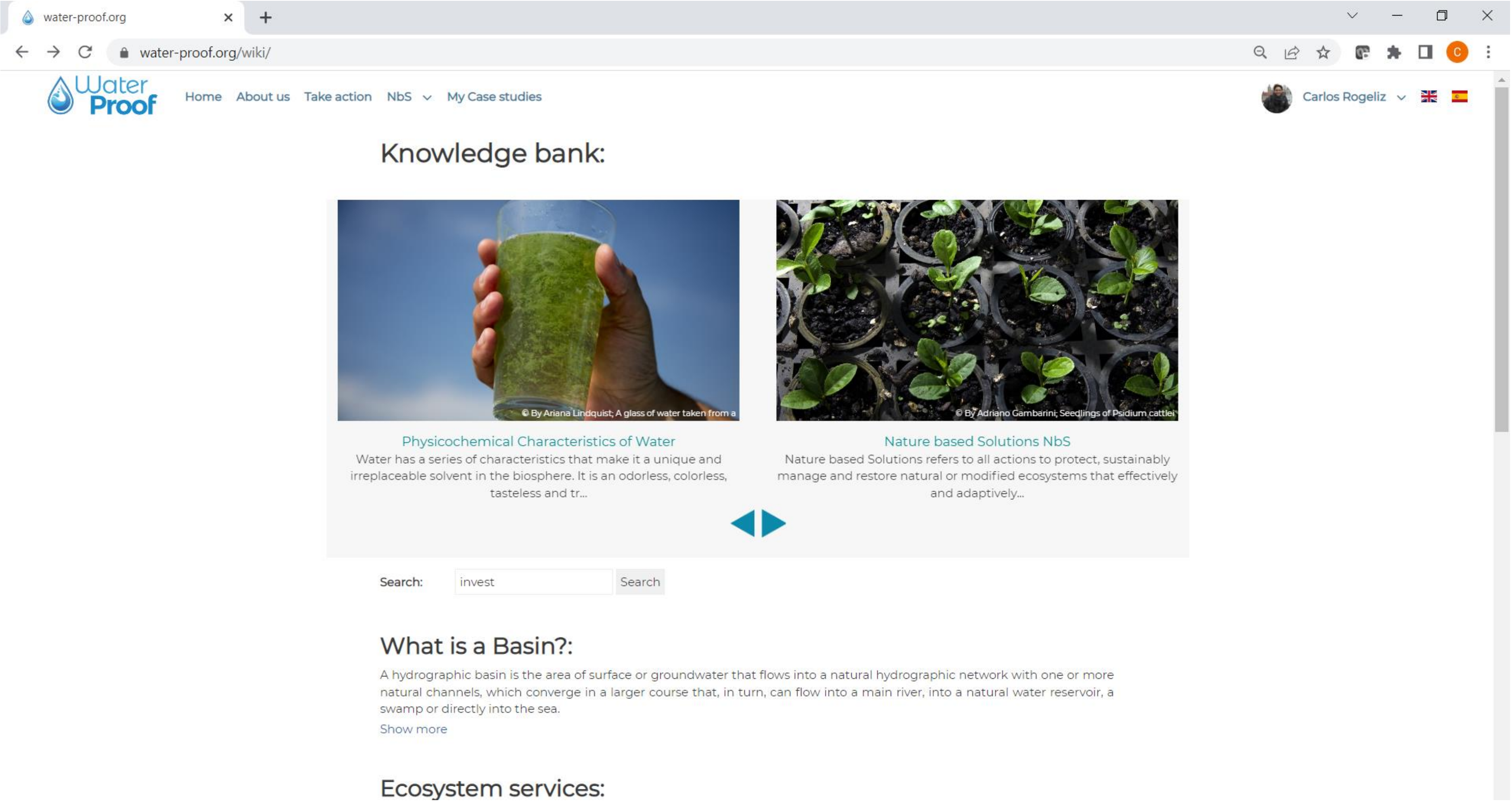
# WATERPROOF FULLY DOCUMENTED AND TRANSPARENT

# WaterProof Fully Documented and Transparent

the international water association



# WaterProof
# Fully Documented and Transparent



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water-proof.org

water-proof.org/wiki/consultar-articulo/90



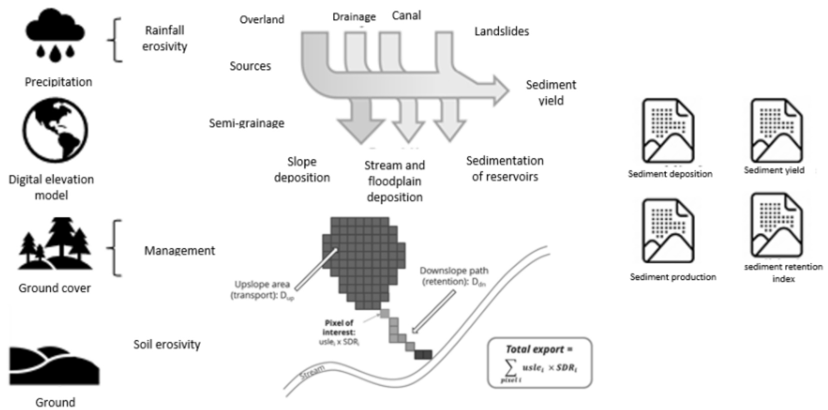
## InVEST - Sediment Delivery Ratio:

Erosion and retention of terrestrial sediments are natural processes that govern the concentration of sediment in streams. Sediment dynamics are mainly determined by climate (particularly rainfall intensity), soil properties, topography and vegetation; and anthropogenic factors such as agricultural activities or the construction and operation of dams. Major sources of sediment include land erosion (detached and transported soil particles by rain and overland flow), gullies (channels that concentrate flow), bank erosion, and massive erosion (or landslides; see Merrit 2003 for a review). Sinks include deposition on slopes, floodplains or in the river, and retention of reservoirs.

The magnitude of this effect is mainly governed by: i) the main sources of sediment (the change in land use will have a lesser effect in the basins where the sediments do not come mainly from surface flow); and ii) the spatial distribution of sediment sources and sinks (e.g., land use change will have less effect if sediment sources are buffered by vegetation).

InVest service analyzes the sediment load delivered to the stream on an annual time scale, as well as the amount of sediment eroded in the basin and retained by vegetation and topographic features.

For each pixel, the model estimates the amount of soil lost annually using the university soil loss equation (USLE); the proportion of sediment that is delivered to a channel and the proportion of soil that is retained before reaching a stream. Figure 1 presents the diagram of the information requirements that the model needs, the processes it considers and the results it generates.




**Fuente:** TNC, 2020

# WaterProof
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water-proof.org

water-proof.org/wiki/consultar-articulo/80

Water Proof

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Carlos Rogeliz

## Cost function for sludge pumping:

The original cost function (A1) for pumping sludge is as follows:

$$O\&M = 4 \times 10^{-7} x^3 - 0.0058\, x^2 + 43.748\, x + 11\,622$$

This has as variable (x) the sludge pumping rate in gallons per minute. Applying the conversion factors from gallons per minute to liters per second, applying a factor of 5% which represents the sludge production that occurs in a plant and applying the elasticity factor, the function obtained is as follows.

$$\text{O\&M} = (\text{A1}) * (\text{B2})$$

$$O\&M_{TL} = \left(\left((4 * 10^{-7}) * \left(15.85 * 0.05 * Q_{CSInfra}\right)^3\right) - \left(0.0058 * \left(15.85 * 0.05 * Q_{CSInfra}\right)^2\right) + \left(43.748 * \left(15.85 * 0.05 * Q_{CSInfra}\right)\right) + 11622\right) * \left(1 + \left(0.1 * \left(\frac{Csed_{CSInfra,input} - 203}{203}\right)\right)\right)$$

## Bibliography


Preliminary Cost Estimation Models for Construction, Operation, and Maintenance of Water Treatment Plants. 2013. Jwala R. Sharma, Ph.D., M.ASCE; Mohammad Najafi, Ph.D., P.E., F.ASCE; and Syed R. Qasim, Ph.D., P.E., M.ASCE. | https://ascelibrary.org/doi/abs/10.1061/%28ASCE%29IS.1943-555X.0000155


## Referencies

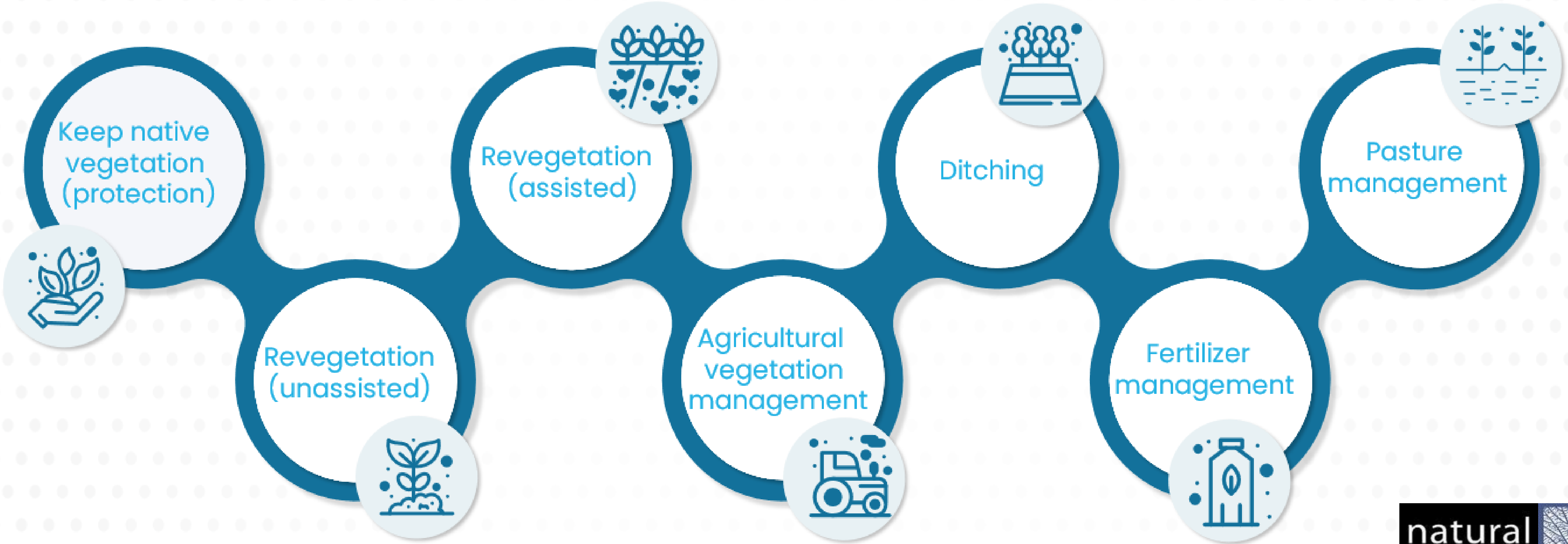

¿Qué es una bomba de lodos y cómo funciona? | https://pfspumps.com/blog/what-is-a-sludge-pump-and-how-does-it-work/


Go to Wiki

# MODELING IN RIOS AND INVEST

# What is RiOS?

RiOS is a software tool for prioritization that allows for identification of sites where certain activities can produce the greatest benefits for people and nature at the lowest cost.




natural capital PROJECT RIOS

# Modeling in RIOS & INVEST

# How does RiOS operate?

In general, RIOS operates under a distributed scheme, with its basic operating unit being a pixel. Operationally, RIOS is divided into two parts.

## Portfolio Investment Advisor

Generic formulation (with user-defined factor weights)

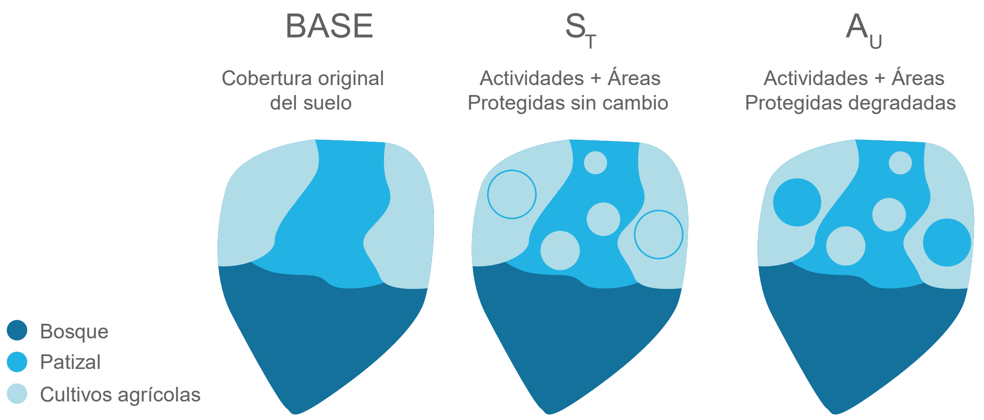
$$\frac{(U * W_U) + ((1 - D) * W_D) + ((1 - X) * W_X) + (R * W_R) + (E * W_E) + (S * W_S) + (F * W_F) + (B * W_B)}{\sum W}$$

$$X_i = X_{old} + (X_{ref} - X_{old})P$$

- $Xi$ Value of parameter X for the new (scenario 1) land cover
- $Xold$ Value of parameter X for the original (baseline) land cover
- $Xref$ Value of parameter X for the reference land cover
- $P$ Proportional transition (user specified)

## Portfolio Translator

Land Use/ Land Cover

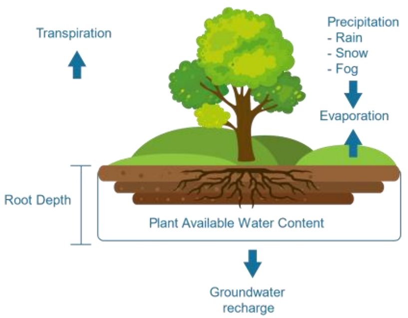


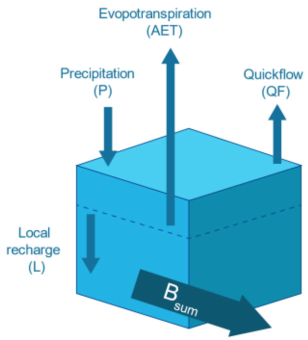

**Source:** Vogl et al. (2016)

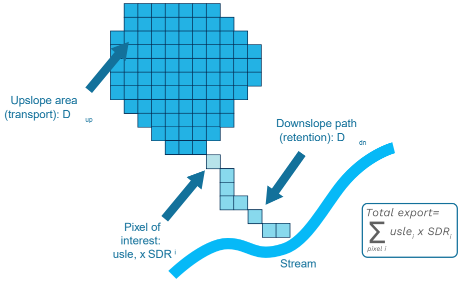
# Modeling in RIOS & INVEST

## What is InVEST?

InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs) is a family of tools for quantifying the values of natural capital in clear, credible, and practical ways. InVEST enables decision-makers to quantify the importance of natural capital, to assess the tradeoffs associated with alternative choices



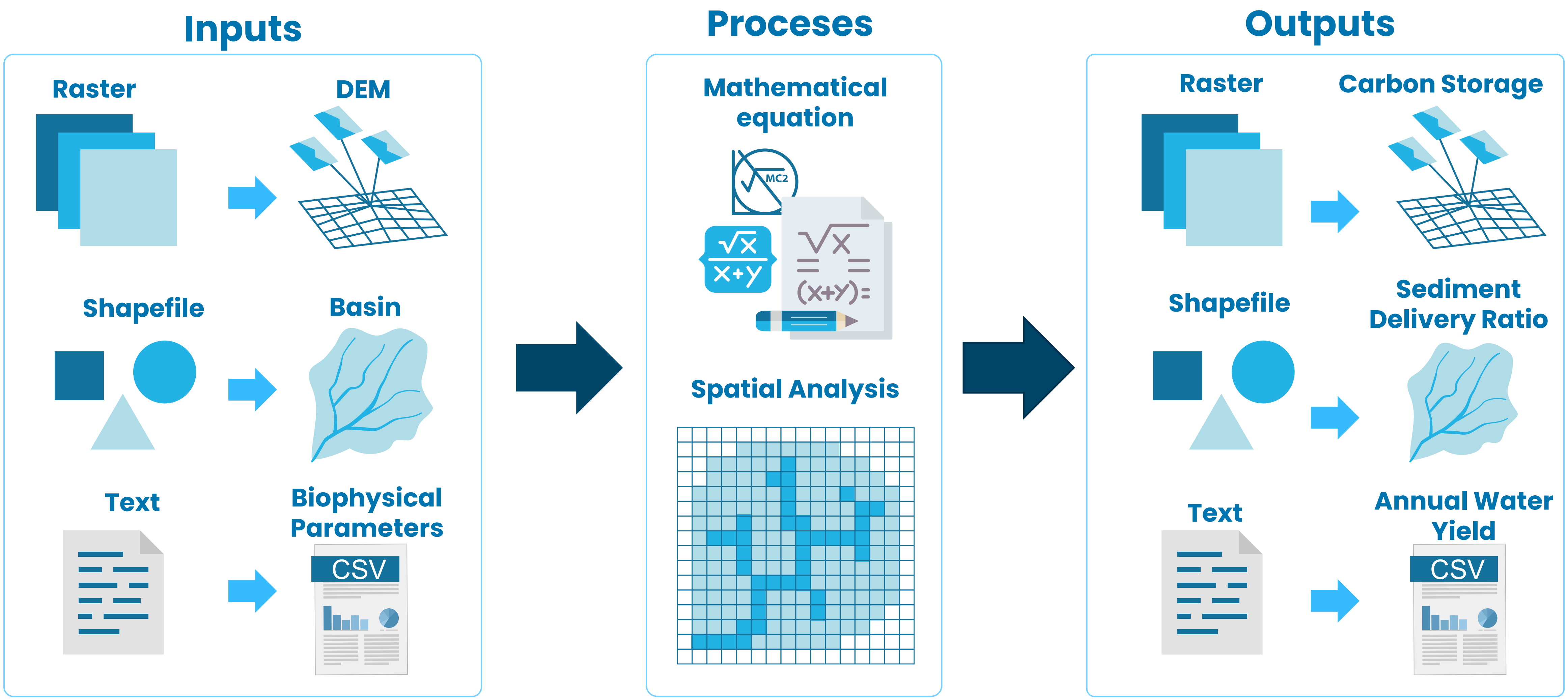

## Which InVEST tools does WaterProof use?

Currently, WaterProof integrates the following InVEST models to evaluate the benefits of nature-based solutions (NbS):

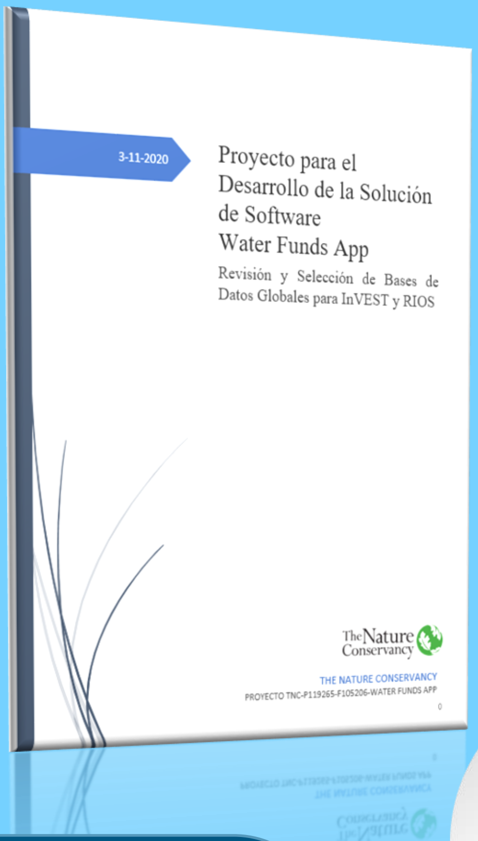
- AWY - Annual Water Yield
- SWY - Seasonal Water Yield
- SDR - Sediment Delivery Ratio
- NDR - Nutrient Delivery Ratio
- CSS - Carbon Storage and Sequestration

# Modeling in RIOS & INVEST

## How do InVEST models operate?

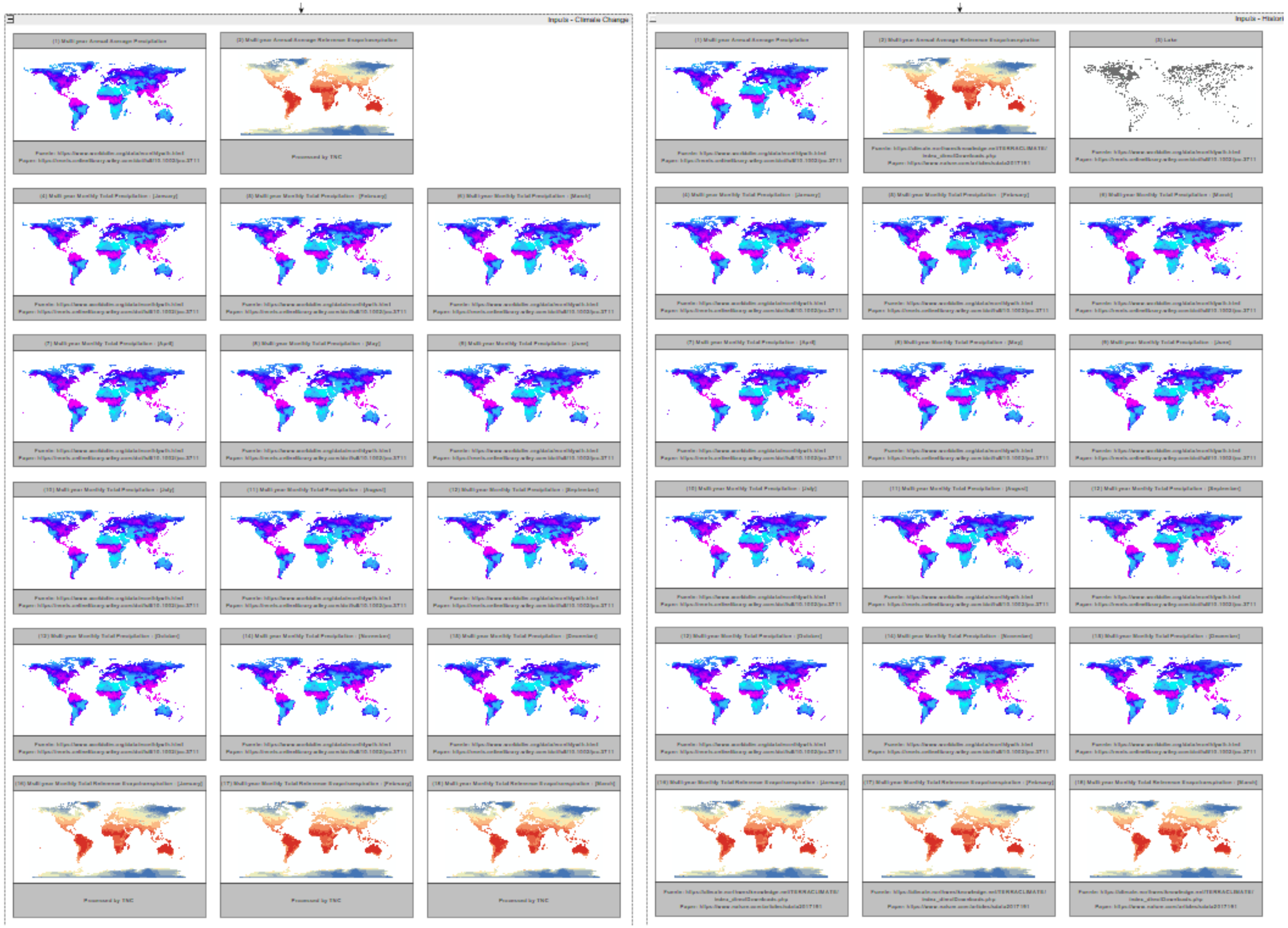


# Modeling in RIOS & INVEST

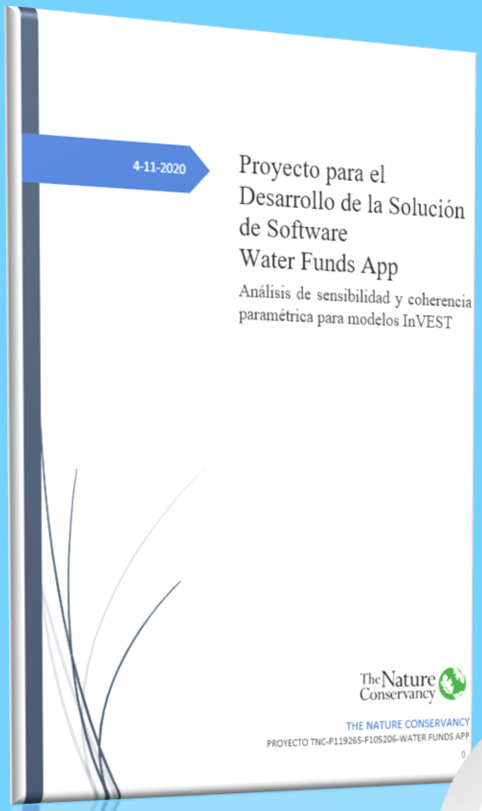



## INPUT DATABASES

PostGIS

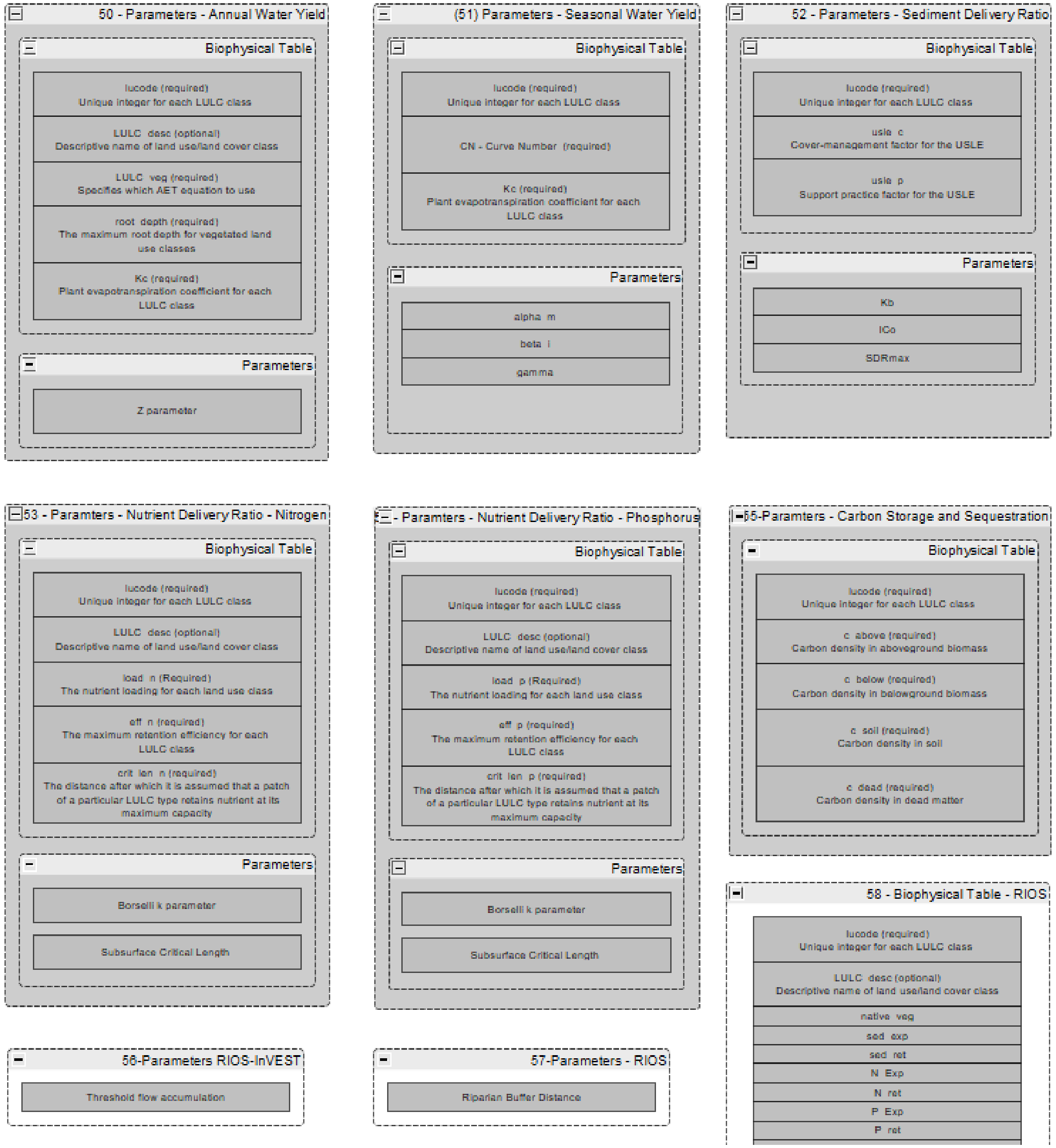


# Modeling in RIOS & INVEST




PostgreSQL

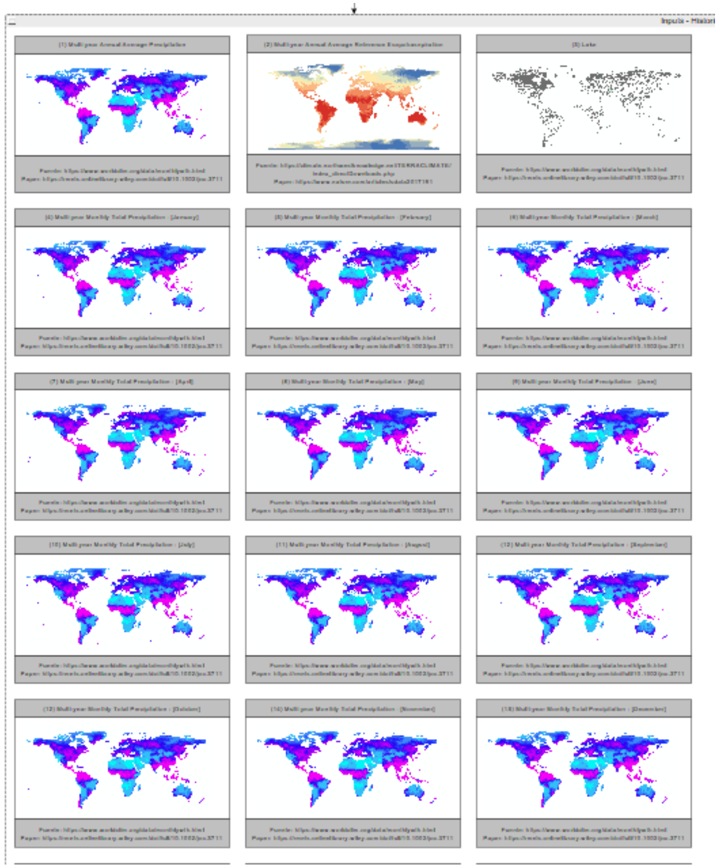
# INPUT DATABASES

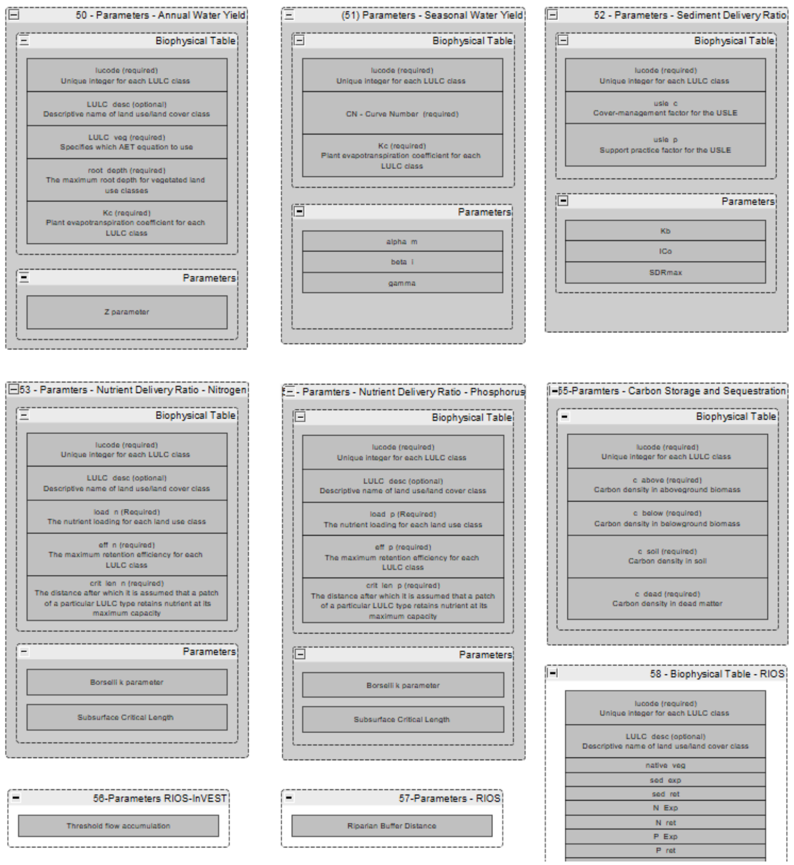


# Modeling in RIOS & INVEST

the international water association

PostGIS + PostgreSQL






## OUTPUT DATABASES

# Modeling in RIOS & INVEST

BIOPHYSICAL TABLES

PARAMETER TABLES

InVEST

integrated valuation of ecosystem services and tradeoffs

RIOS

# 56

MACRO-REGIONS OF THE WORLD

(HYDROSHEDS LEVEL 2)

PostGIS

+

PostgreSQL

BIOPHYSICAL AND PARAMETER TABLES

# Modeling in RIOS & INVEST


PANGAEA.
Data Publisher for Earth & Environmental Science

SEARCH SUBMIT ABOUT CONTA

*Citation:* **Meybeck, Michel; Ragu, Alain (2012):** GEMS-GLORI world river discharge database. *Laboratoire de Géologie Appliquée, Université Pierre et Marie Curie, Paris, France, PANGAEA,* https://doi.org/10.1594/PANGAEA.804574

**Always quote citation above when using data!** You can download the citation in several formats below.

RIS Citation | BibTeX Citation | Copy Citation | Facebook | Twitter

*Abstract:* The GEMS-GLORI register, circulated by UNEP for review in 1996, lists 555 world major rivers discharging to oceans (Q > 10 km**3/year, or A > 10 000 km**2, or sediment discharge > 5Mt/year, or basin population >5M people). Up to 48 river attributes are listed, including major ions and nutrients (C, N, P) in both dissolved, particulate, organic and inorganic forms. For many rivers, two or three sets of data are provided with relevant periods of records and references. Although half of the selected rivers are not yet documented for water quality, most of the first 40 rivers are well described (Irrawady, Zambezi, Ogooue, Magdalena, are noted exceptions). Altogether about 10 000 individual data from 500 references are listed. The global coverage in terms of river discharge and/or drainage area ranges from 40 to 67% for most major water quality attributes but drops to 25% for some organic and/or particulate forms of N and P. Planned development of the register includes collection of information on particulate chemistry and data on endorheic rivers and selected tributaries.

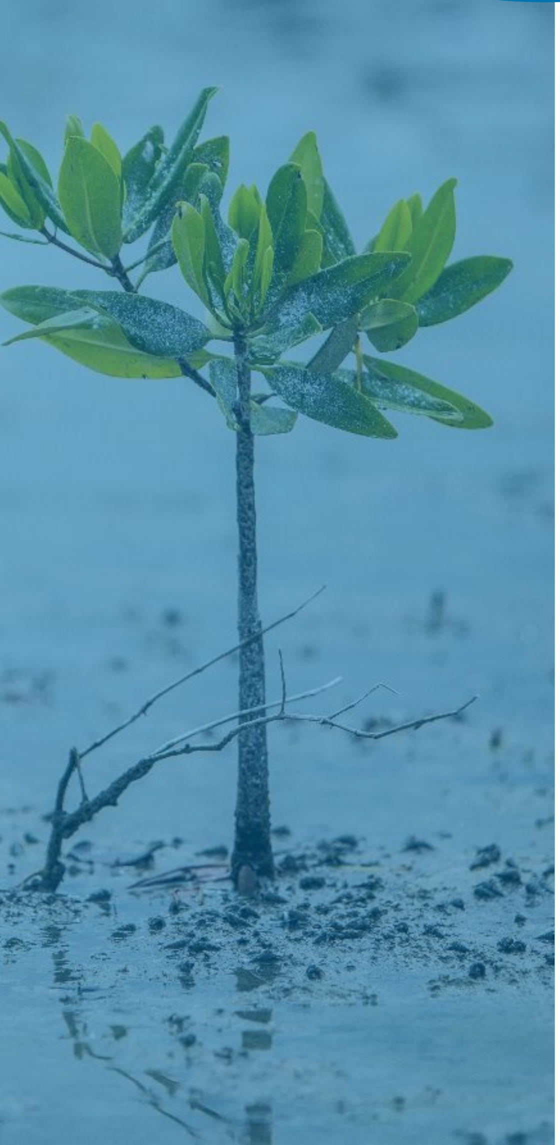
*Related to:* **Meybeck, Michel; Ragu, Alain (1997):** Presenting the GEMS-GLORI, a compendium of world river discharge to the oceans. *Freshwater Contamination (Proceedings of Rabat Symposium S4, April-May). IAHS Publications,* **243**, 3-14, hdl:10013/epic.34684.d001

**Meybeck, Michel; Ragu, Alain (1996):** River discharges to the oceans: an assessment of suspended solids, major ions and nutrients. *UNEP, Environment Information and Assessment,* **(draft)**, 240 pp, hdl:10013/epic.34685.d001

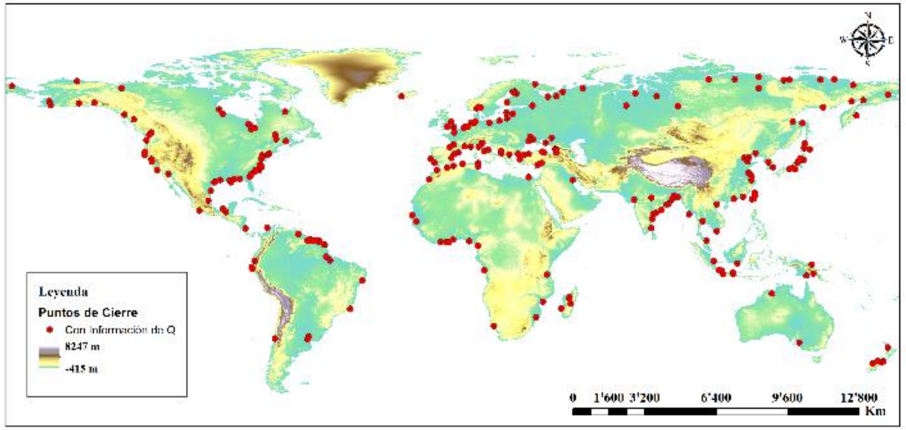
*Coverage:* *Median Latitude:* 27.050165 * *Median Longitude:* 11.834417 * *South-bound Latitude:* -50.050000 * *West-bound Longitude:* -177.666700 * *North-bound Latitude:* 76.000000 * *East-bound Longitude:* 177.966700

SENSITIVITY ANALYSIS AND PARAMETRIC COHERENCE FOR INVEST MODELS

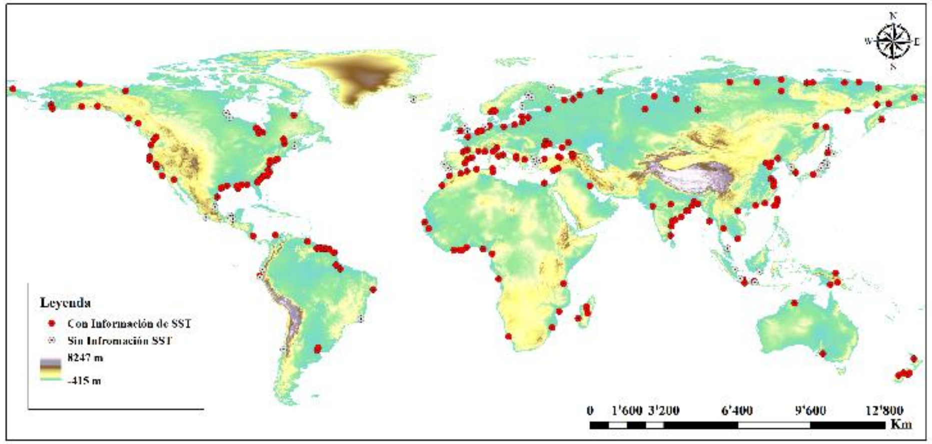
# Modeling in RIOS & INVEST



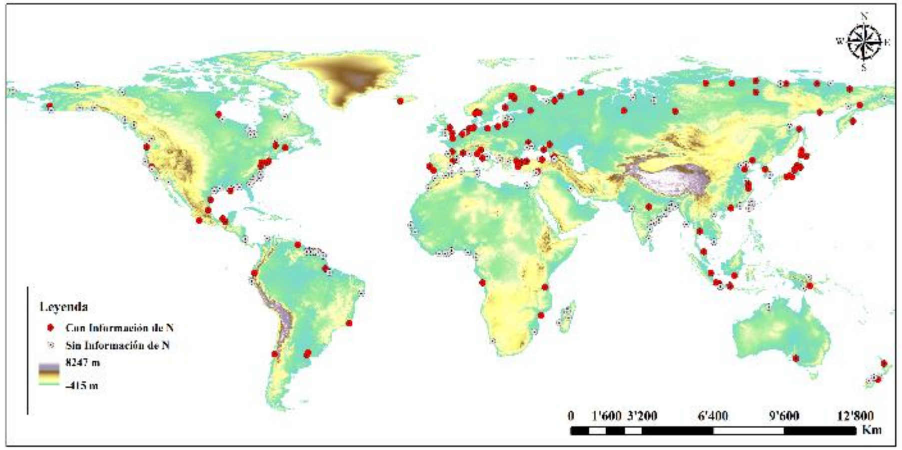
Streamflow



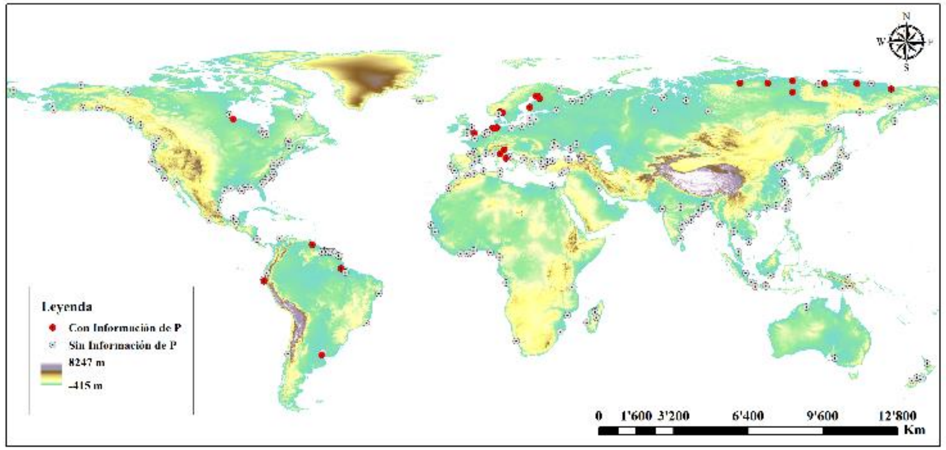

Suspended Sediment Concentration




Nitrogen Concentration



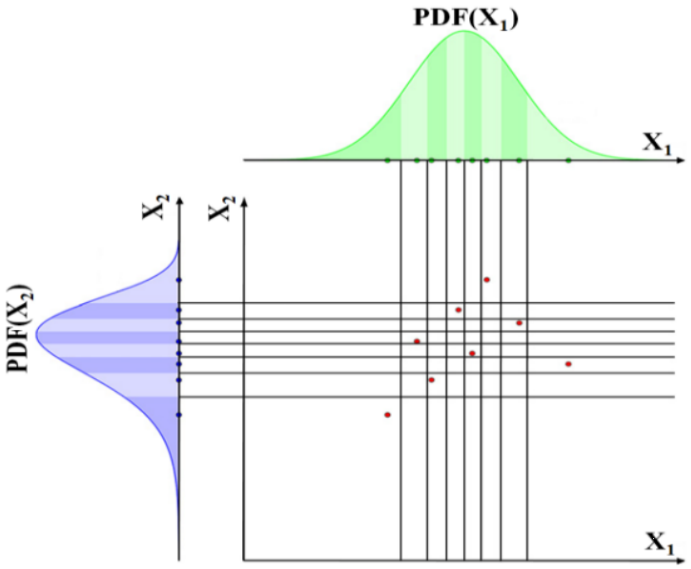

Phosphorus Concentration




SENSITIVITY ANALYSIS AND PARAMETRIC COHERENCE FOR INVEST MODELS

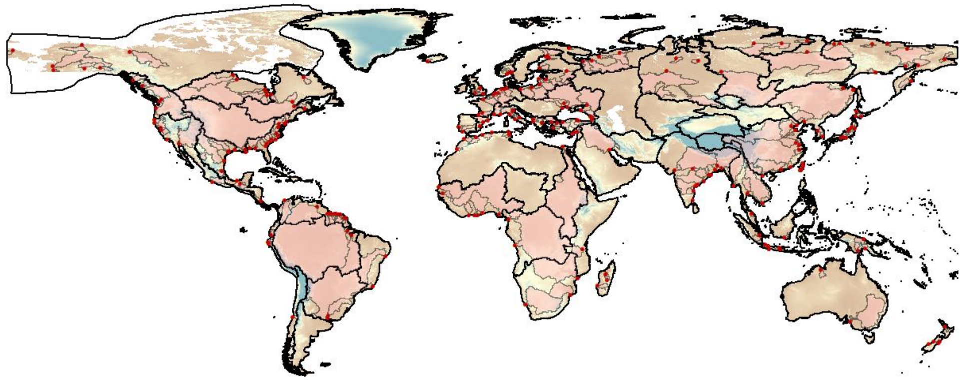
# Modeling in RIOS & INVEST

56 Macro-Regions




**EXPLORING MODEL PARAMETERS**

Latin Hypercube Sampling

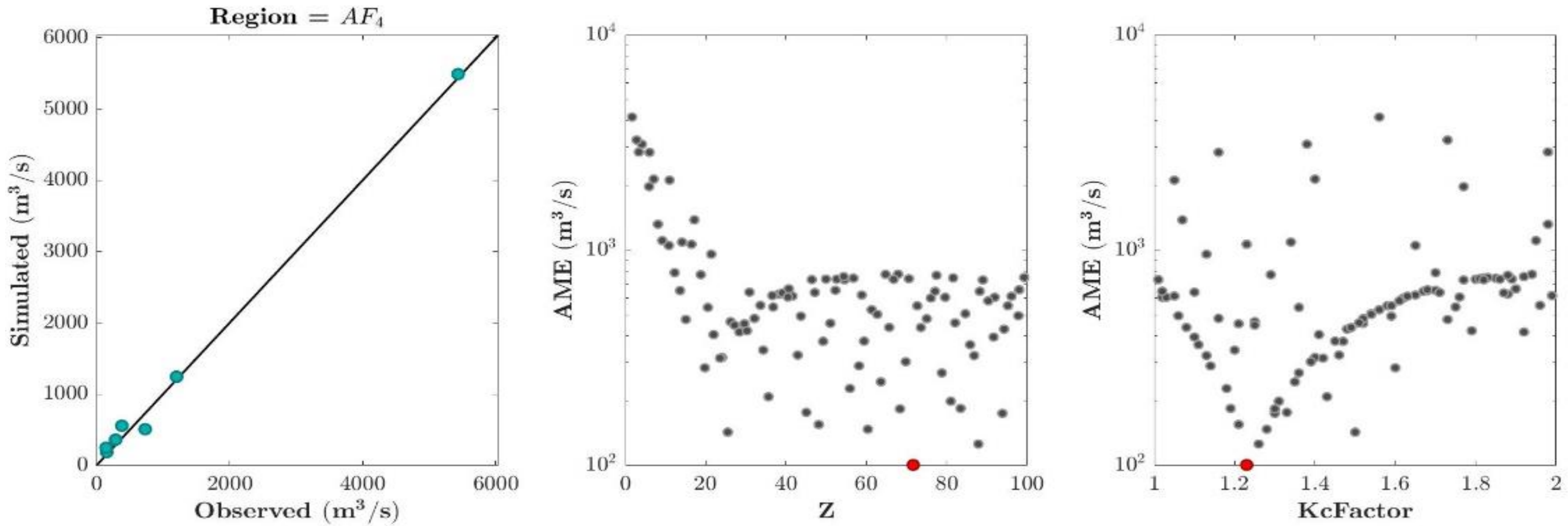


**HYDROSHEDS LEVEL 2**

56 Macro-Regions

# Modeling in RIOS & INVEST

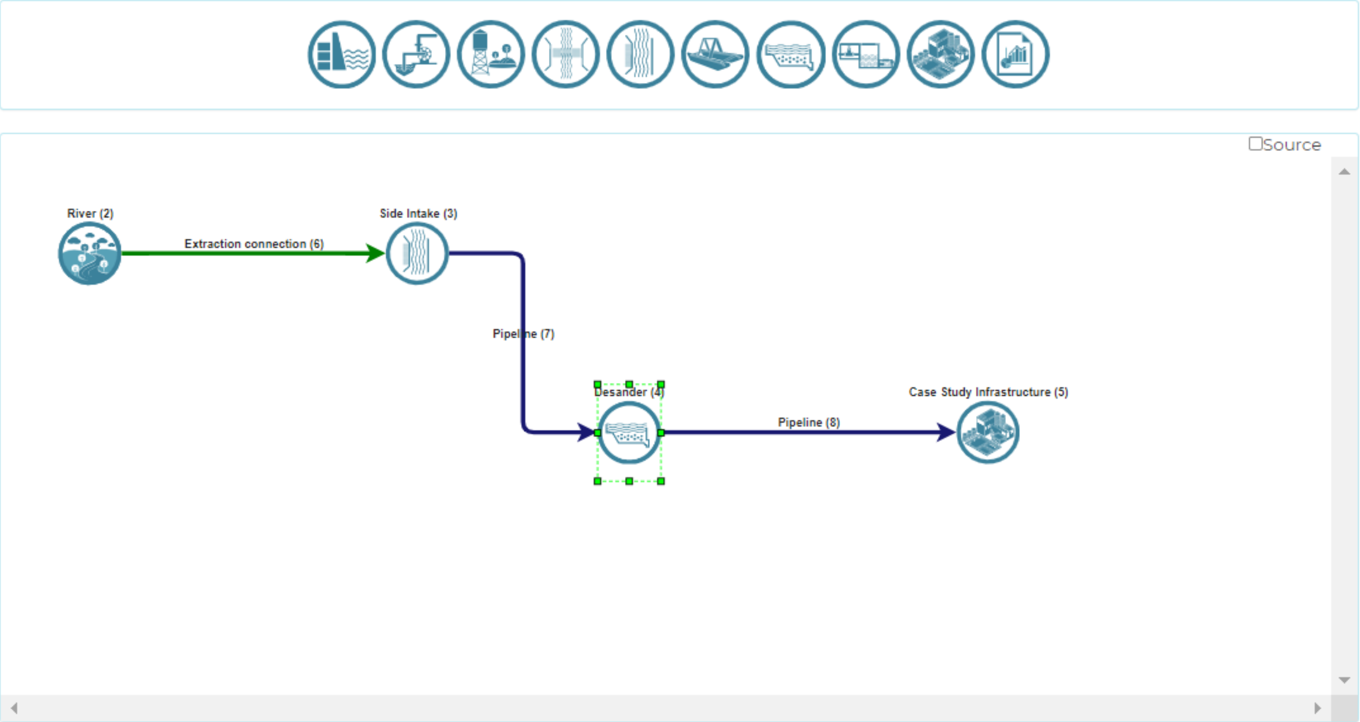
Annual Water Yield



# DRINKING WATER SYSTEMS

# Drinking water systems

# Drinking water systems characterization




WATER INTAKE AND PRE-TREATMENT INFRASTRUCTURE TYPIFICATION

1. Reservoir (E)
2. Raw Water Pondage (RAC)
3. Pumping (B)
4. Water Intake (BO)
   4.1. Bottom Intake
   4.2. Lateral Intake
   4.3. Floating Intake
5. Desander (D)
6. Break Pressure Chamber(CQ)
7. Pipeline (T)
8. Channel (C)
9. River (R)
10. Connection (CX)
11. Connection with extraction (CEXT)
12. Case Study Infrastructure (CSINFRA)
13. External Input (EXTInput)

# Drinking water systems characterization

**CLASSIFICATION OF WATER QUALITY IN THE RIVER**

+

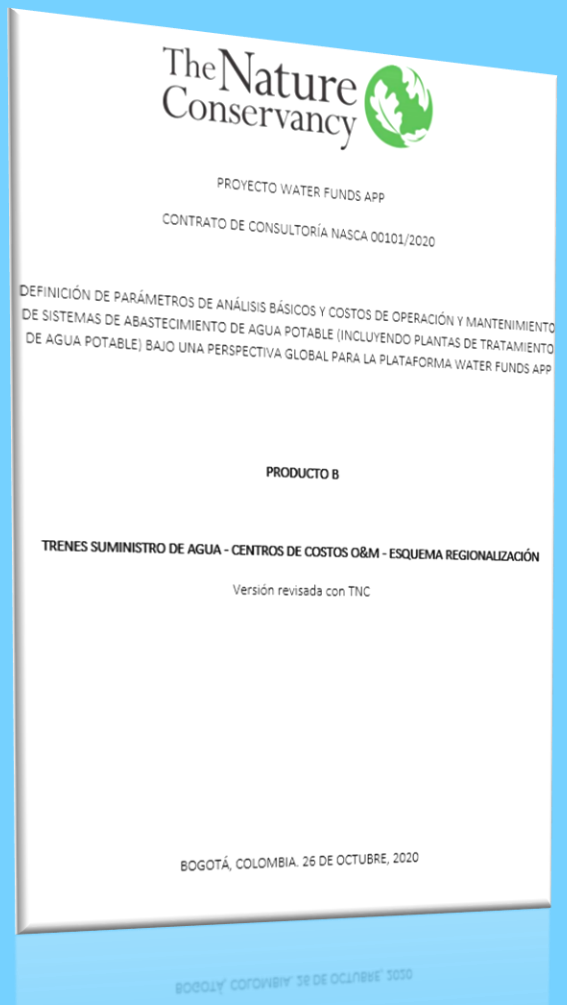
**NORMATIVE CLASSIFICATION OF DRINKING WATER QUALITY BY COUNTRY**

→

**DRINKING WATER TREATMENT PLANTS TYPIFICATION**

# Drinking water systems

## Drinking water systems characterization


The Nature Conservancy

PROYECTO WATER FUNDS APP

CONTRATO DE CONSULTORÍA NASCA 00101/2020

DEFINICIÓN DE PARÁMETROS DE ANÁLISIS BÁSICOS Y COSTOS DE OPERACIÓN Y MANTENIMIENTO DE SISTEMAS DE ABASTECIMIENTO DE AGUA POTABLE (INCLUYENDO PLANTAS DE TRATAMIENTO DE AGUA POTABLE) BAJO UNA PERSPECTIVA GLOBAL PARA LA PLATAFORMA WATER FUNDS APP

PRODUCTO B

TRENES SUMINISTRO DE AGUA - CENTROS DE COSTOS O&M - ESQUEMA REGIONALIZACIÓN

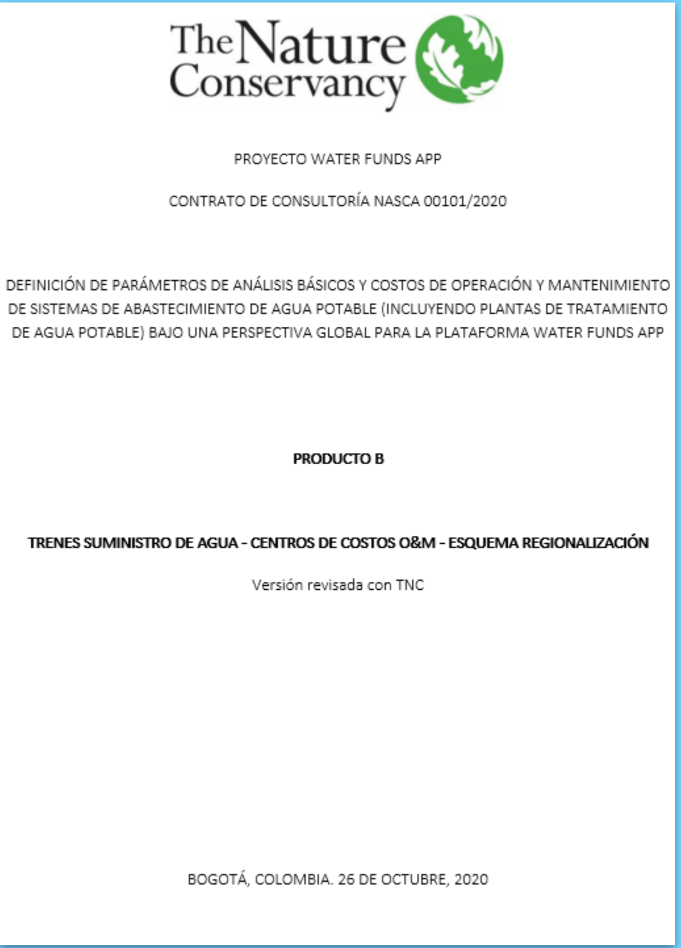
Versión revisada con TNC

BOGOTÁ, COLOMBIA. 26 DE OCTUBRE, 2020

### CLASSIFICATION OF WATER QUALITY IN THE RIVER

| Water quality levels | Good | Regular | Deficient | Very Deficient |
|---|---|---|---|---|
| Csed_R (mg/L) | < 4,4 | (4,4 - 56) | (56 - 203) | > 203 |
| CN_R (mg/L) | < 10 | (10 - 20) | (20 - 30) | > 30 |
| CP_R (mg/L) | < 0,2 | (0.2 - 1) | (1 - 4) | > 4 |
| Category | A | B | C | D |

# Drinking water systems characterization


The Nature Conservancy

PROYECTO WATER FUNDS APP

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DEFINICIÓN DE PARÁMETROS DE ANÁLISIS BÁSICOS Y COSTOS DE OPERACIÓN Y MANTENIMIENTO DE SISTEMAS DE ABASTECIMIENTO DE AGUA POTABLE (INCLUYENDO PLANTAS DE TRATAMIENTO DE AGUA POTABLE) BAJO UNA PERSPECTIVA GLOBAL PARA LA PLATAFORMA WATER FUNDS APP

**PRODUCTO B**

**TRENES SUMINISTRO DE AGUA - CENTROS DE COSTOS O&M - ESQUEMA REGIONALIZACIÓN**

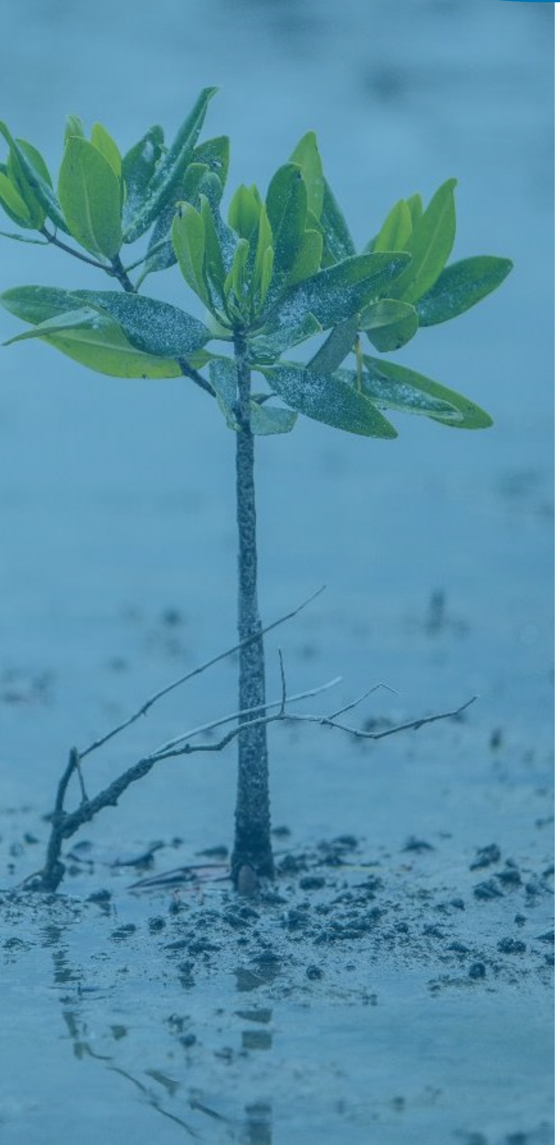
Versión revisada con TNC

BOGOTÁ, COLOMBIA. 26 DE OCTUBRE, 2020

## NORMATIVE CLASSIFICATION OF DRINKING WATER QUALITY BY COUNTRY

| Drinking water quality: normative classification | | | | |
|---|---|---|---|---|
| | High (1) | Normal (2) | Low (3) | Very Low (4) |
| | SST < = 2.65 mg/L | SST < = 2.65 - 5.6 mg/L | SST < = 5.6 - 17 mg/L | SST < = 17 mg/L |
| | N < = 5 mg/L | N < = 5 - 11 mg/L | N < = 11 - 20 mg/L | N < = 20 mg/L |
| Category | 1 | 2 | 3 | 4 |

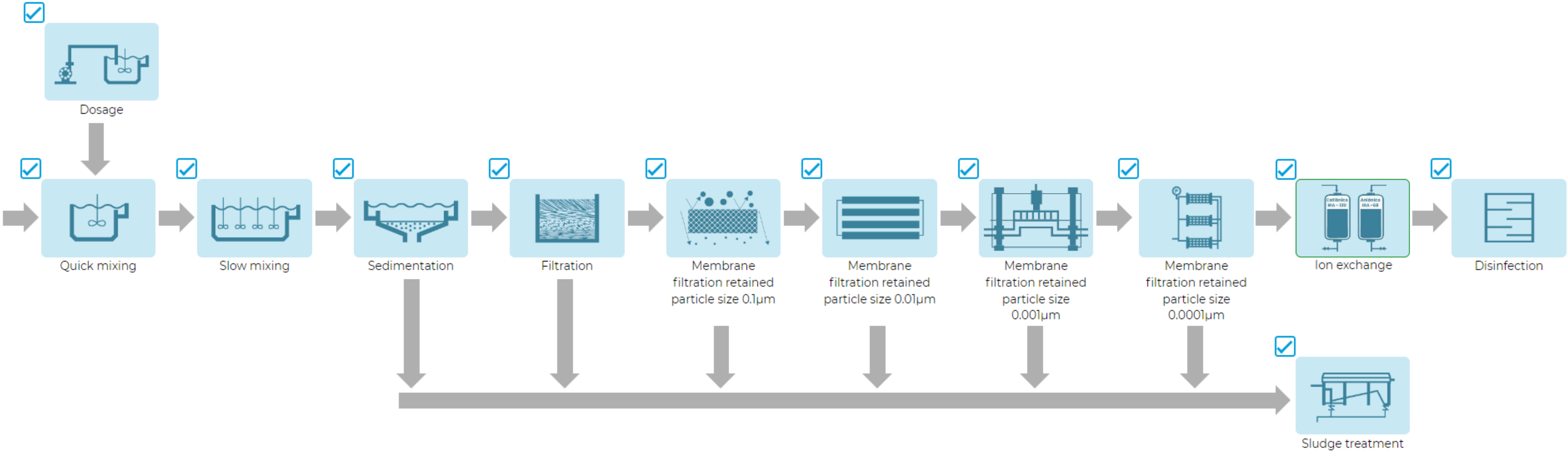
# Drinking water systems characterization



| Calidad de la fuente | Calidad del agua potable: clasificación normativa | | | |
|---|---|---|---|---|
| | **1** | **2** | **3** | **4** |
| **A** | Planta E | Planta F | Planta G | Planta G |
| **B** | Planta E | Planta D | Planta F | Planta F |
| **C** | Planta B | Planta C | Planta D | Planta D |
| **D** | Planta A | Planta A | Planta C | Planta D |

# Drinking water systems characterization

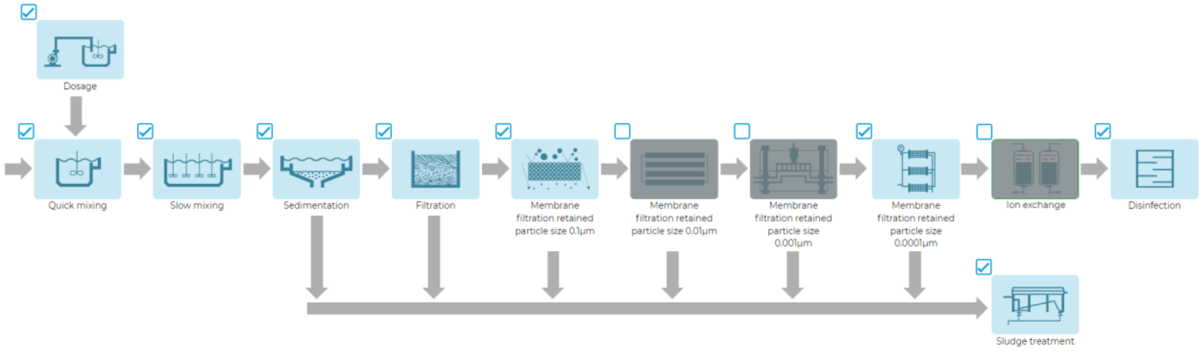
## Generic Treatment Train



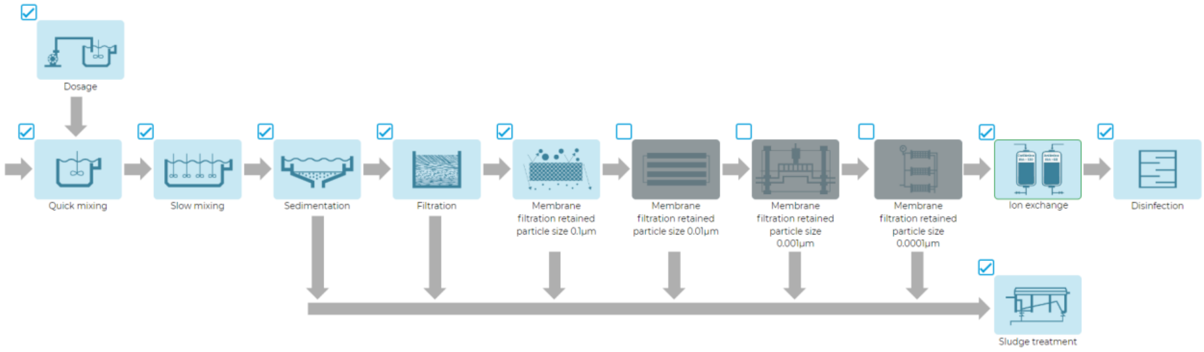
# Drinking water systems

# Progress in drinking water systems characterization

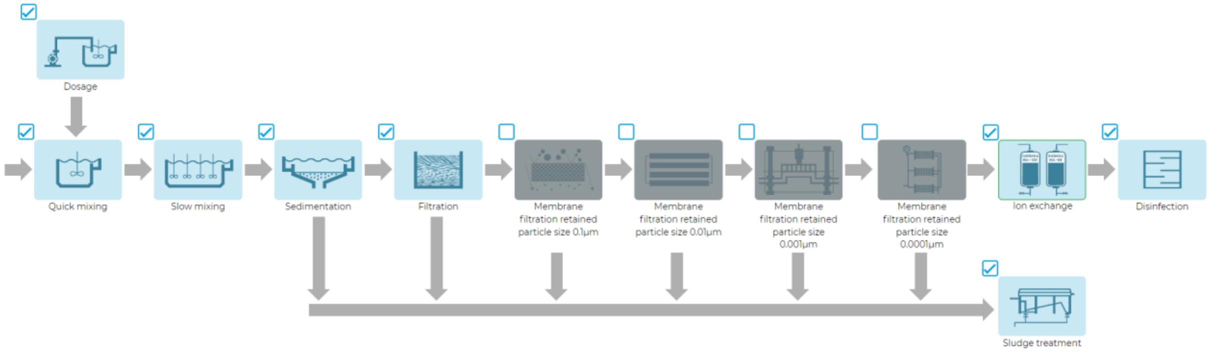
## Plant A



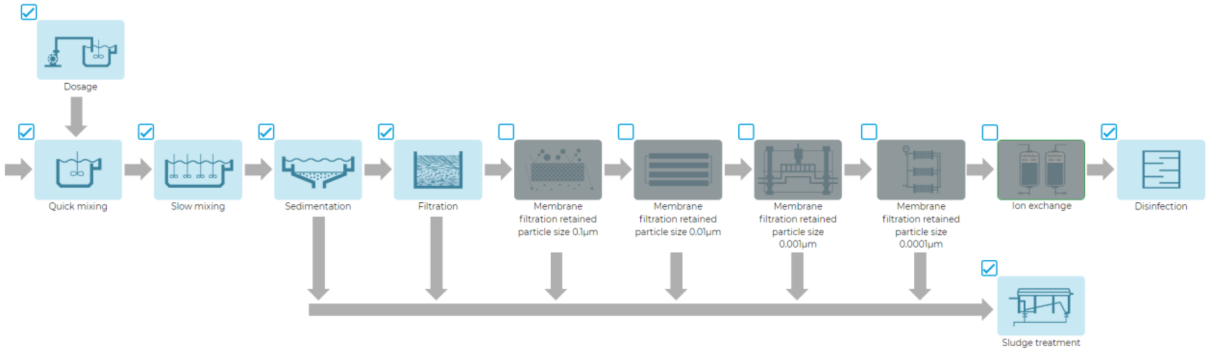

## Plant B




## Plant C

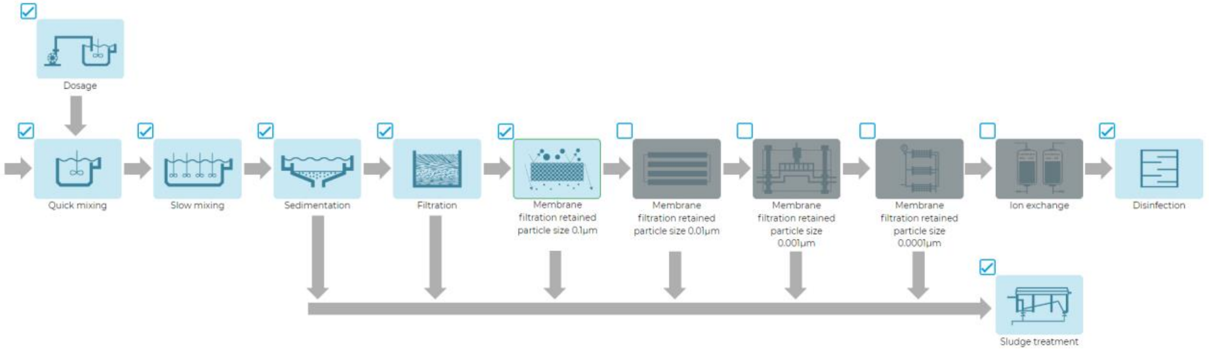



## Plant D

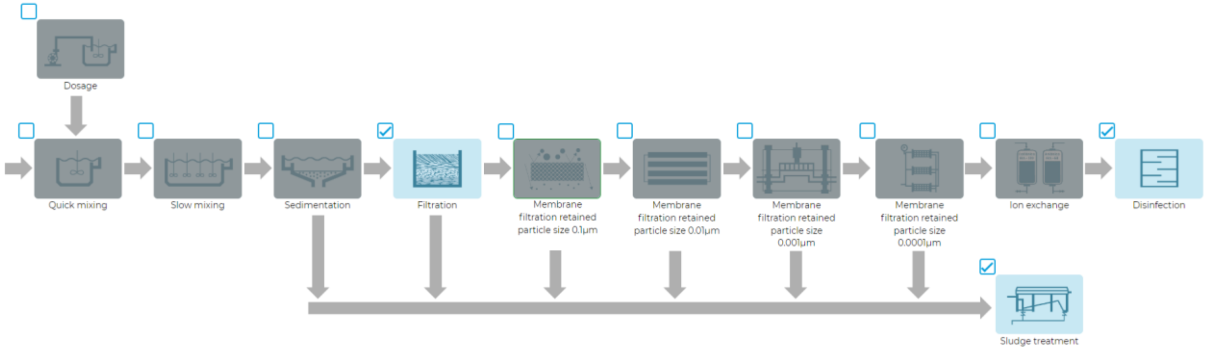


# Drinking water systems characterization

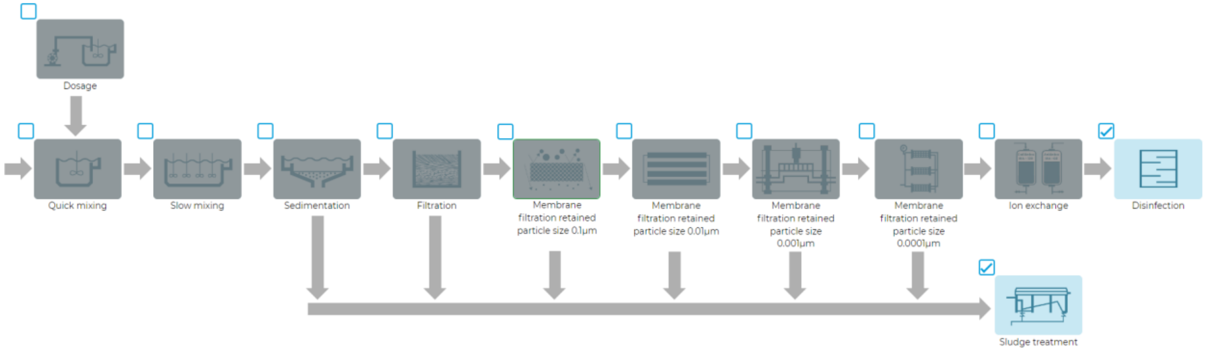
## Plant E




## Plant F



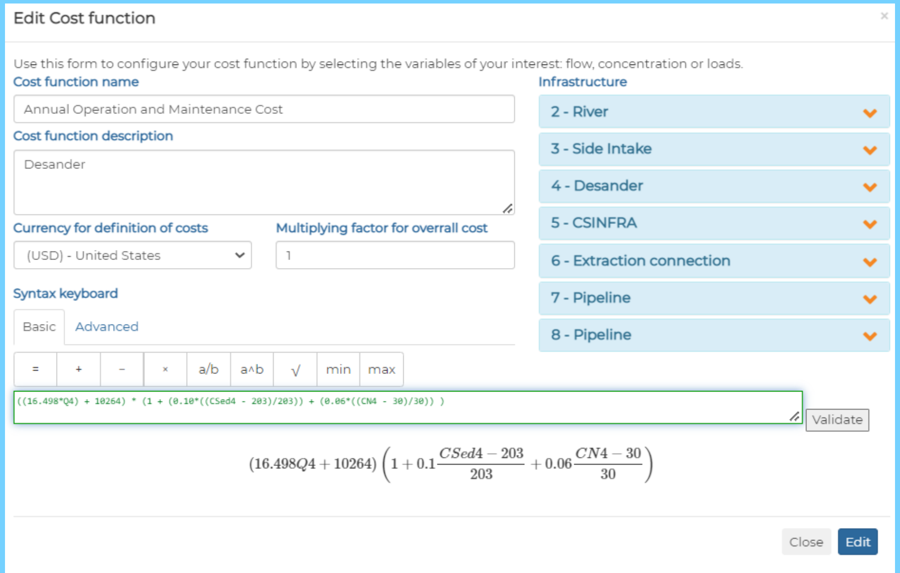

## Plant G




DRINKING WATER TREATMENT PLANTS TYPIFICATION

# COST FUNCTIONS

# Cost functions




EACH STRUCTURE TRANSPORTS A PARTICULAR FLOW RATE AND RETAINS A SPECIFIC AMOUNT OF SEDIMENTS, NITROGEN OR PHOSPHORUS !!!!

## MATHEMATICAL EXPRESSIONS OF TYPE

$$O\&M = 1.202 * 10^{1.828(\log(86.4*Q))^{0.598}\}+1.876} * \left(1 + \left(0.24 * \left(\frac{S_1 - 56}{56}\right)\right) + \left(0.06 * \left(\frac{N_1 - 20}{20}\right)\right)\right)$$

## CAN BE A FUNCTION OF:

- Flow
- Sediment concentration
- Nitrogen concentration
- Phosphorus concentration
- Sediment Load
- Nitrogen Load
- Phosphorus Load
- Retained Sediment Load
- Retained Nitrogen Load
- Retained Phosphorus Load

# Cost functions

the international water association

The Nature Conservancy

PROYECTO WATER FUNDS APP

CONTRATO DE CONSULTORÍA NASCA 00101/2020

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**PRODUCTO C**

**FUNCIONES DE COSTOS Y FORMATO PARA LA BASE DE DATOS GLOBAL**

BOGOTÁ, COLOMBIA. 26 DE OCTUBRE, 2020

Ecological Economics 151 (2018) 195–209

Contents lists available at ScienceDirect

Ecological Economics

journal homepage: www.elsevier.com/locate/ecolecon

ELSEVIER

## The Effects of Source Water Quality on Drinking Water Treatment Costs: A Review and Synthesis of Empirical Literature

James I. Price*, Matthew T. Heberling

*Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, OH 45268, United States*

ARTICLE INFO

*Keywords:*
Water quality
Source water protection
Community water systems
Drinking water treatment
Avoided treatment costs
Economic analysis

ABSTRACT

Watershed protection, and associated *in situ* water quality improvements, has received considerable attention as a means for mitigating health risks and avoiding expenditures at drinking water treatment plants (DWTPs). This study reviews the literature linking source water quality to DWTP expenditures. For each study, we report information on the modeling approach, data structure, definition of treatment costs and water quality, and statistical methods. We then extract elasticities indicating the percentage change in drinking water treatment costs resulting from a 1% change in water quality. Forty-six elasticities are obtained for various water quality parameters, such as turbidity, total organic carbon (TOC), nitrogen, sediment loading, and phosphorus loading. An additional 29 elasticities are obtained for land use classification (e.g., forest, agricultural, urban), which often proxy source water quality. Findings indicate relatively large ranges in the estimated elasticities of most parameters and land use classifications. However, average elasticities are smaller and ranges typically narrower for studies that incorporated control variables consistent with economic theory in their models. We discuss the implications of these findings for a DWTP's incentive to engage in source water protection and highlight gaps in the literature.

WATER RESOURCES RESEARCH, VOL. 34, NO. 4, PAGES 849–853, APRIL 1998

## Costs of water treatment due to diminished water quality: A case study in Texas

David Dearmont
Research Division, Nebraska Department of Revenue, Lincoln

Bruce A. McCarl
Department of Agricultural Economics, Texas A&M University, College Station

Deborah A. Tolman
Department of Environmental Sciences and Resources, Portland State University, Portland, Oregon

**Abstract.** The cost of municipal water treatment due to diminished water quality represents an important component of the societal costs of water pollution. Here the chemical costs of municipal water treatment are expressed as a function of raw surface water quality. Data are used for a 3-year period for 12 water treatment plants in Texas. Results show that when regional raw water contamination is present, the chemical cost of water treatment is increased by \$95 per million gallons (per 3785 $m^3$) from a base of \$75. A 1% increase in turbidity is shown to increase chemical costs by 0.25%.

AGU PUBLICATIONS

Water Resources Research

RESEARCH ARTICLE

10.1002/2014WR016422

## Comparing drinking water treatment costs to source water protection costs using time series analysis

**Matthew T. Heberling[1], Christopher T. Nietch[2], Hale W. Thurston[1], Michael Elovitz[2], Kelly H. Birkenhauer[3], Srinivas Panguluri[3], Balaji Ramakrishnan[3], Eric Heiser[4], and Tim Neyer[4]**

[1]Sustainable Technology Division, National Risk Management Research Laboratory, Office of Research and Development, US Environmental Protection Agency, Cincinnati, Ohio, USA, [2]Water Supply and Water Resources Division, National Risk Management Research Laboratory, Office of Research and Development, US Environmental Protection Agency, Cincinnati, Ohio, USA, [3]CB&I Federal Services LLC, Cincinnati, Ohio, USA, [4]Clermont County Water Resources Department, Batavia, Ohio, USA

**Key Points:**
- Determine how treatment costs change due to changes in source water quality
- Error correction model estimates short and long-run effects on treatment costs
- Polynomial distributed lag model translates watershed load to treatment costs

**Supporting Information:**
- Supporting Information S1

**Correspondence to:**
M. T. Heberling,
Heberling.Matt@epa.gov

**Citation:**
Heberling, M. T., C. T. Nietch, H. W. Thurston, M. Elovitz, K. H. Birkenhauer, S. Panguluri, B. Ramakrishnan, E. Heiser, and T. Neyer (2015), Comparing drinking water treatment costs to source water protection costs using time series analysis, *Water Resour. Res.*, *51*, 8741–8756, doi:10.1002/2014WR016422.

Received 16 SEP 2014

**Abstract** We present a framework to compare water treatment costs to source water protection costs, an important knowledge gap for drinking water treatment plants (DWTPs). This trade-off helps to determine what incentives a DWTP has to invest in natural infrastructure or pollution reduction in the watershed rather than pay for treatment on site. To illustrate, we use daily observations from 2007 to 2011 for the Bob McEwen Water Treatment Plant, Clermont County, Ohio, to understand the relationship between treatment costs and water quality and operational variables (e.g., turbidity, total organic carbon [TOC], pool elevation, and production volume). Part of our contribution to understanding drinking water treatment costs is examining both long-run and short-run relationships using error correction models (ECMs). Treatment costs per 1000 gallons (per 3.79 $m^3$) were based on chemical, pumping, and granular activated carbon costs. Results from the ECM suggest that a 1% decrease in turbidity decreases treatment costs by 0.02% immediately and an additional 0.1% over future days. Using mean values for the plant, a 1% decrease in turbidity leads to \$1123/year decrease in treatment costs. To compare these costs with source water protection costs, we use a polynomial distributed lag model to link total phosphorus loads, a source water quality parameter affected by land use changes, to turbidity at the plant. We find the costs for source water protection to reduce loads much greater than the reduction in treatment costs during these years. Although we find no incentive to protect source water in our case study, this framework can help DWTPs quantify the trade-offs.

## Preliminary Cost Estimation Models for Construction, Operation, and Maintenance of Water Treatment Plants

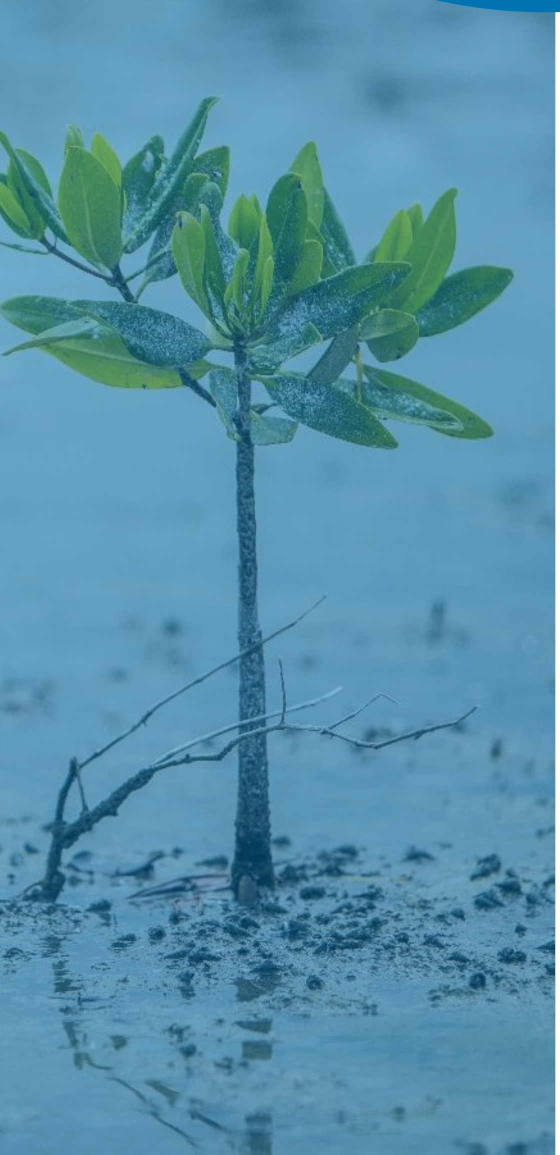
Jwala R. Sharma, Ph.D., M.ASCE[1]; Mohammad Najafi, Ph.D., P.E., F.ASCE[2]; and Syed R. Qasim, Ph.D., P.E., M.ASCE[3]

**Abstract:** Reliable cost estimation of construction, operation, and maintenance (O&M) of water treatment plants is essential for project planning and design. The authors have developed construction and O&M cost models for different unit operations and processes involved in water treatment plants. These models are developed from historical cost data and can be used to develop preliminary cost estimates for major project components and to screen alternative process trains of a water treatment project during the planning phases of the project. The historical cost data were updated to April 2011 costs by using cost indexes from Engineering News Record (ENR) and Bureau of Labor Statistics (BLS), in addition to April 2011 costs of energy and labor. This paper presents the use of a single cost index to further update construction and O&M costs. This approach has significant advantages over using multiple indexes (such as ENR and BLS indexes) for different cost components. Using the method presented in this paper, future cost updating by ENR construction and building cost indexes becomes simple and straightforward. Actual bid prices for one new water treatment plant construction and two water treatment plant expansion projects were obtained from reputed consulting firms and compared to estimated costs by using the cost models presented in this paper. Further validation is recommended by use of the equations and comparisons of the costs to the detailed estimates and actual bids. Accurate forecasting of the costs of a project is site specific and cannot be generalized. Design plans and specifications are needed to develop accurate cost estimates based on equipment, materials, and labor. **DOI:** 10.1061/(ASCE)IS.1943-555X.0000155. 

**CE Database subject headings:** Water treatment plants; Construction costs; Maintenance; Costs.

**Author keywords:** Construction costs; Operation and maintenance costs; Water treatment plants; Cost estimation.

# Cost functions



1. **EMBALSE (E)**

| DESCRIPCIÓN | ID | FUNCIÓN DE COSTO |
|---|---|---|
| RETIRO DE BUCHÓN (RB) | 1 | $O\&M_E = \min \begin{cases} 0.8515 * WP_{E,ret} * \left(\frac{1*10^3}{31536}\right) \\ 0.0532 * WN_{E,ret} * \left(\frac{1*10^3}{31536}\right) \end{cases}$ |
| DRAGADO (DR) | 2 | $O\&M_E = \left((-1.075*10^{-6}) * \left(0.315 * Wsed_{P,ret} * \left(\frac{1*10^6}{31536}\right)\right)^2\right) + \left(9.675 * \left(0.315 * Wsed_{P,ret} * \left(\frac{1*10^6}{31536}\right)\right)\right)$ |

2. **RESERVORIO DE AGUA CRUDA (RAC)**

| DESCRIPCIÓN | ID | FUNCIÓN DE COSTO |
|---|---|---|
| RETIRO DE BUCHÓN | 3 | $O\&M_{RAC} = \min \begin{cases} 0.8515 * WP_{E,ret} * \left(\frac{1*10^3}{31536}\right) \\ 0.0532 * WN_{E,ret} * \left(\frac{1*10^3}{31536}\right) \end{cases}$ |
| DRAGADO | 4 | $O\&M_{RAC} = \left((-5.064*10^{-4}) * \left(0.315 * Wsed_{RAC,ret} * \left(\frac{1*10^6}{31536}\right)\right)^2\right) + \left(126.6 * \left(0.315 * Wsed_{RAC,ret} * \left(\frac{1*10^6}{31536}\right)\right)\right)$ |

3. **BOMBEO (B)**

| DESCRIPCIÓN | ID | FUNCIÓN DE COSTO |
|---|---|---|
| COSTOS DE OPERACIÓN Y MANTENIMIENTO ANUAL (O&M) | 5 | $O\&M_B = ((11126.6 * Q_B) + 30929.7) * \left(1 + \left(0.24 * \left(\frac{Csed_{B,input} - 56}{56}\right)\right) + \left(0.06 * \left(\frac{CN_{B,input} - 20}{20}\right)\right)\right)$ |

Water Proof

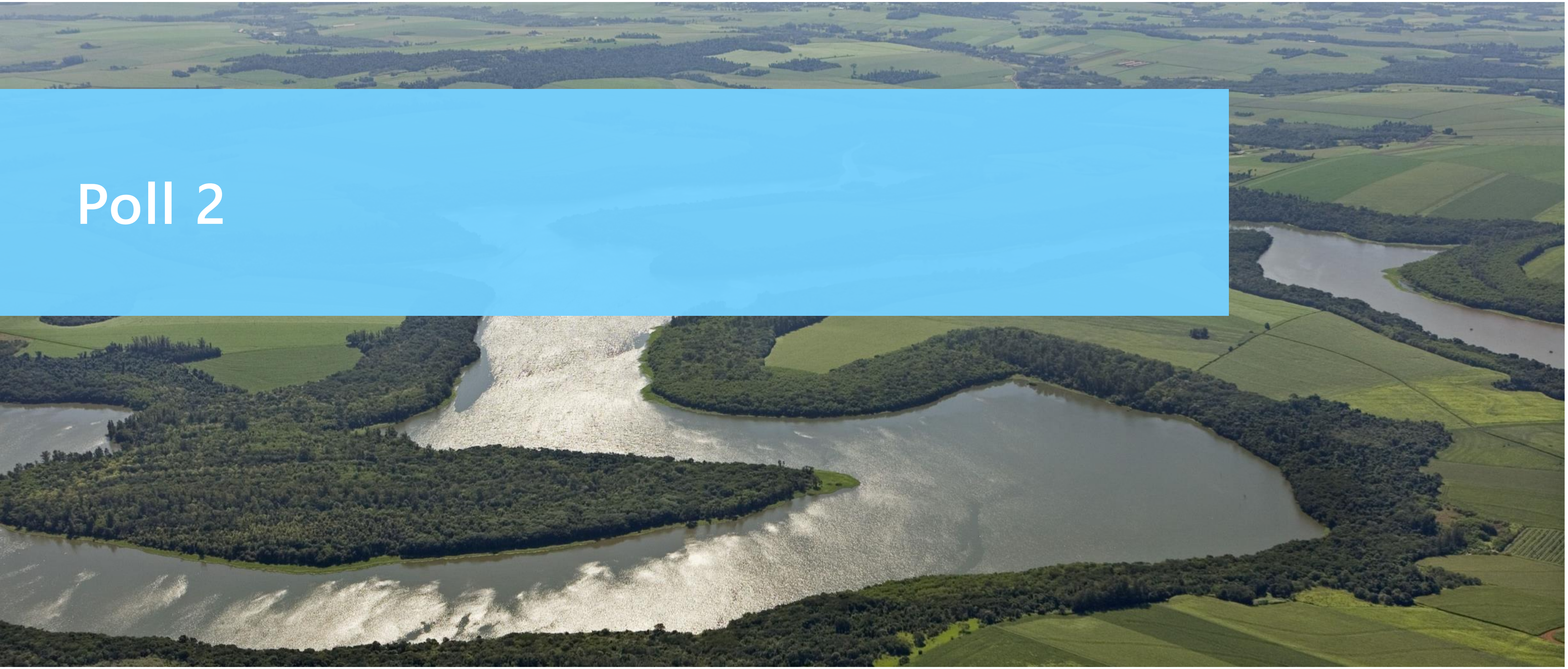
the international water association


**Version 1.0**

https://water-proof.org/


WaterProof
NbS for Water
THANK YOU

# Poll 2



inspiring change

The Nature Conservancy

IWA the international water association

# WaterProof live demonstration

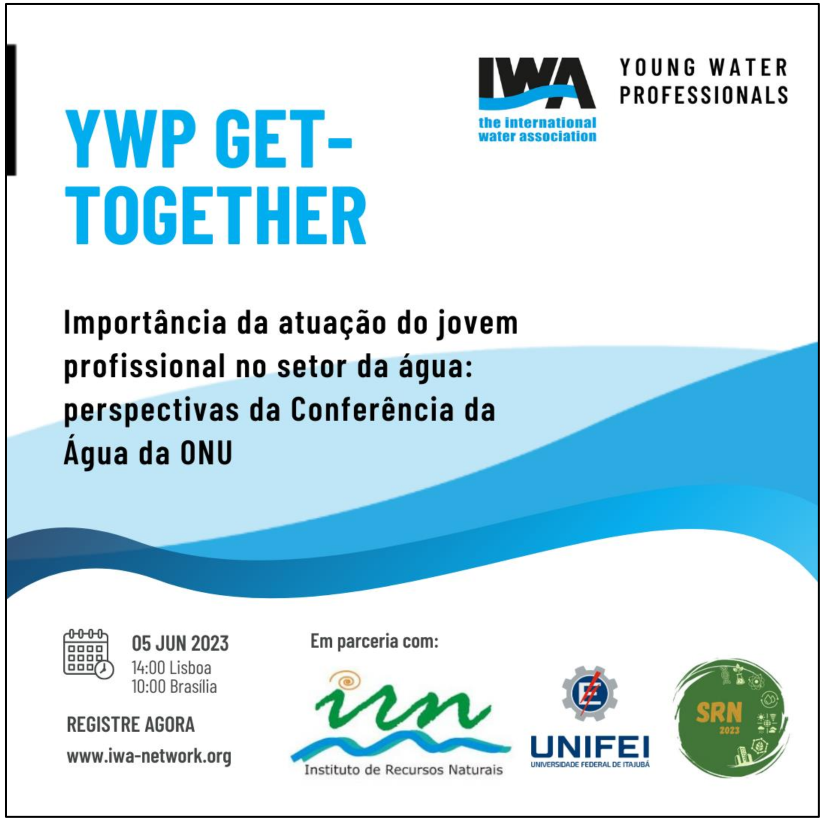
PART 3

inspiring change

# Q&A

MODERATOR: BROOKE ATWELL

# UPCOMING LEARNING OPPORTUNITIES





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**http://www.iwa-network.org/iwa-learn/**

# WATERPROOF VIRTUAL COURSE - RAPID RETURN ON INVESTMENT OF NATURE-BASED SOLUTIONS FOR WATER SECURITY

the international water association

- The objective of this course is to encourage the use of WaterProof, an application specifically designed for project managers to efficiently obtain an indicative and rapid Nature-Based Solutions (NbS) investment portfolio, along with the associated ROI.

**Duration:** **Three weeks (June 15-July 6)**

The participant must allocate at least 2 hours per week for the development of the activities

**Target audience:**

Professionals and technicians responsible for designing projects to improve water availability and management, who are interested in analyzing return on investment in the implementation of NbS.

**Tutors:**

3 tutors will provide support and guidance to participants through the available communication tools, with 1-on-1 sessions available July 4-6..

# WATERPROOF VIRTUAL COURSE - RAPID RETURN ON INVESTMENT OF NATURE-BASED SOLUTIONS FOR WATER SECURITY

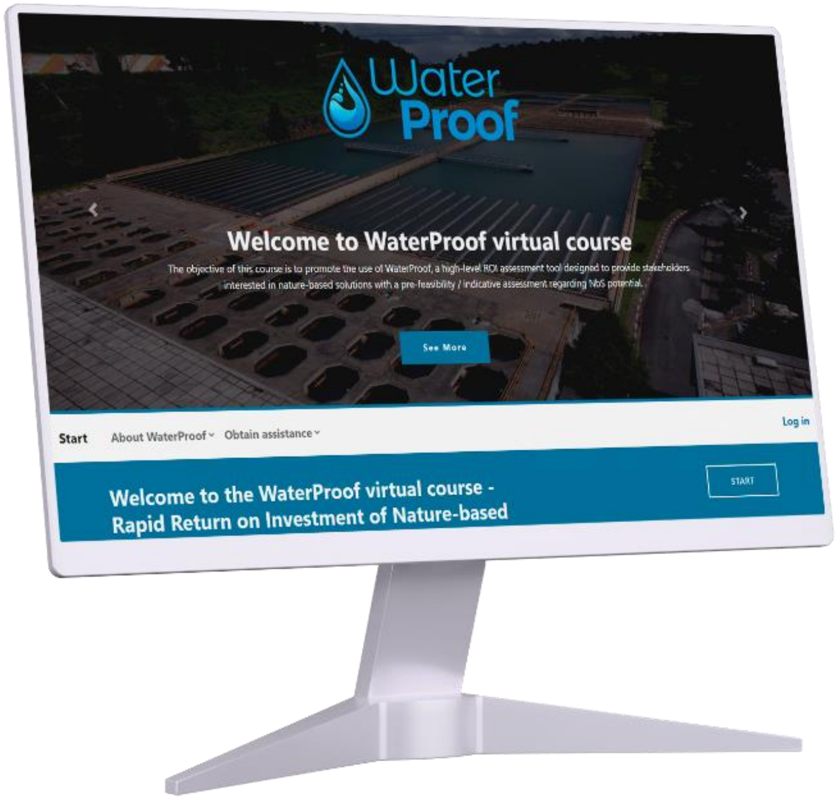
**Carlos Rogéliz** is a Civil Engineer, Master´s in Water Resources, with extensive knowledge in hydrological and hydraulic mathematical modeling, management and planning of water resources and management of technical scientific tools for the analysis of hydrological systems. With experience in research and consulting projects related to hydraulic studies of rivers, management of geographic information systems and generation of software and applications oriented to engineering information. He currently works as a conservation program leader in integrated water resources management for The Nature Conservancy in Colombia.

**Jonathan Nogales** is a Agricultural Engineer, Master's candidate in Hydro systems. He has extensive knowledge in hydrological and hydraulic mathematical modeling, Big Data, spatial analysis and computational development. Jonathan has worked for more than five years in research and consulting projects, specializing in technical analysis of watersheds, climate change, management of geographic information systems, software generation and applications oriented to the analysis and compilation of engineering information.

**Pilar Galindo** is Systems Engineer and Software Engineering Specialist, with experience in leadership and development of technology projects, especially in low web environments and mobile environments. In charge of the analysis and gathering of requirements associated with the design of information systems.

With experience in the monitoring and intervention of projects, in the coordination of training spaces, as well as the generation of printed and digital dissemination products.

Water Proof




**Version 1.0**
https://water-proof.org/

the international water association

## Contents

1. General concepts of NbS and their importance in water security
2. Mathematical modeling overview
   - InVest
   - Integrated Valuation of Ecosystem Services and Tradeoffs – InVEST
3. Costs related to the implementation of NbS.
4. WaterProof features

Each module is supported by explanatory videos in English and supplementary bibliography.

You will be evaluated through quizzes and a practical exercise on WaterProof.

If you want to be part of the first cycle of online training, please send an email to waterproof@tnc.org with the subject **'Registration for WaterProof Online Course'** indicating your name.

# THANK YOU!

Kari Vigerstol, kvigerstol@tnc.org
Carlos Rogéliz, carlos.rogeliz@tnc.org
Brooke Atwell, brooke.atwell@tnc.org