INSPIRE
Innovative Solutions for
Plastic Free European Rivers

SCIENTIFIC WEBINAR
INSPIRE-
from Observation to Modelling

Welcome!

TODAY's AGENDA

- A short INTRODUCTION to the INSPIRE project
  Daniel González Fernández (University of Cádiz-Spain) - daniel.gonzalez@uca.es
- Microlitter sampling
  Mariana Miranda (VLIZ-Belgium) - mariana.miranda@vliz.be
- Camera and drones for macrolitter observations
  Liesbeth De Keukelaere (VITO-Belgium) - liesbeth.dekeukelaere@vito.be
- Data flow from observations to modelling
  Miranda Stibora (WUR-Netherlands) - miranda.stibora@wur.nl

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INSPIRE
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About INSPIRE: intro

- Dr. Daniel González Fernández – University of Cádiz, Spain
- Research Fellow Scientist in the Department of Biology
- Expert in monitoring and assessment of floating macrolitter in riverine and marine environments
- Project leader INSPIRE WP1 on Riverine Litter Monitoring

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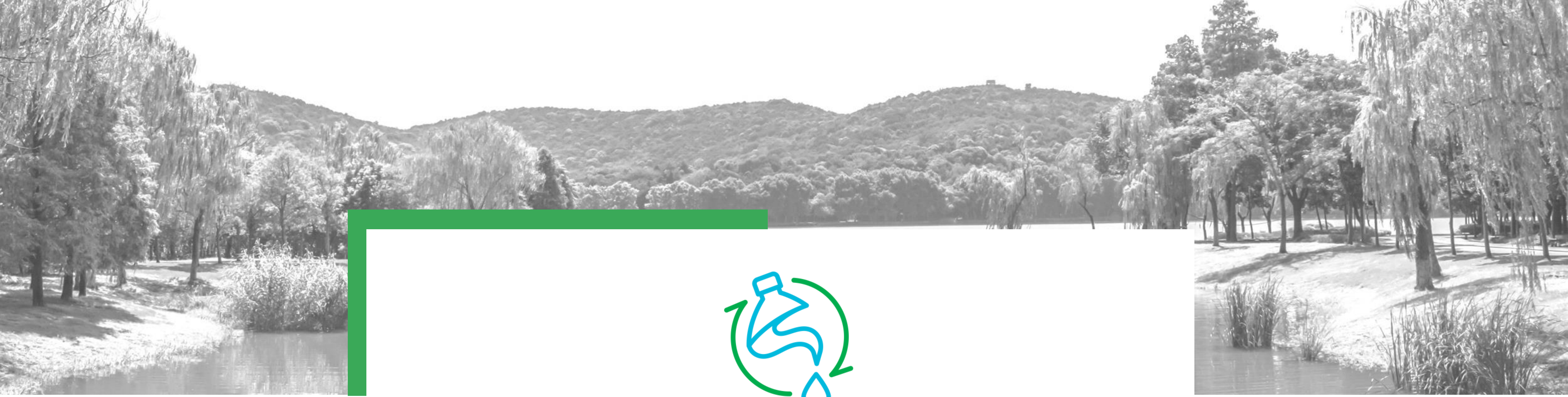

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INTRODUCTION

Horizon Europe INSPIRE project

Innovative Solutions for Plastic Free European Rivers (2023-2027)

Daniel González Fernández - University of Cádiz, Spain

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What is INSPIRE?

INSPIRE is a 4-year Mission project funded under the call HORIZON-MISS-2022-OCEAN-01.

The project will contribute to the drastic **reduction of litter, macro and microplastics in European rivers**.

INSPIRE contributes to the Mission "**Restore our Ocean and Waters by 2030**".

PREVENT AND ELIMINATE POLLUTION OF OUR OCEANS, SEAS AND WATERS

- Reduce by at least 50% plastic litter
- Reduce by at least 30% microplastics
- Reduce by at least 50% nutrient losses, chemical pesticides

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Consortium

26 partners from **15 countries** with a **common mindset**:

Find innovative solutions, **try** them out, **measure** results, **optimize**, **replicate**, **scale up** and **engage** new users.

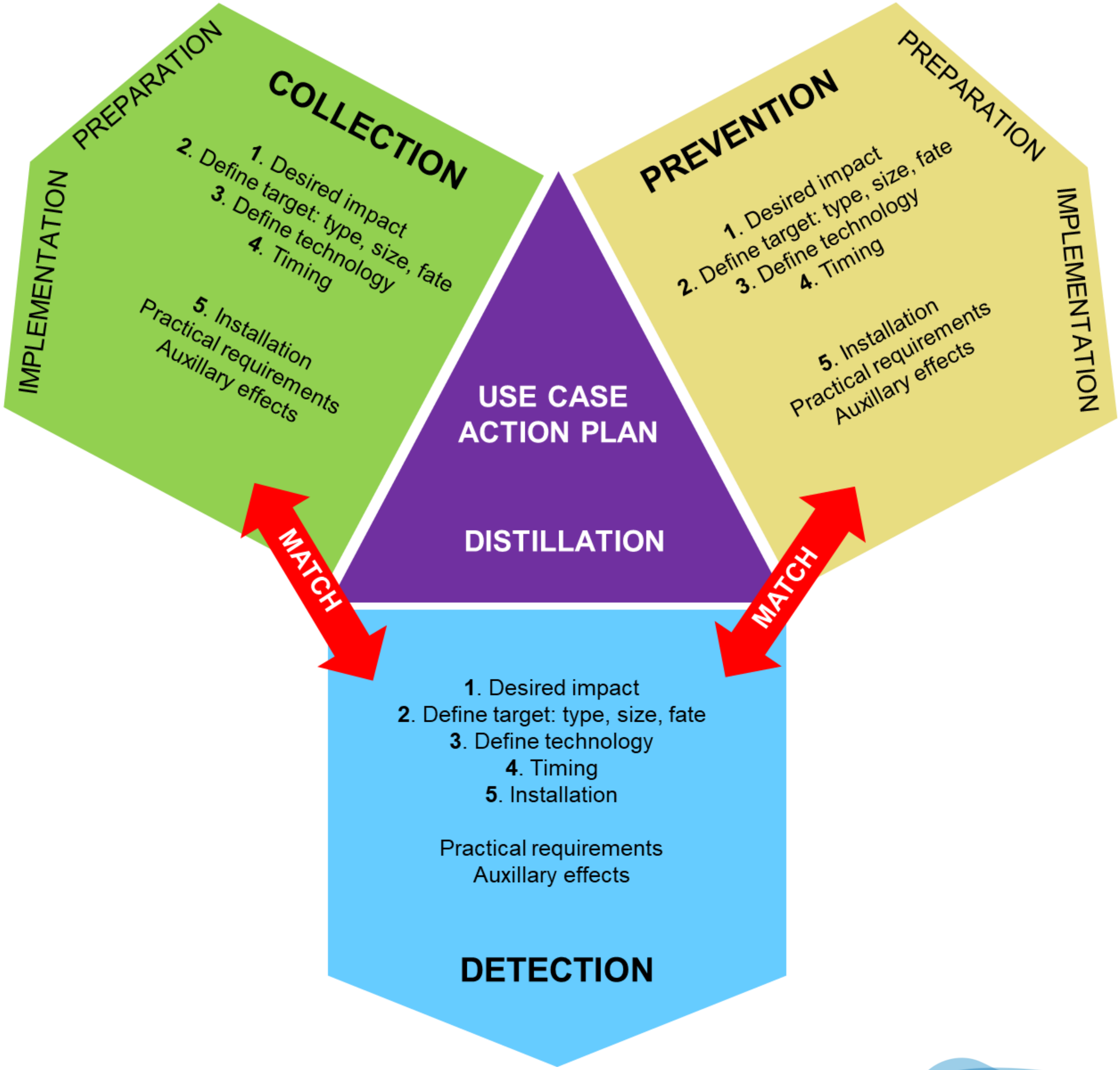
In other words, "INSPIRE" people for the reduction of litter, macro and microplastics in European rivers and ultimately the ocean.

Particip. number	Particip. Acronym	Participant organization name	country
1	VLIZ	VLAAMS INSTITUUT VOOR DE ZEE	BELGIUM
2	VITO	VLAAMS INSTITUUT VOOR TECHNOLOGISCH ONDERZOEK	BELGIUM
3	UM	UNIVERSITY OF MARIBOR	SLOVENIA
4	CLERA	CLERA.ONE	SLOVENIA
5	RC	MOLD	ITALY
6	FF	FISHFLOW INNOVATIONS	NETHERLANDS
7	CIIMAR	CENTRO INTERDISCIPLINAR DE INVESTIGACAO MARINHA E AMBIENTAL	PORTUGAL
8	123	123 ZERO	SLOVENIA
9	FRE	FRESENIUS UNIVERSITY	GERMANY
10	WUR	WAGENINGEN UNIVERSITY & RESEARCH	NETHERLANDS
11	BMI	BIO-MI	CROATIA
12	MINDS	MINDS TECHNOLOGIES AND ENVIRONMENTAL SCIENCES PC	GREECE
13	KTH	KTH ROYAL INSTITUTE OF TECHNOLOGY	SWEDEN
14	GREIN	GRE-IN	GREECE
15	CNR	CONSIGLIO NAZIONALE DELLE RICERCHE	ITALY
16	EXIT	EXIT FOUNDATION	SERBIA
17	UCA	UNIVERSITY OF CÁDIZ	SPAIN
18	ANRI	ALCHEMIA NOVA RESEARCH & INNOVATION GEMEINNUTZIGE GmbH	AUSTRIA
19	ARCHA	ARCHA	ITALY
20	INFOR	INFORDATA	ITALY
21	CIR	CIRCE BIOTECH	AUSTRIA
22	RCU	RIVER CLEAN UP	BELGIUM
23	WnW	WASTE & WATER	FRANCE
24	RWA	ROMANIAN WATER ASSOCIATION	ROMANIA
25	AIT	ASIAN INSTITUTE OF TECHNOLOGY	THAILAND
26	NOR	NORIA	NETHERLANDS

Work methodology of INSPIRE
Holistic DCP concept

The holistic approach of INSPIRE is summed up in the DCP concept:

1. **DETECTION**
   of the pollution located in the river and on the riverbanks
2. **COLLECTION**
   of litter, macro- and microplastics in the river and on riverbanks
3. **PREVENTION**
   of litter, macro- and microplastics before entering the rivers
   - stopping it in its waste stream
   - developing biodegradable alternatives



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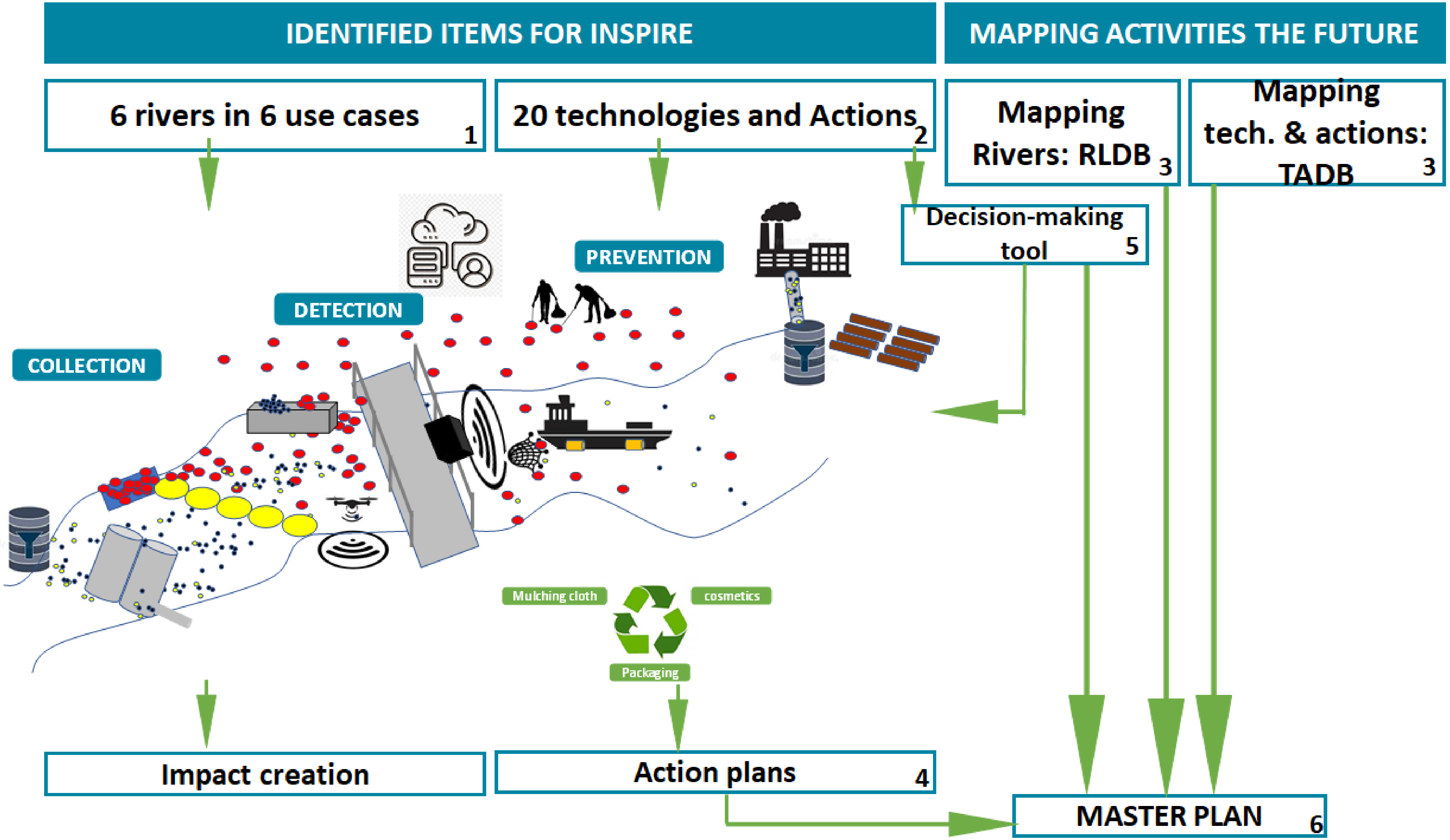
Holistic DCP concept



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INSPIRE will contribute to the drastic reduction of litter, including macro and microplastics, in European rivers, with a holistic approach conceptualized in the **"DCP concept"**:

- **DETECTION** of the pollution present in the river and at the riverbanks:

Meso/macro litter

Bridge mounted AI camera (VITO) & AI-enabled CCTV (AIT) for litter detection

AI enabled drones for riverbank monitoring

JRC Floating Litter Monitoring app & EEA Marine LitterWatch app

Micro litter

Ferrybox & Manta net & grab samplers for sampling different compartments

inspire-europe.org/solutions

- **COLLECTION** of litter in the rivers and at the riverbanks:

Archimedean Drum Screw to capture debris and litter

Fish Friendly litter removing trawling net

River Cleaning System

CLEAN TRASH collection cage

CirCleaner litter removal system

Patje Plastic

Litter removal with citizen engagement

- **PREVENTION** of litter to enter the river by:

Collecting it from its waste stream

- **Super-TW-Net filter**
- **Clera.One water recycling system**
- **EcoPlex Microplastic Remover**
- **Photocatalytic reactor**

Developing alternatives for non-degradable polluting products

Mulch films and greenhouse films

Coating of paper cups and dishes

Coatings for food preservation applications

Cosmetic formulations without packaging

Zero-waste supply chain innovations

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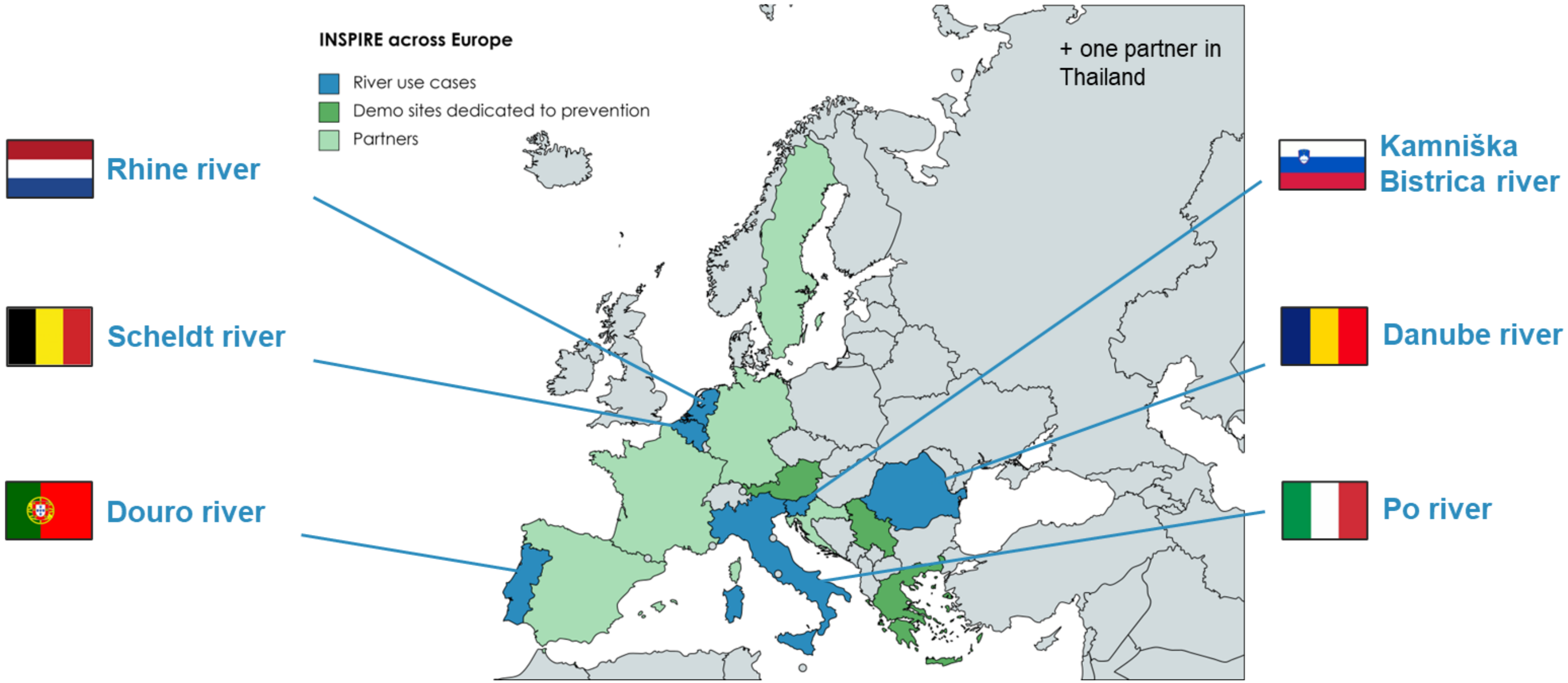
We will develop, implement, test and validate methodologies and solutions to fight against the pollution of rivers by:

- Implementing and testing sets of solutions created by combining the different technologies and actions in 6 river use cases and ≥ 3 circular solution test sites (Serbia, Greece and Austria).
- Assessing the **cost-benefit and sustainability** and **optimizing** the implemented measures with support from forecasting and modelling tools.
- Developing action plans using the data and results collected during the use cases and demo sites.

Developing of a modular **Master Plan (MaP)** for scaling up the solutions and offer 'fit for all' solutions applicable and replicable in all rivers in Europe.



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Microlitter sampling

- Dr. Mariana Miranda - VLIZ, Belgium
- MSc in Environmental Engineering, PhD in Chemical and Biological Engineering (University of Porto, Portugal), Post-doc at VLIZ in Ocean and Health Division-Plastics in Local and Global Waters
- Research interest: plastic aging/degradation in the environment, micro and mesolitter observations in rivers and at sea, assessment of plastic removal efficiency of cleanup technologies and FTIR analysis for environmental plastic identification
- INSPIRE project coordination team

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Monitoring microlitter in riverine environments

Mariana Miranda

VLIZ

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2021 2030 United Nations Decade of Ocean Science for Sustainable Development

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Goals

In INSPIRE, monitoring microlitter (including microplastics) serves two major goals:

1. the quantification of the **baseline pollution level** (before the INSPIRE solutions deployment)
2. the estimation of the **removal effectiveness/efficiency of the INSPIRE solutions**

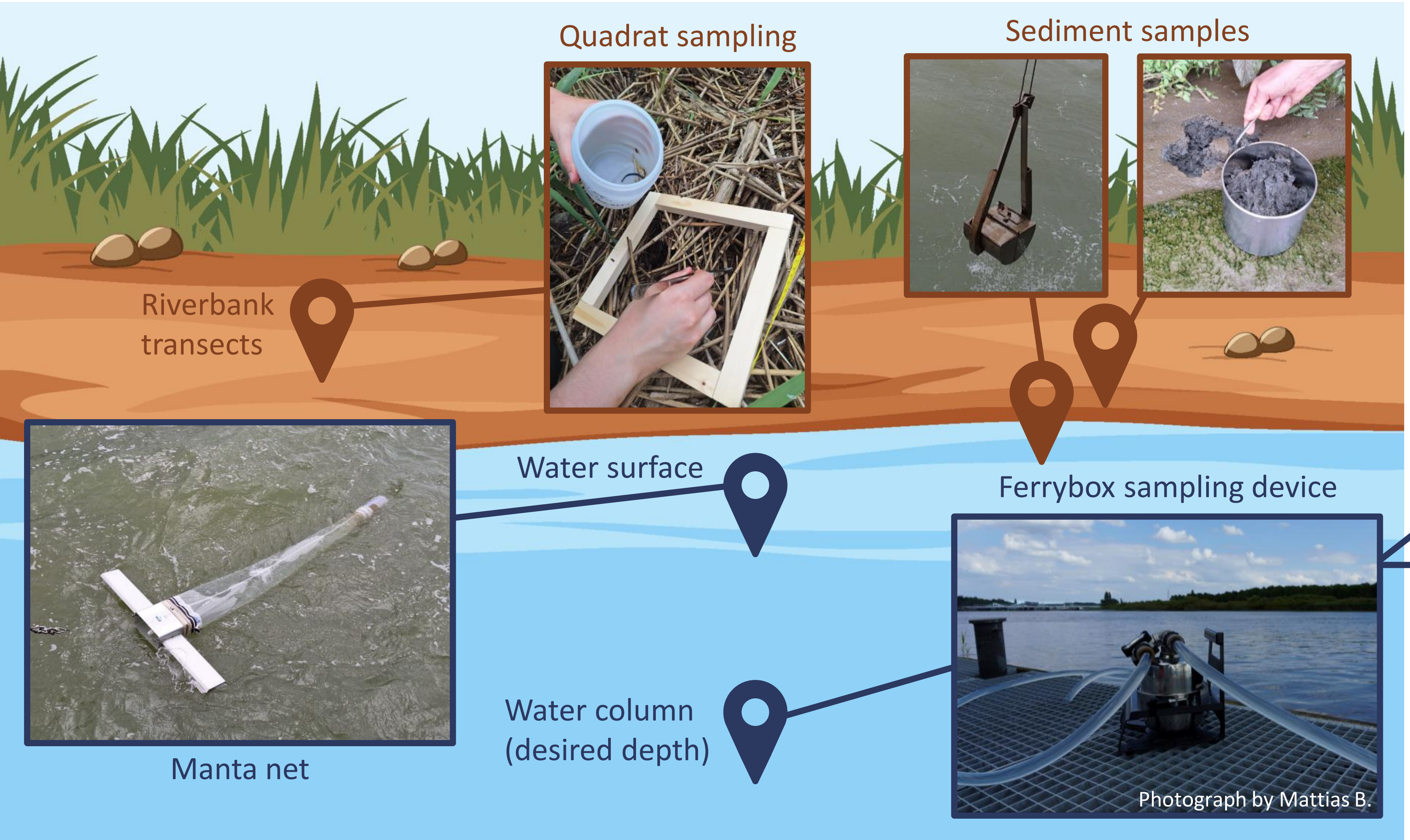
Main output:
Microlitter & microplastic datasets for riverine litter database, modelling tasks, and solutions assessment.

- Harmonization and comparability between demo cases for sampling, processing, analysis and data reporting.

As most microplastic originates from macroplastic, **monitoring will occur at all INSPIRE rivers.**

- Rhine river
- Scheldt river
- Douro river
- Kamniška Bistrica river
- Danube river
- Po river

Field measurements and sampling methods



Other measurements and metadata:

- Time of sample collection/measurement
- GPS coordinates
- Photographs
- Water level
- Water flow and volume collected/filtered

- Physicochemical water parameters:
  - Temperature
  - pH
  - Electrical conductivity
  - Salinity
  - Dissolved Oxygen
  - Turbidity

On the sieves:

- microplastics (MPs)
- tire wear particles (TWPs) fraction 1

Outlet water:

- tire wear particles (TWPs) fraction 2
- tire wear leachables (TWL)

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Sampling campaign preparation

Before field work is fundamental to:

1. Define the objective(s) of the sampling campaign
2. Select the sampling location(s) and obtain the necessary permits and authorizations from the local and regional/national authorities
3. Select the type of sampling to perform and the sampling methods and equipment
4. Prepare a sampling plan, including the above points info, relevant contacts, the sampling schedule, team info and tasks, weather and tides forecast, and list of materials to prepare
5. Prepare the materials needed (with a check list), the campaign and sample codes, and field notebook or field datasheets to fill in during the field work

Recommended: Have already ready the templates to complete after the campaign the report with work performed and issues found, and the spreadsheet to complete with metadata and direct measurements taken in the field.

Quadrats sampling - materials to bring to a riverbank observation campaign

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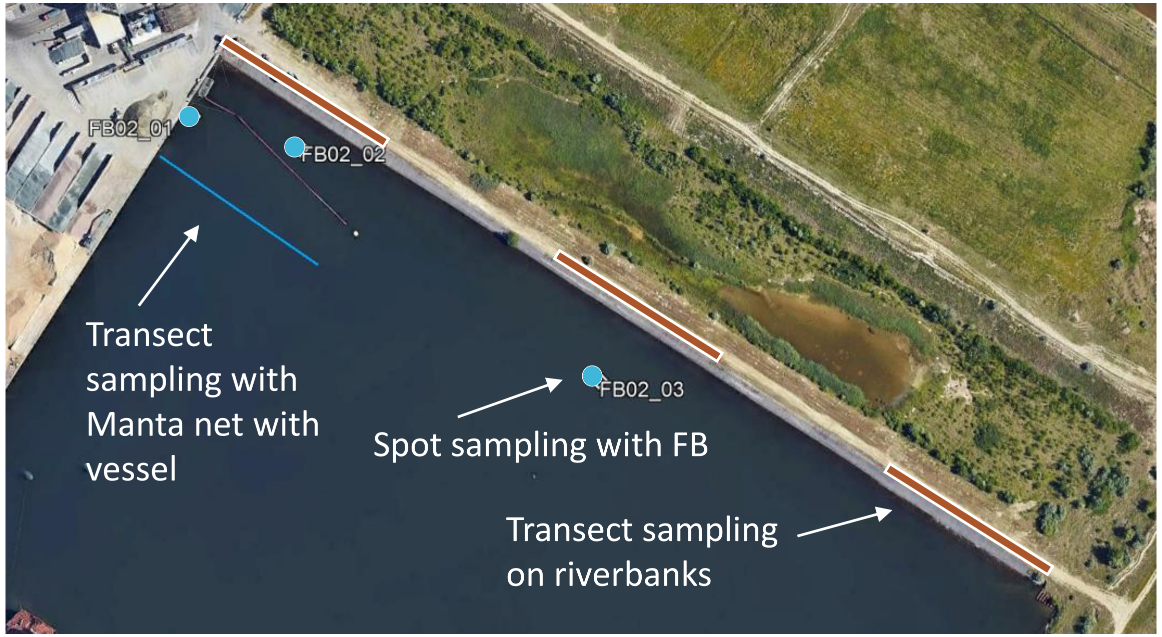
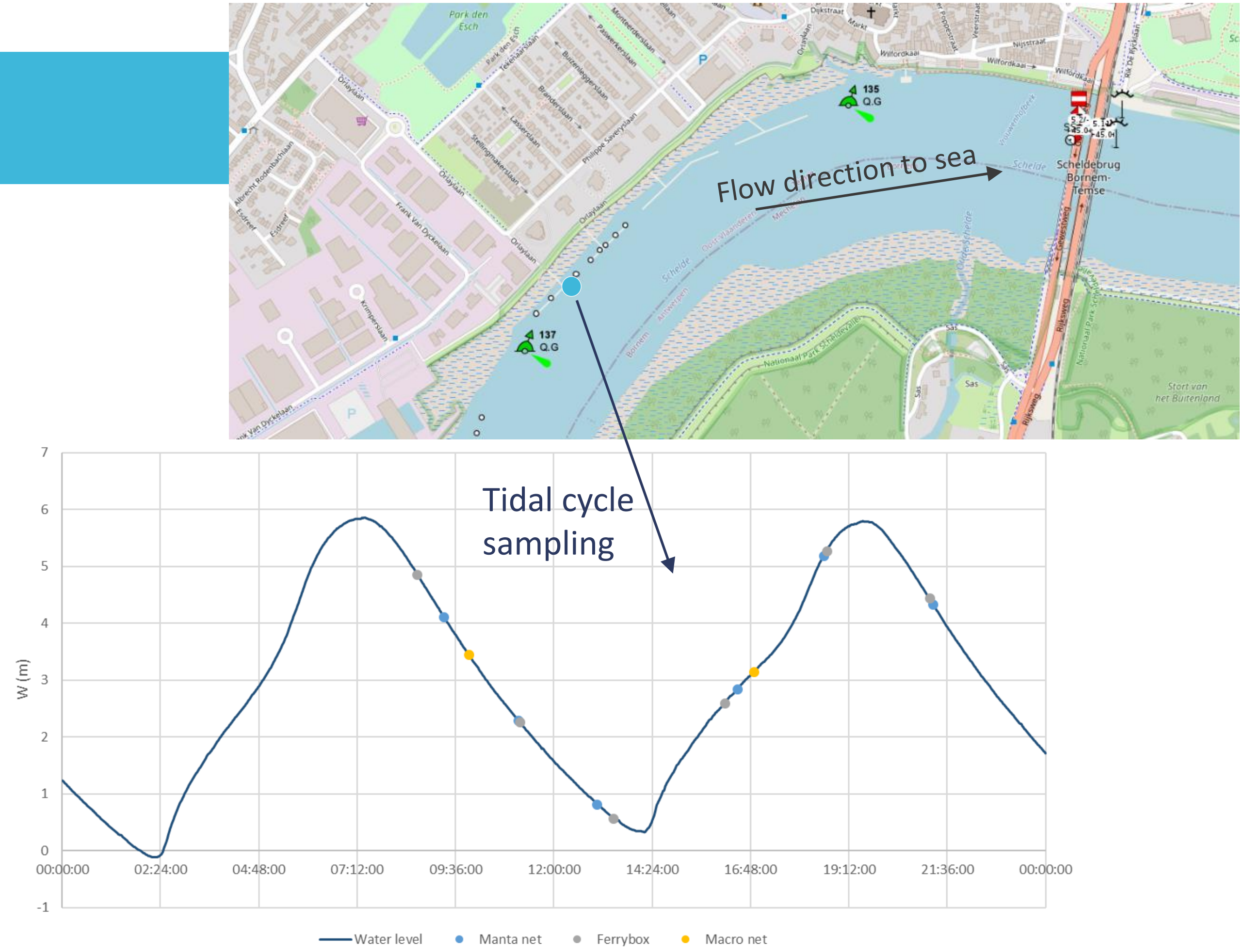
Types of sampling



Doeldok (Port of Antwerp)



Tidal cycle sampling in Temse (Scheldt River) on 7th August 2024

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Types of sampling

- Defined frequency (monitoring) e.g., seasonal sampling – Baseline pollution levels

Temse (Scheldt River)

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Types of sampling

- Litter removal solutions impact on pollution levels

Before deployment of solution

After deployment of solution

FishFlow INNOVATIONS

Archimedean Drum Screen in the Port of Oostende (BE)

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Water surface: Manta net

1. Rinsing materials with the river water and collecting blank samples

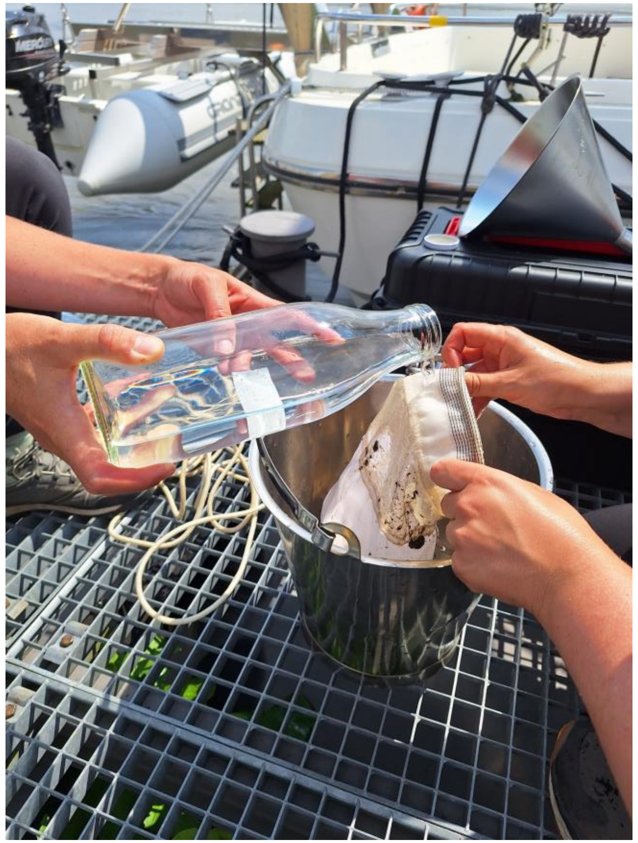
Photograph by Mattias B.

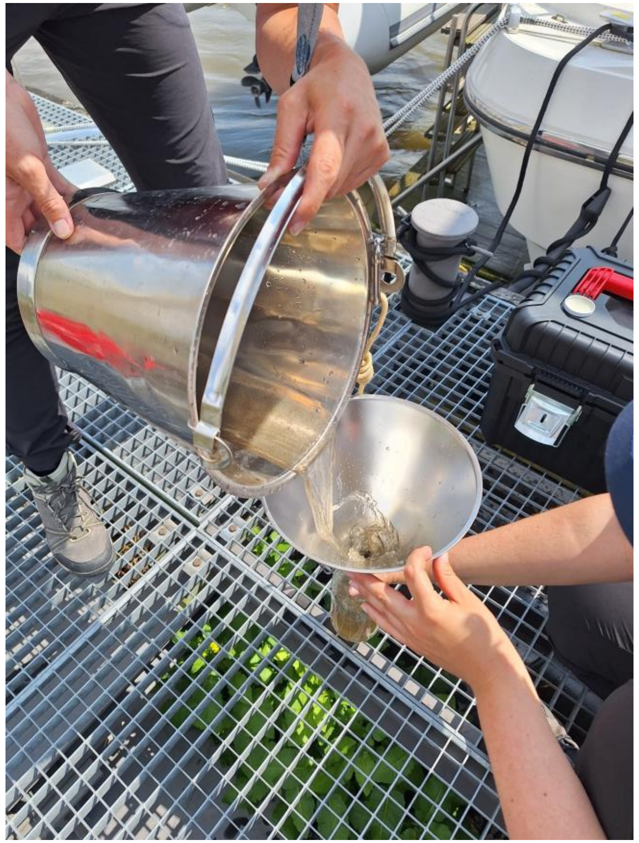
2. Recording flowmeter value and deploying of the Manta net (e.g., 200 µm) for the desired time (1-10 min) or transect

Net-end where the microlitter ≥ 200 µm is collected

Water surface: Manta net

3. Recording flowmeter value and collecting the litter inside the net end





4. Sample storage in the cold until laboratory processing and analysis

Photographs by
Mattias B.

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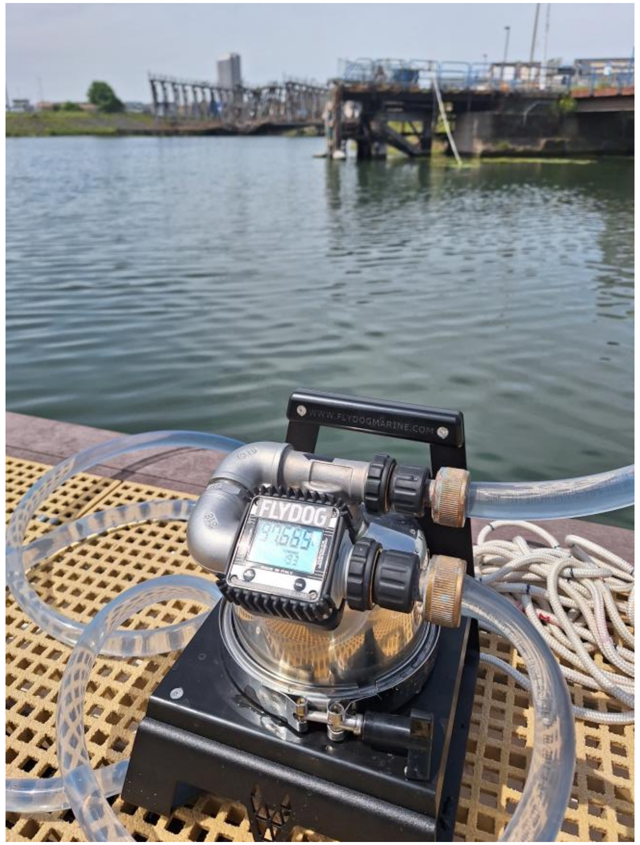
Water column: Ferrybox sampling device



Ferrybox inlet: river water
at desired depth or below vessel

MPs	TWPs
1 mm	200 µm
200 µm	50 µm
50 µm	25 µm

Volume filtered and flow rate (≈ 20 L/min) are measured

Ferrybox outlet: filtered water
- released back to the river
- TWL sample
- TWPs fraction 2 (< 25 µm)

Photograph by Mattias B.

The Ferrybox sampling device can be connected to a submersible pump or a pumping system available in a research vessel.

Different combinations of sieves mesh sizes can be used. In INSPIRE/VLIZ: 25 µm, 50 µm, 100 µm, 200 µm, 300 µm, 500 µm, 1 mm

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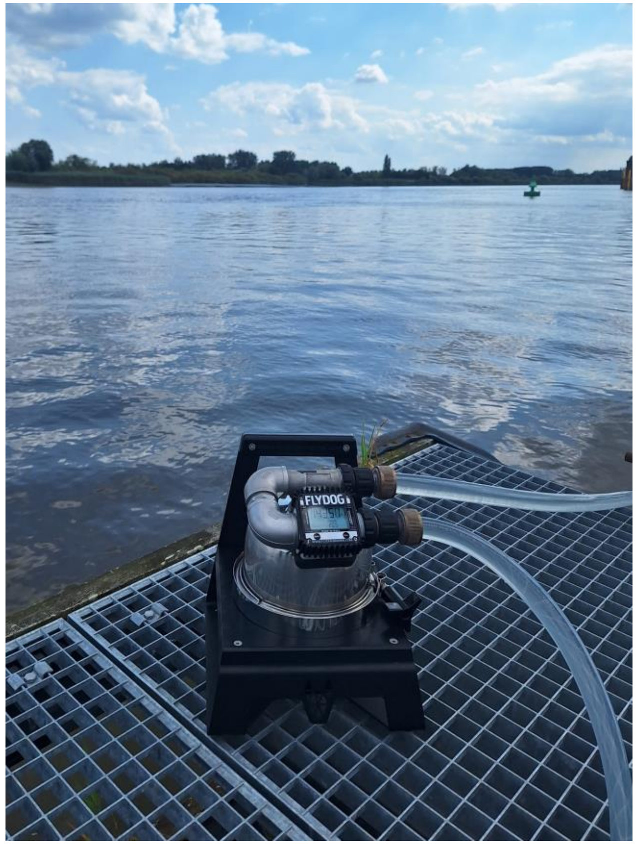
Water column: Ferrybox sampling device

1. Rinsing materials with the ultrapure water (or river water for the tubing and pump) and collecting blank samples

2. Turning on the underwater pump for the desired time (usually 10 min for > 200 µm). At 5 min, we collect water samples from the ferrybox outlet



Water column: Ferrybox sampling device

3. Turning off the pump and recording volume filtered. Opening the ferrybox and collecting the litter on the selected sieves
4. Sample storage in the cold until laboratory processing and analysis

Photograph by Mattias B.

Photograph by Mattias B.

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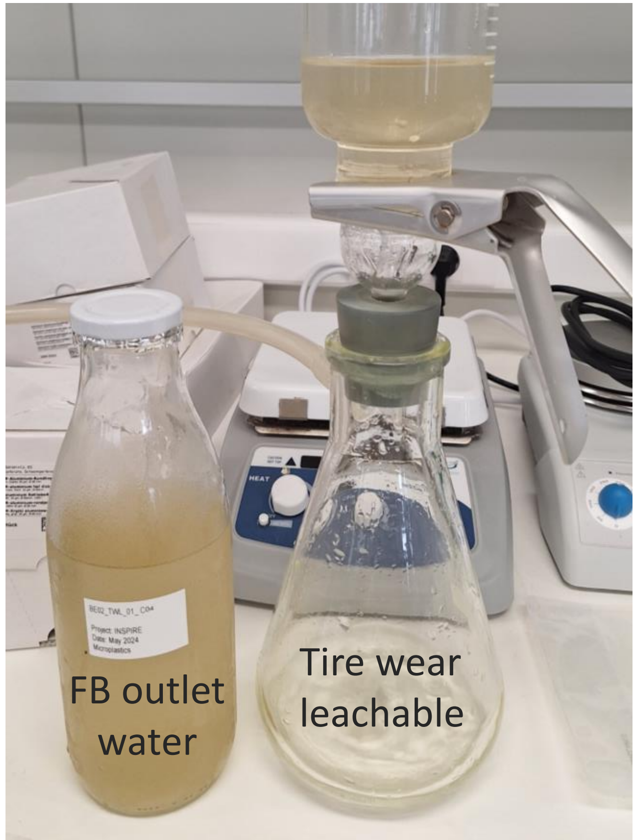
Water samples processing and analysis at the laboratory: tire wear

HOCHSCHULE FRESENIUS
UNIVERSITY OF APPLIED SCIENCES



Vacuum filtration with 0.2 µm 47 mm cellulose acetate membrane filters

↓

16 chemical marker compounds for tire wear analyzed in the filtered water by SPE & LC-MS/MS (MRM)

Main outputs:
µg/L for each compound compounds detected

1. Two step vacuum filtration to obtain two TWP fractions:
   1. ≥ 25 µm
   2. > 0.02 µm and < 25 µm
2. Sample preparation
3. TWP analysis using:
   - ICP-MS – Zn
   - LC-MS/MS (MRM) – extractable organic tire wear markers

Main outputs:
TWPs in mg/L or mg/kg based on conversion factors

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Water samples processing and analysis at the laboratory: microplastics

Processing in four steps:

1. Digestion with 10% KOH (48 h, 50 °C, 150 rpm)
2. Digestion with ≈16% H_2O_2 (48 h, 50 °C, 150 rpm)
3. (Optional) Density separation with NaI
4. Filtration and staining with Nile red

Meyers, N.; Bouwens, J.; Catarino, A.I.; De Witte, B.; Everaert, G. (2024). Extraction of microplastics from marine seawater samples followed by Nile red staining, ***in***: De Witte, B. *et al. ANDROMEDA portfolio of microplastics analyses protocols.* pp. 35-45 (Open Access)

Analysis in two steps:

1. Fluorescence (stereo)microscope
2. µFTIR

Meyers, N.; De Witte, B.; Catarino, A. I.; Everaert, G. (2024). Automated microplastic analysis: Nile red staining and random forest modelling. ***in:*** De Witte, B. et al. ANDROMEDA portfolio of microplastics analyses protocols. pp. 69-84 (Open Access)

Main outputs:
particles/L
characteristics of the particles

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Sediment (riverbanks or bottom of river channel)

Photograph by Mattias B.

River channel: Van Veen grab (from pontoon)

River channel: Van Veen grab (from vessel)

Riverbank: with metal shovel/spade

Processing in three steps:

1. Density separation with NaI (3x) (72 h)
2. Digestion with 10% H_2O_2 (1 week)
3. Filtration and staining with Nile red

Meyers, N.; De Witte, B.; Catarino, A.I.; Everaert, G. (2024). Extraction of microplastics from marine sediment samples followed by Nile red staining, ***in:*** De Witte, B. et al. ANDROMEDA portfolio of microplastics analyses protocols. pp. 46-55 (Open Access)

Analysis in two steps:

1. Fluorescence (stereo)microscope
2. µFTIR

Main outputs:
particles/g & characteristics of the particles

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Riverbanks: quadrat sampling in transects (bigger micro- and mesolitter)

1. Placing the transect (e.g., 30 m) on the selected location on the riverbank for the litter observations

2. Placing three quadrats (20 x 20 cm) at beginning, middle and end of transect. Collecting the litter ≥ 1 mm, down to 5 cm depth

Photograph by Ana C.

Riverbanks: quadrat sampling in transects

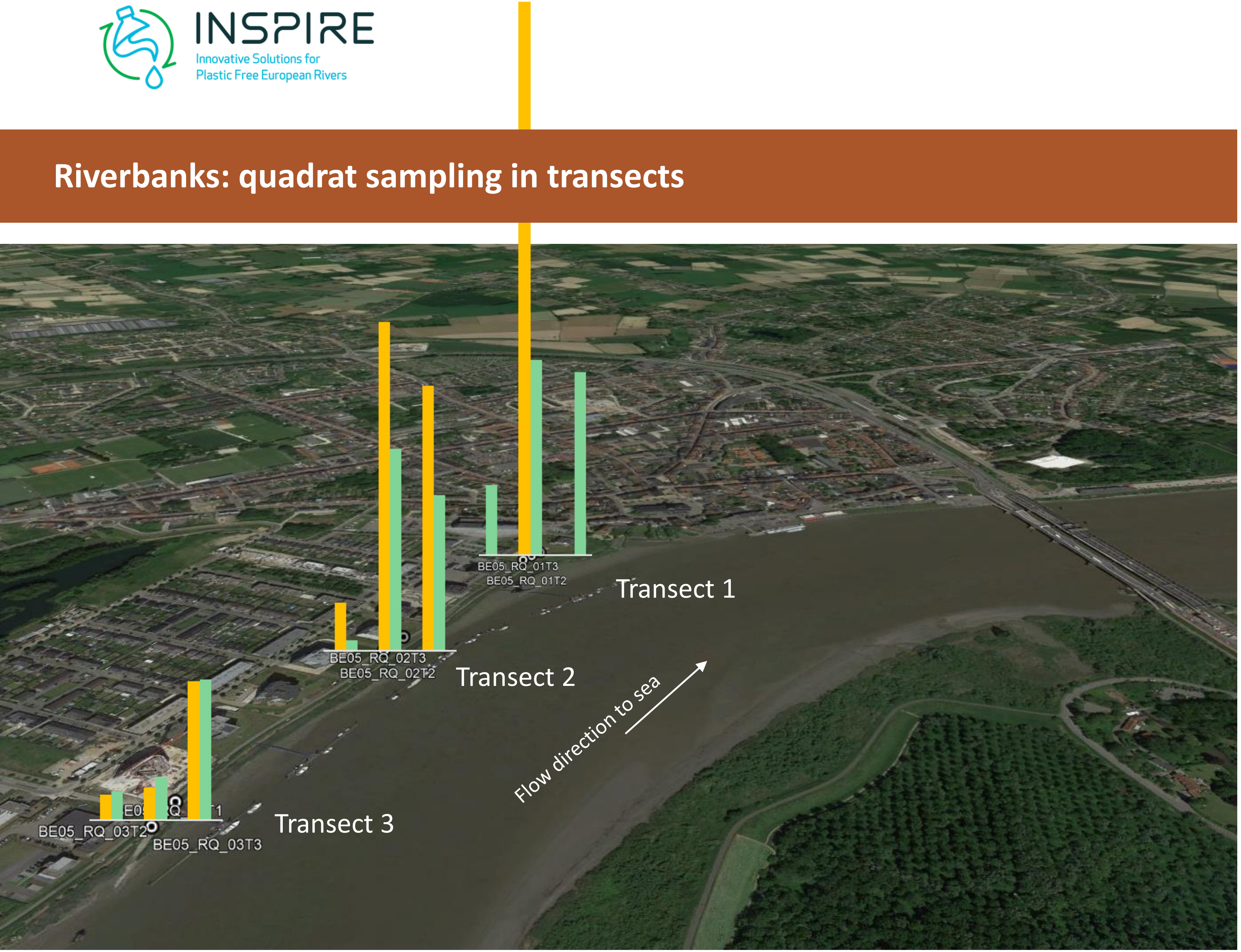
Example of quadrat BE10_RQ_02T2 (Summer sampling campaign in Temse) in the field (left) and after cleaning (right).

3. Storing the samples in a dry place until further processing. The samples should be cleaned, place in one or more Petri dishes and dried as soon as possible.

4. Separation of macrolitter (> 2.5 cm) items from meso- and bigger microlitter. Weighting the total fractions and counting the number of items.

5. Characterization of the items by size, shape, colour, transparency, and material (ATR-FTIR).

Riverbanks: quadrat sampling in transects



Spring (June)

Summer (September)

Preliminary data (number of particles) for litter in quadrats (20x20 cm) in Temse:

- #Spring = [6 , 113]
- #Summer = [14 , 309]*
  (*two quadrats not yet analysed for transect 1)

Outputs:

- Distribution and quantification of pollution levels (particles/m^2)
- Seasonality
- Characteristics (e.g., sizes and polymers found at the locations)
- Link to the sources of the pollution

Take away messages

- Different sampling methods are available for the different environmental compartments and that can be used for riverine environments, such as:
  - Manta net
  - Ferrybox sampling device
  - Van Veen grab
  - Sediment scoop
  - Quadrats

- The same detection technologies can be used for different types of sampling campaigns, allowing to meet different goals and monitoring/research needs.

- Need to collect all data and metadata following a uniform template and guidelines, allowing for comparability between sampling campaigns performed in different countries.

Litter on the Rhine banks in Londenhaven (Rotterdam). Photograph by Mattias B.

Microlitter particle collected in Temse under the fluorescent microscope. Photograph by Juliette G.

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Thanks to the collaboration with the FRE team: Luca Muth and Stephan Wagner

Special thanks to the VLIZ plastic team: Ana Catarino, Giulia Leone, Julie Muyle, Juliette Grandjean, Mattias Bossaer, Nelle Meyers, Therese Nitschke

Londenhaven (Port of Rotterdam) VLIZ team

Temse (Scheldt) Summer tidal cycle team

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2021 2030 United Nations Decade of Ocean Science for Sustainable Development

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Camera and drones for macrolitter observations

- Liesbeth De Keukelaere - VITO, Belgium
- Bio-science engineer specialized in soil and water management (KU Leuven, Belgium)
- Researcher at VITO Remote Sensing for aquatic applications
- INSPIRE: tracking macrolitter pollution in rivers and river banks using bridge mounted cameras and drones

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INSPIRE – Fixed camera and drone observations for macrolitter monitoring

Innovative Solutions for Plastic Free European Rivers (2023-2027)

Liesbeth De Keukelaere (VITO, BE)

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Litter pollution in rivers

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Macrolitter monitoring

Fixed cameras on bridges
Floating

Drone observations
Riverbank

Smartphone apps
Floating/riverbank

Clean-up activities
Riverbank

Macroplastic samples (subsets)
Floating/Riverbank/ Water column

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Macrolitter monitoring

Fixed cameras on bridges
Floating

Drone observations
Riverbank

Smartphone apps
Floating/riverbank

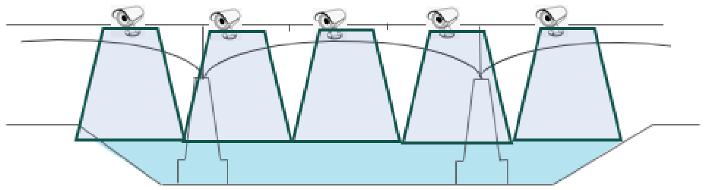
Clean-up activities
Riverbank

Macroplastic samples (subsets)
Floating/Riverbank/ Water column

Fixed cameras

AIM

Obtain information of the amount of plastic passing in the river (# items/unit of time). Baseline monitoring and changes over time and space.



METHODOLOGY

Data

- Cameras mounted under bridge
- Long term monitoring
- Remote control
- NRT Data transfer

Processing

- Convolutional Neural Network for object detection
- Towards flux via similarity metrics between objects based on features extracted from foundation models.

Outcome

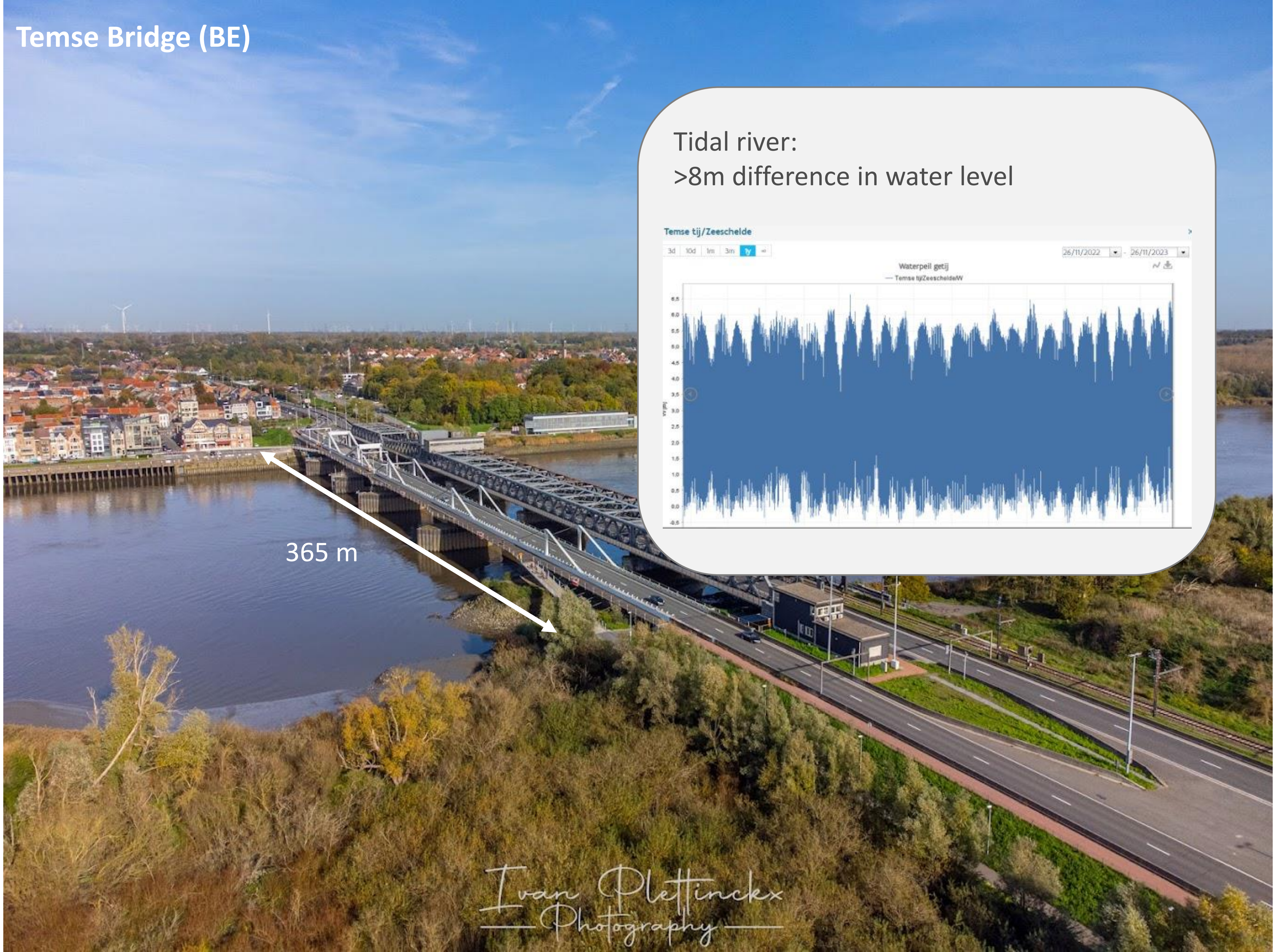
- Baseline monitoring
- Long-term monitoring to detect trends and changes
- Detect hotspots where most plastics passes
- Improve waste management practices


Temse Bridge (BE)
Ivan Plettinckx
Photography

Temse Bridge (BE)

Temse Bridge (BE)

Tidal river:
>8m difference in water level

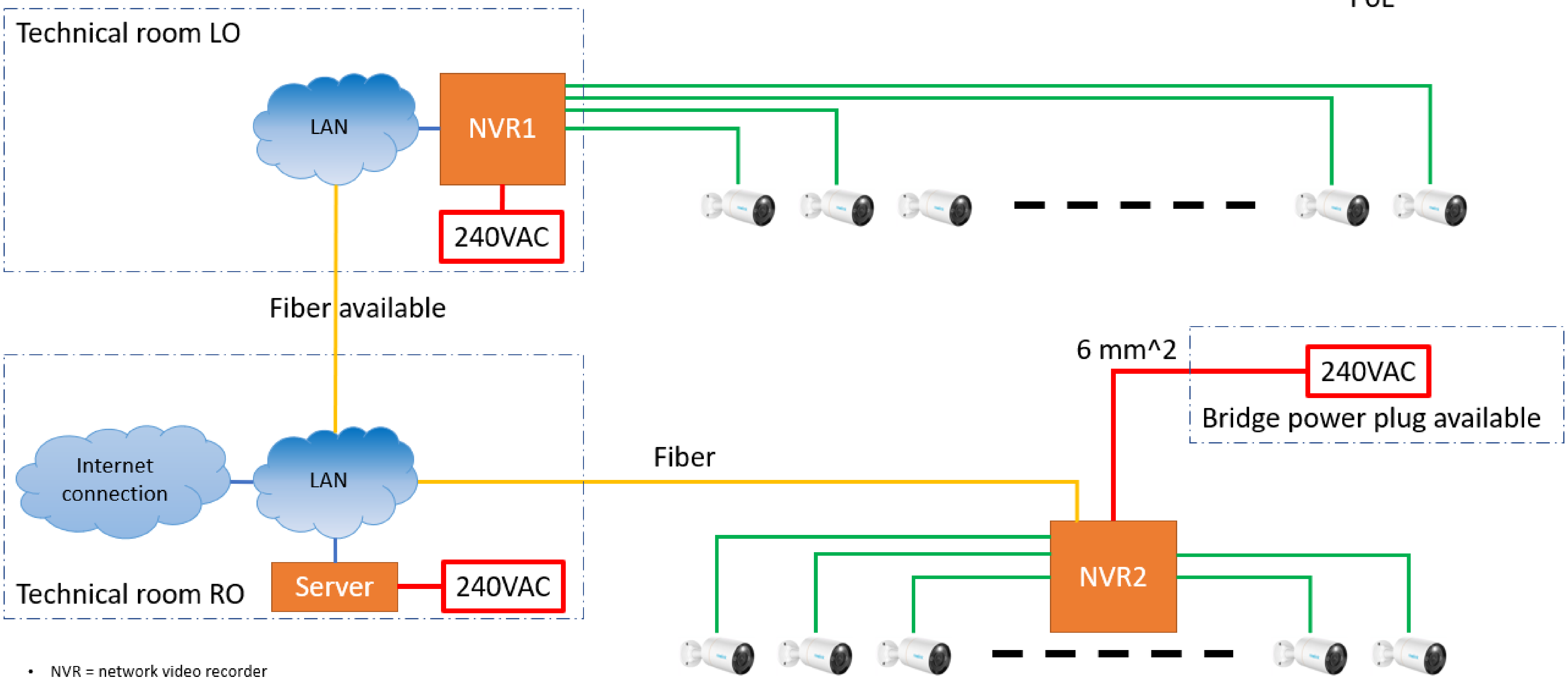


Temse Bridge (BE)

- 22 camera's installed :
  - 21 pointed to water
  - 1 pointed to sky (horizontal view)

Operational since 22 Aug 2024

Connection overview



- NVR = network video recorder
- PoE = power over ethernet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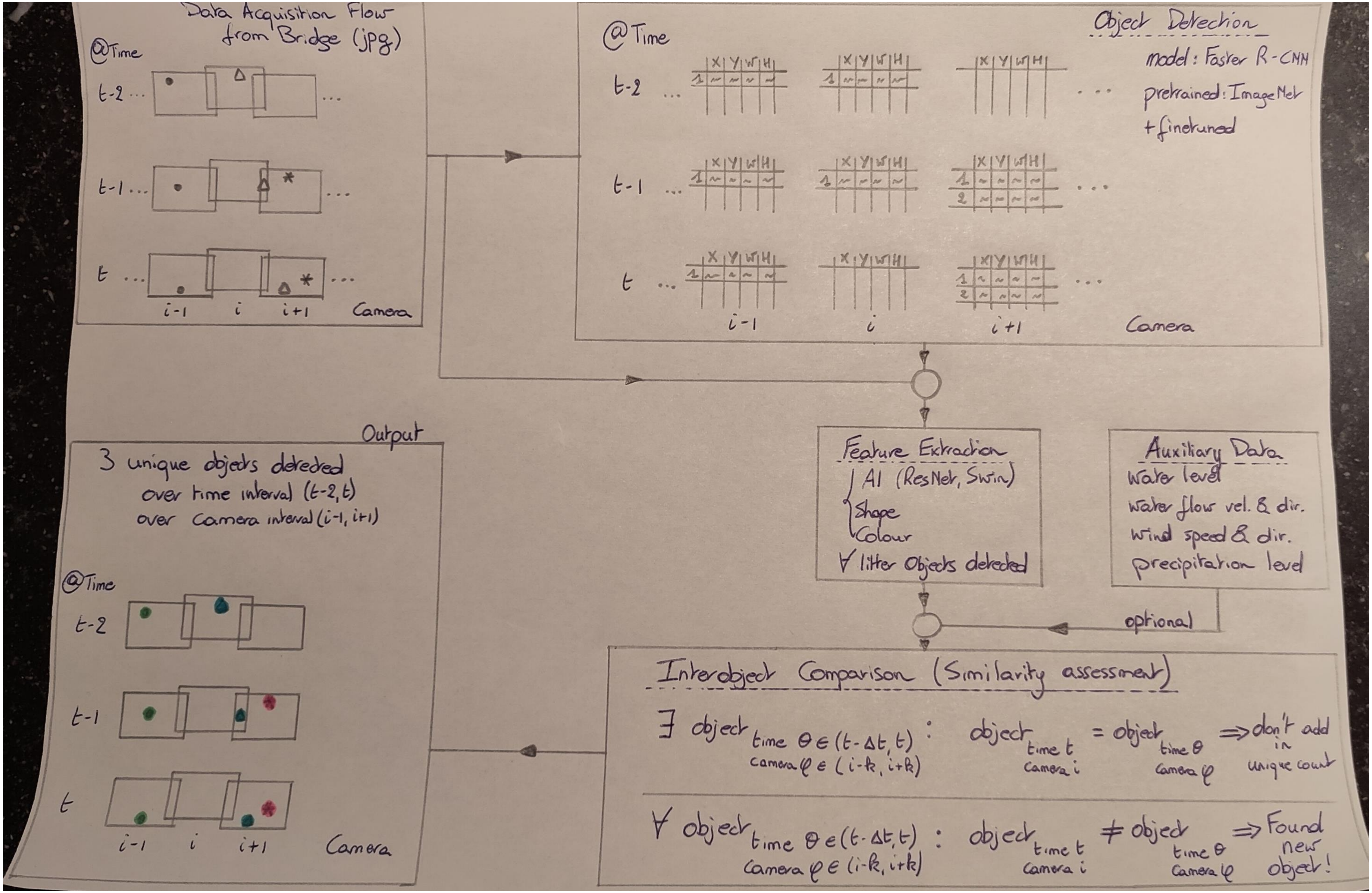
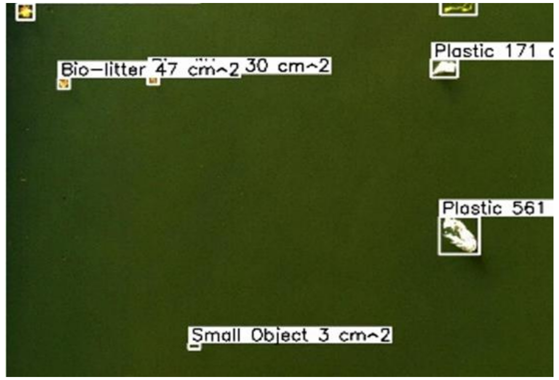

Data Acquisition Flow from Bridge (jpg)
@Time
t-2
t-1
t
i-1
i
i+1
Camera
Object Detection
model: Faster R-CNN
pretrained: ImageNet
+ finetuned
X Y W H
Feature Extraction
AI (ResNet, Swin)
Shape
Colour
∀ litter Objects detected
Auxiliary Data
water level
water flow vel. & dir.
wind speed & dir.
precipitation level
optional
Interobject Comparison (Similarity assessment)
∃ object time θ ∈ (t-Δt, t) camera φ ∈ (i-k, i+k) : object time t camera i = object time θ camera φ ⇒ don't add in unique count
∀ object time θ ∈ (t-Δt, t) camera φ ∈ (i-k, i+k) : object time t camera i ≠ object time θ camera φ ⇒ Found new object!
Output
3 unique objects detected
over time interval (t-2, t)
over camera interval (i-1, i+1)

Fixed cameras

OUTCOME

1. Object detection
- Plastics vs organic matter/ plastic categories
- Item size



2. Object identification: recognize same item in different images

3. Plastic flux: # items / time / river section

Drones

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AIM

Derive maps showing geospatial locations of plastic debris and densities.

METHODOLOGY

Data
- Drone flights
- Operated by citizens or experts

Processing
- MAPEO drone processing software for georeferencing
- Training of AI model for different backgrounds and plastic types.
- Classification and object detection

Outcome
- Baseline monitoring
- Plastic hotspot maps
- Suggest focus areas for dedicated clean-up activities

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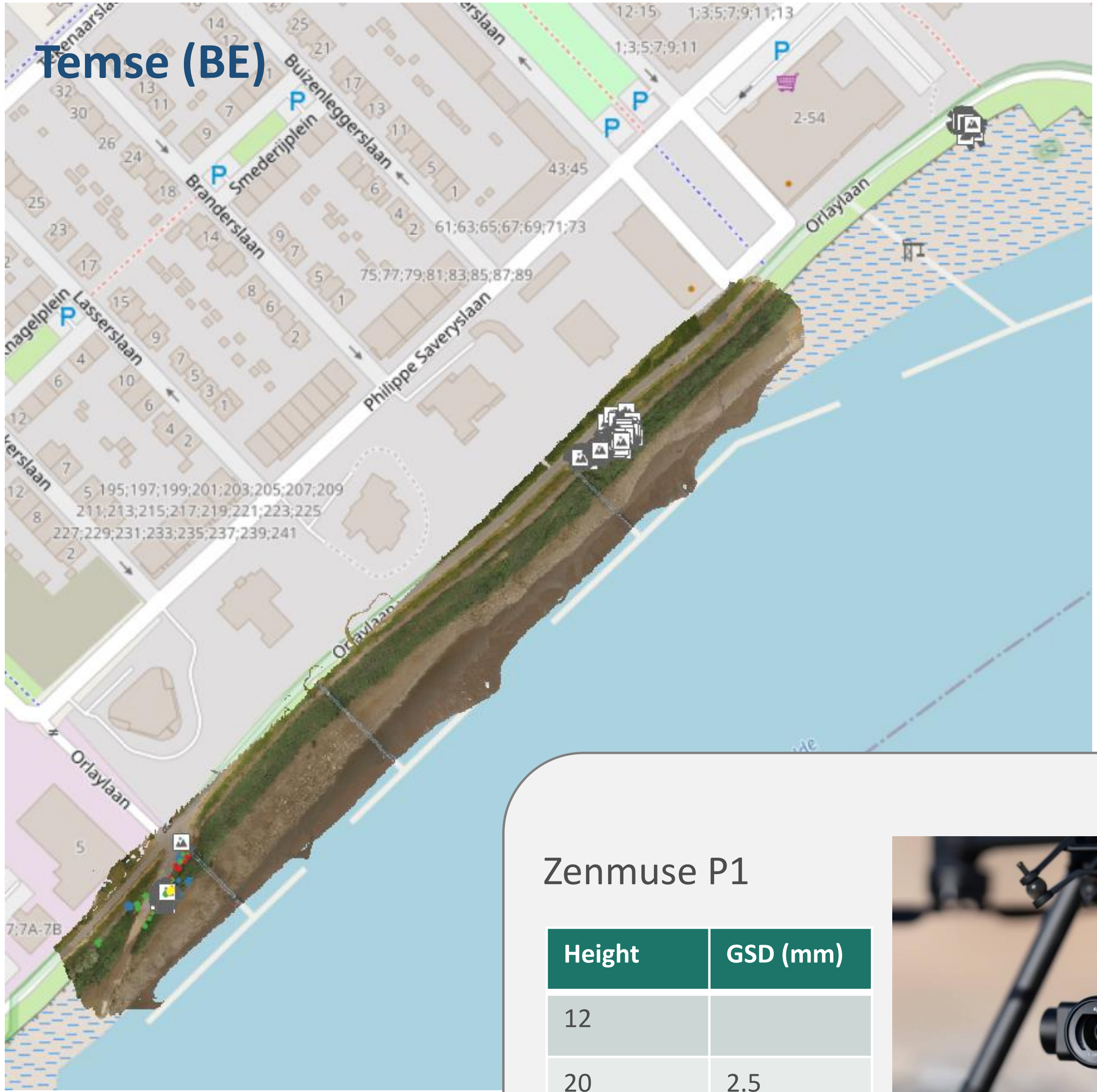
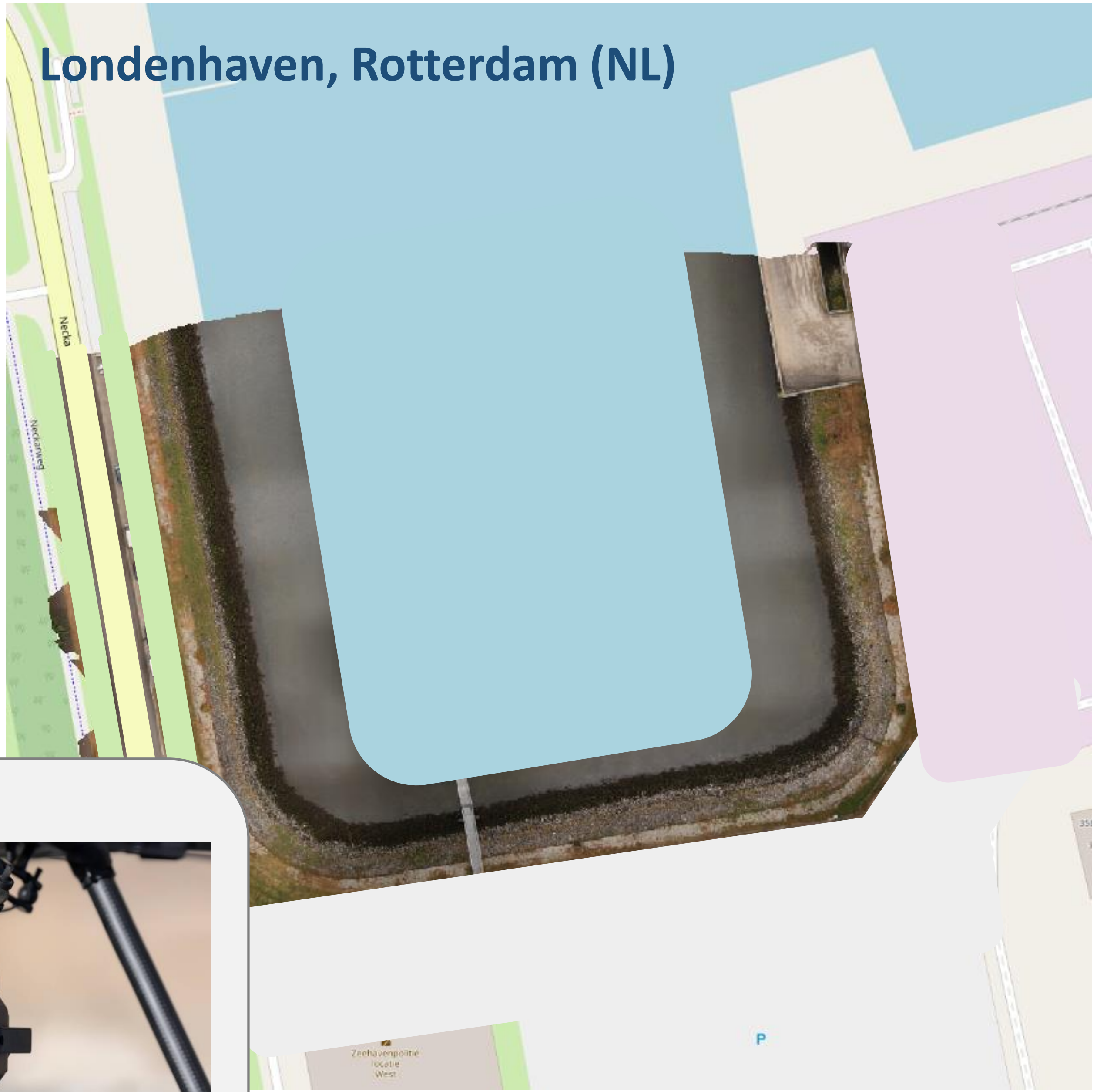
Temse (BE)



Londenhaven, Rotterdam (NL)



Zenmuse P1

Height	GSD (mm)
12	
20	2.5
50	

Drones

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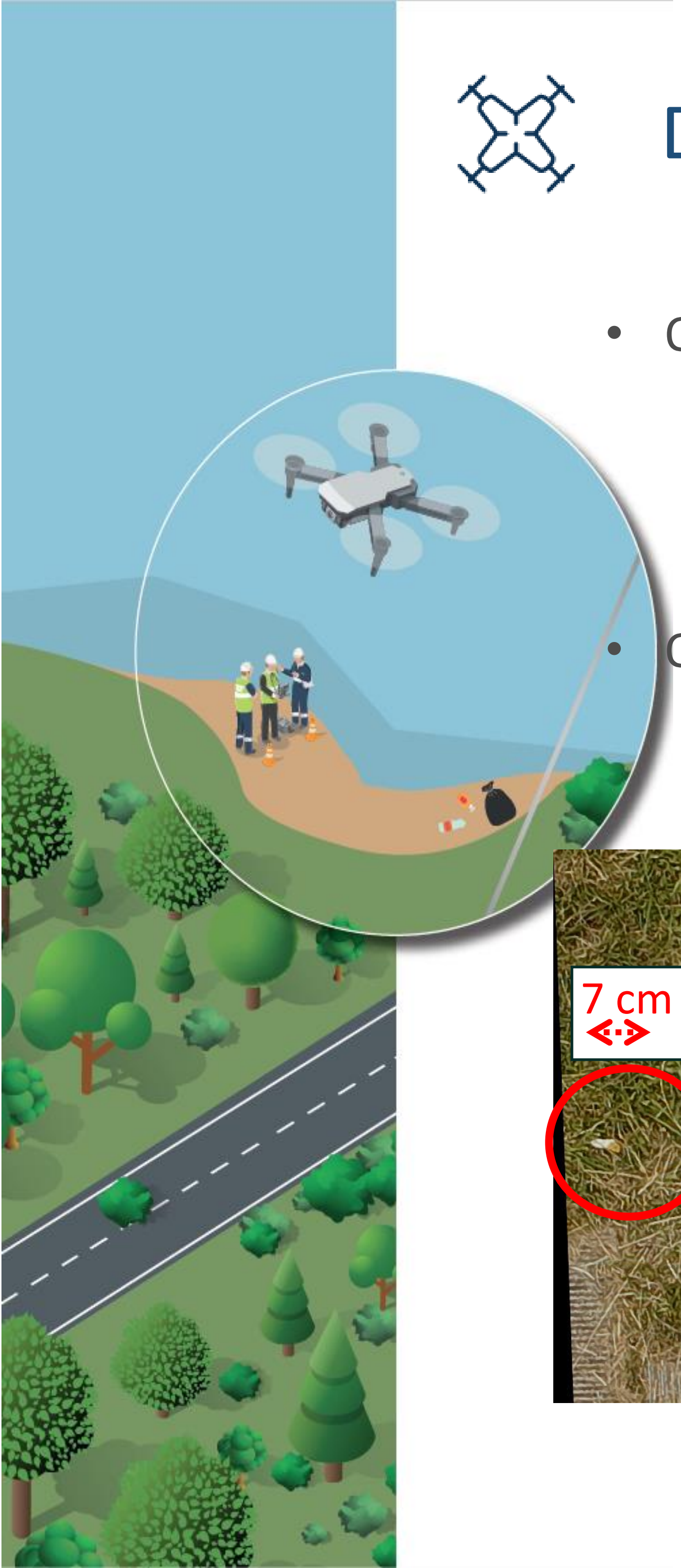

- Original Images
  - Different backgrounds
  - Different Litter (Type, Color, Shape, Size)
  - Obstruction by leaves, rocks,…
- Objects in the order of cm (Tiles are $1m^2$)

Drones

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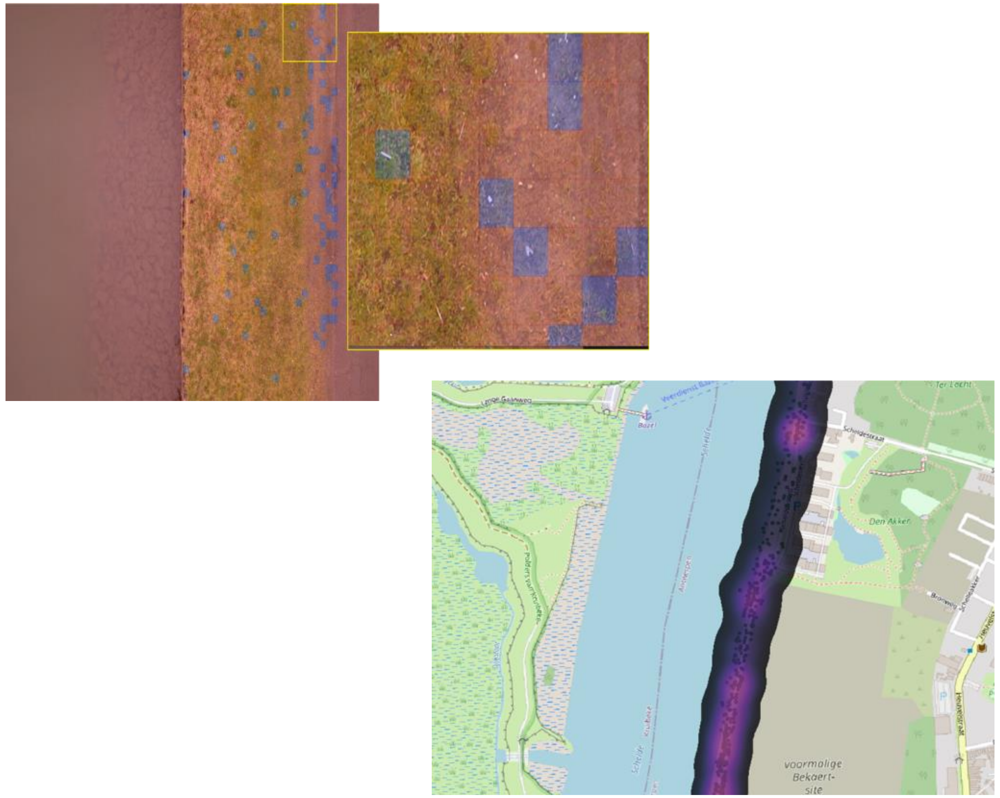
OUTCOMES

1. Plastic object identification

2. Plastic hotspot



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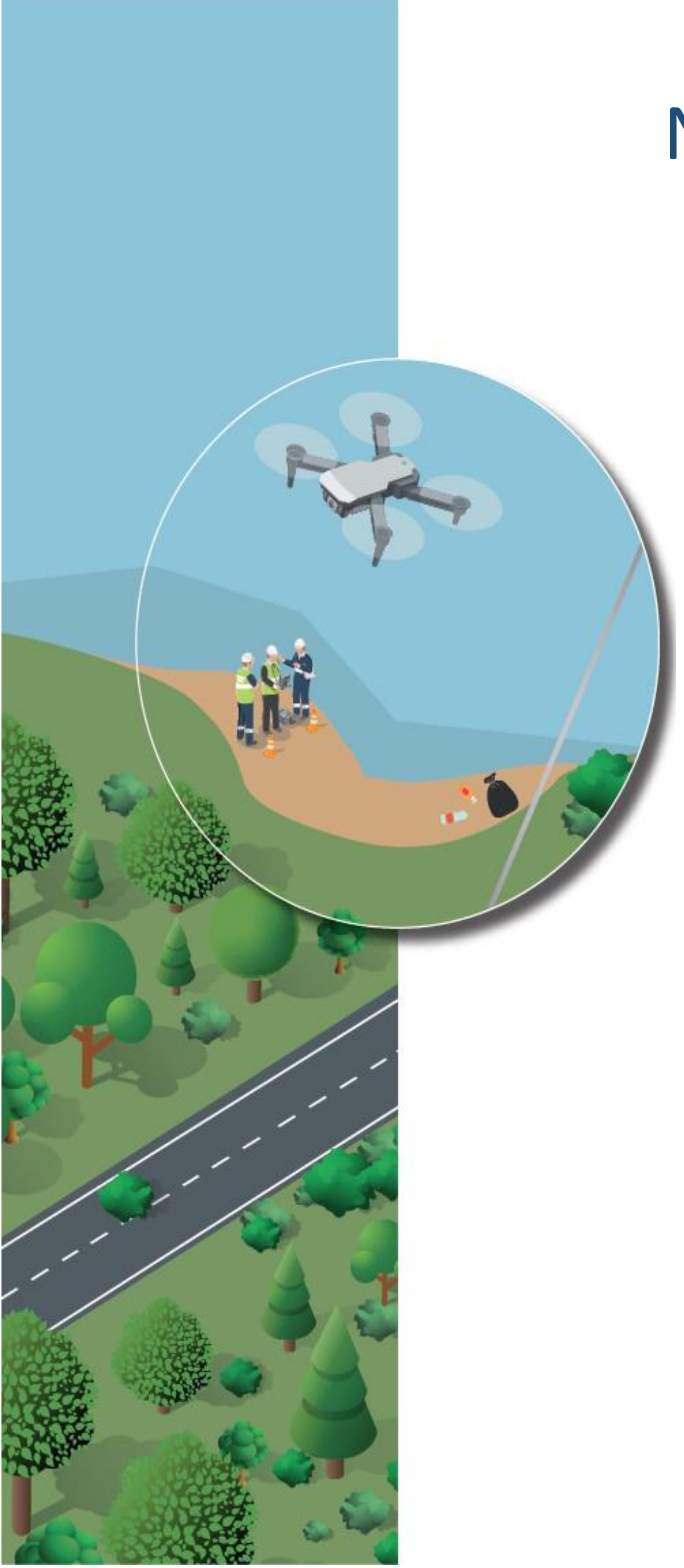

Next steps

<u>Camera</u>:

- Data analysis: How we notice any patterns (tides, weather, inner vs outer bend, …)

- Validate the system true release-catch experiments

- Install a camera system in the Po-river.

<u>Drones</u>

- Seasonal data collection in Temse and 4 flights in Rotterdam

- Data analysis

Thank you!

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Data flow from observations to modelling

- Miranda Stibora - WUR, Netherlands
- MSc Climate Studies, MSc Ecology and Conservation (WUR, Netherlands) specialized in water quality modelling and assessing the effect of management changes to water quality in the Netherlands
- PhD researcher (WUR, Netherlands)
- INSPIRE: development of plastic transport and accumulation model

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INSPIRE data flow from observations to modelling

Innovative Solutions for Plastic Free European Rivers (2023-2027)

Miranda Stibora (WUR, NL)

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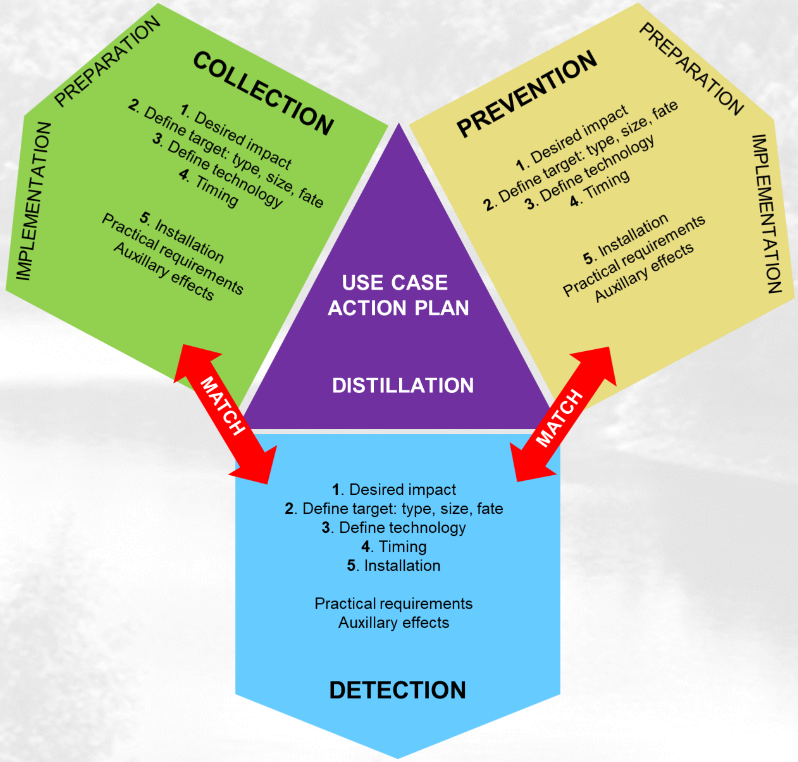
Our role in the INSPIRE project



Our role in the INSPIRE project

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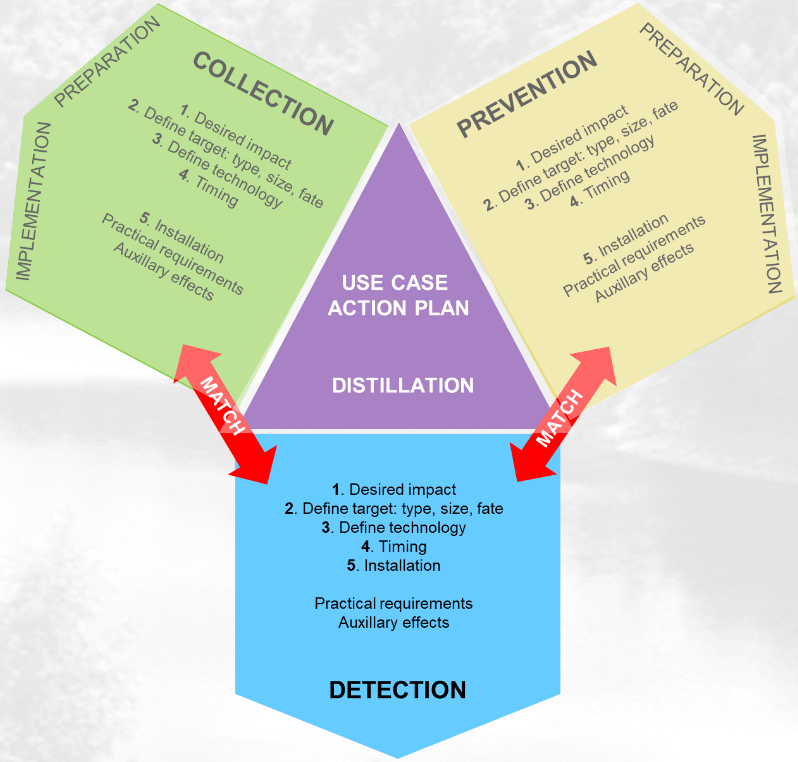
Our role in the INSPIRE project

Observations

Modelling

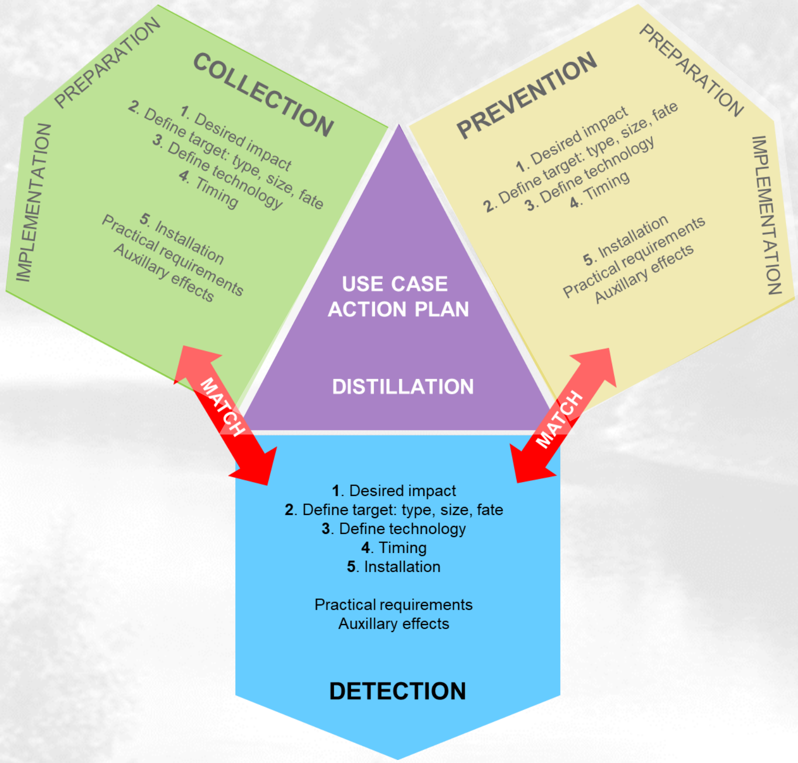


Our role in the INSPIRE project

Observations

1. Riverine litter database (RLDB)
2. Data collected by INSPIRE partners

Modelling



Revise large scale models for plastic transport accumulation in Europe

- An estimate of the exported and accumulated plastic in European rivers
- *Model type*: Spatially probabilistic model
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Hydrological models for plastic transport and accumulation for 6 river case studies

- Provide spatially and temporally explicit plastic transport models
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Why use large scale spatially probabilistic models?

1. Understand the key processes which govern plastic **transport** and **accumulation**

2. Quantify plastic pollution in river basins using field measurements and extrapolate this to data scarce river basins

3. Assess future scenarios of plastic pollution

4. Guide effective and tailored mitigation management practices

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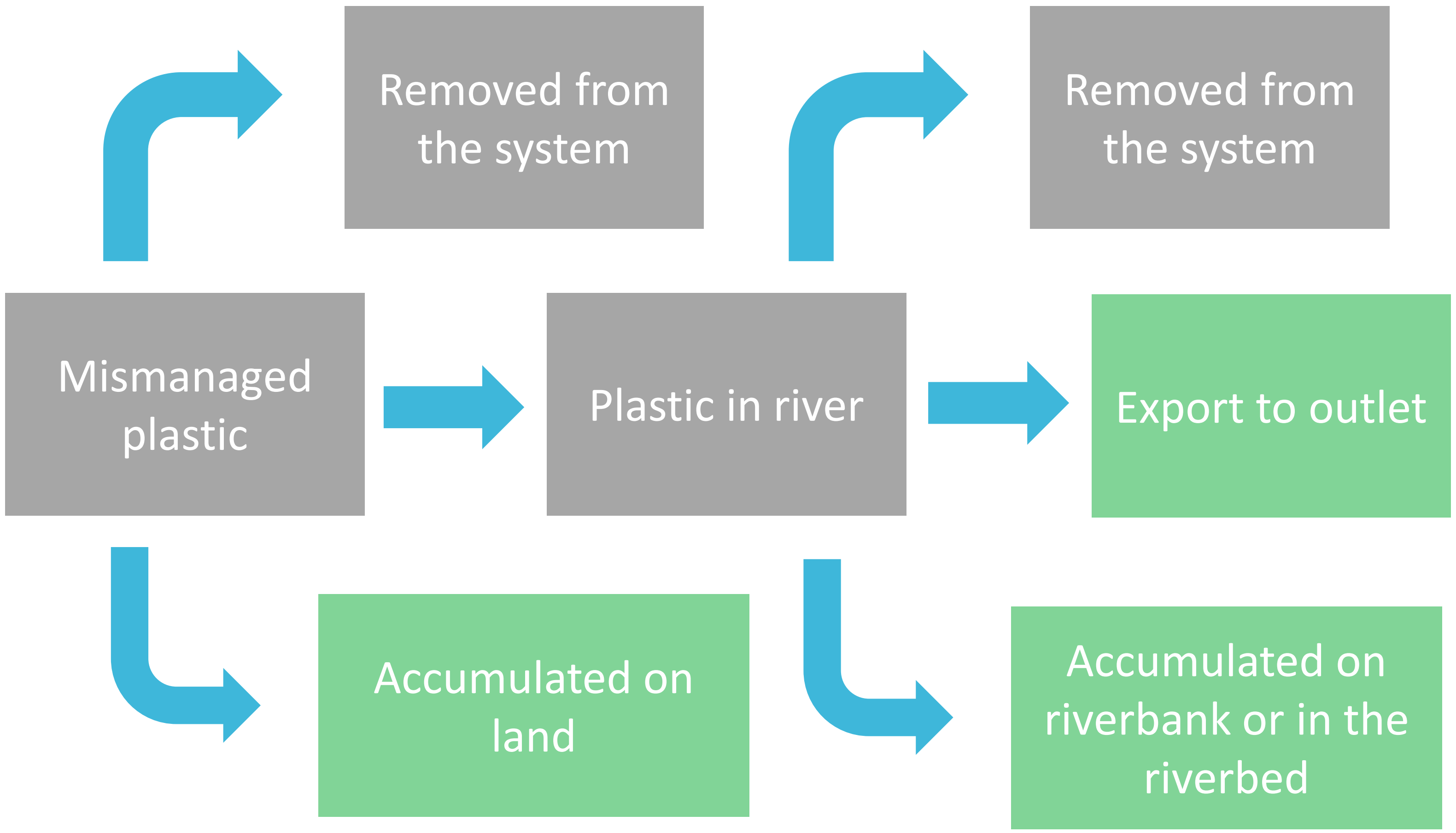
Model framework



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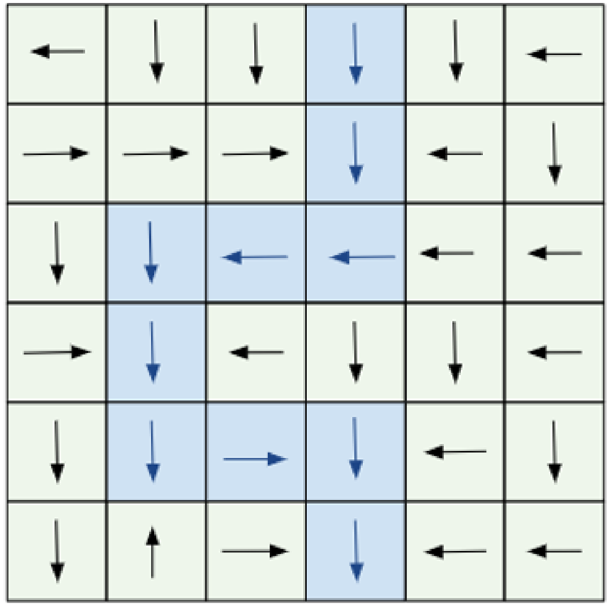

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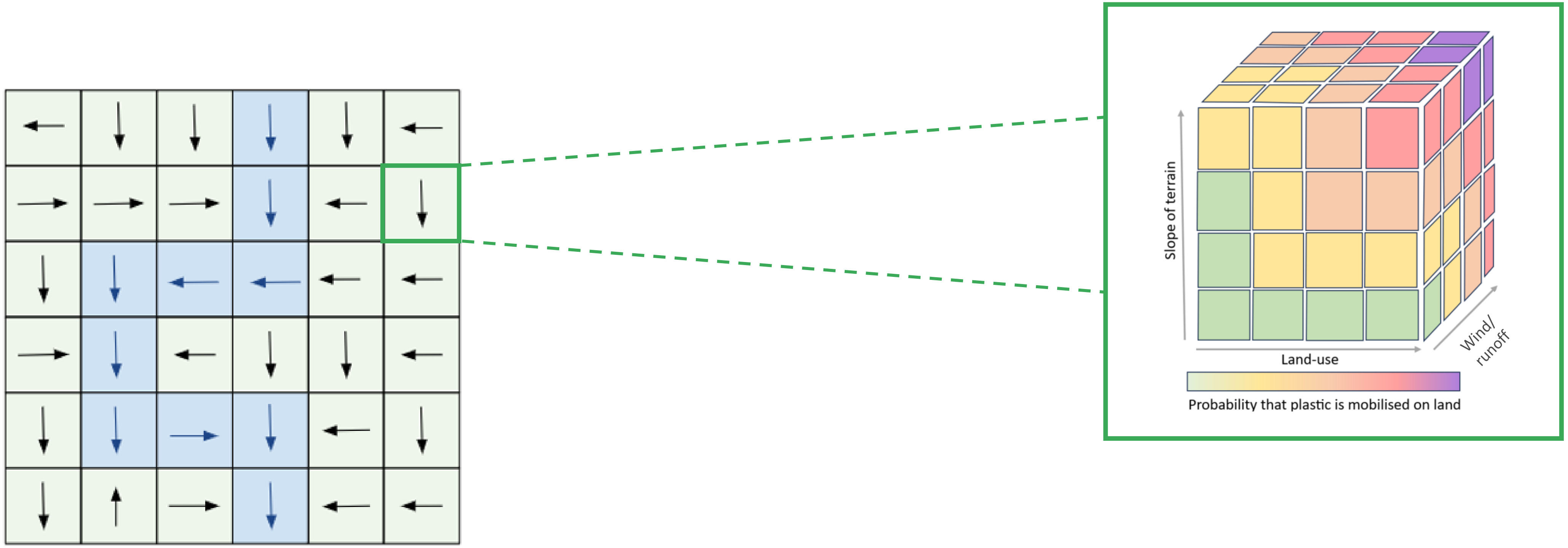

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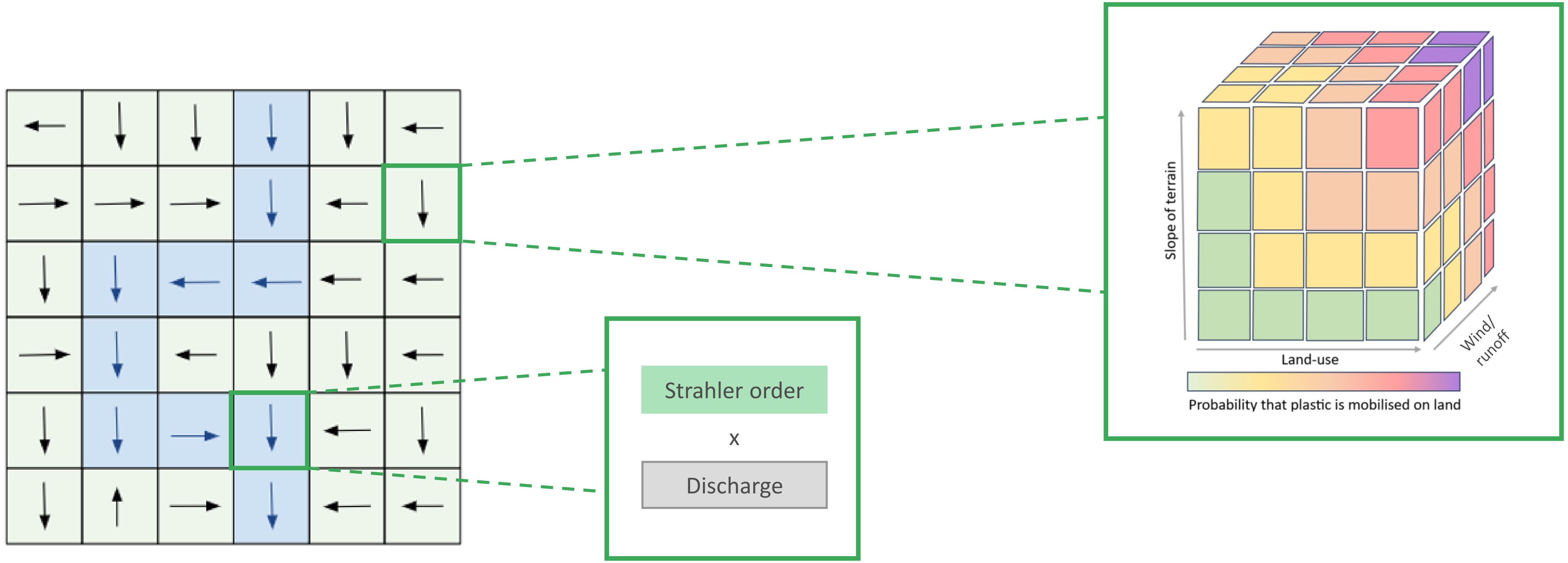
Model framework



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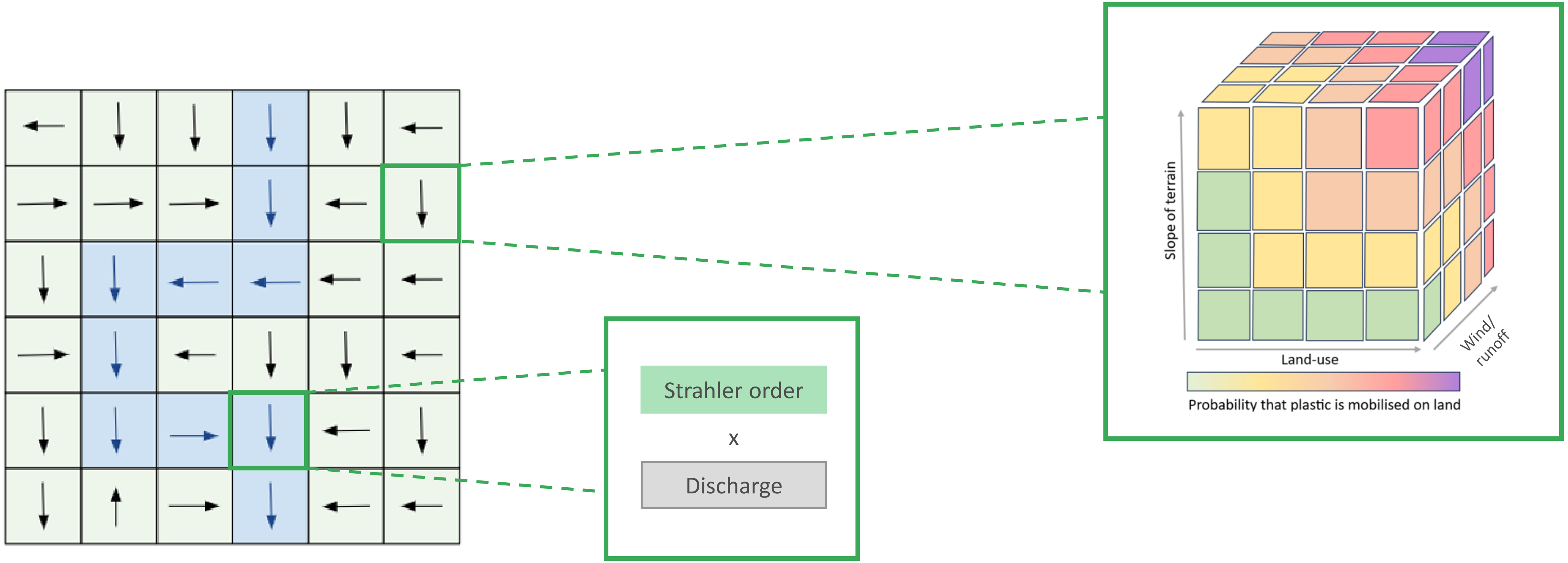

Open source

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Model calibration

Riverine Litter Database (RLDB)

1st Round: Model calibration
2nd Round: Model validation

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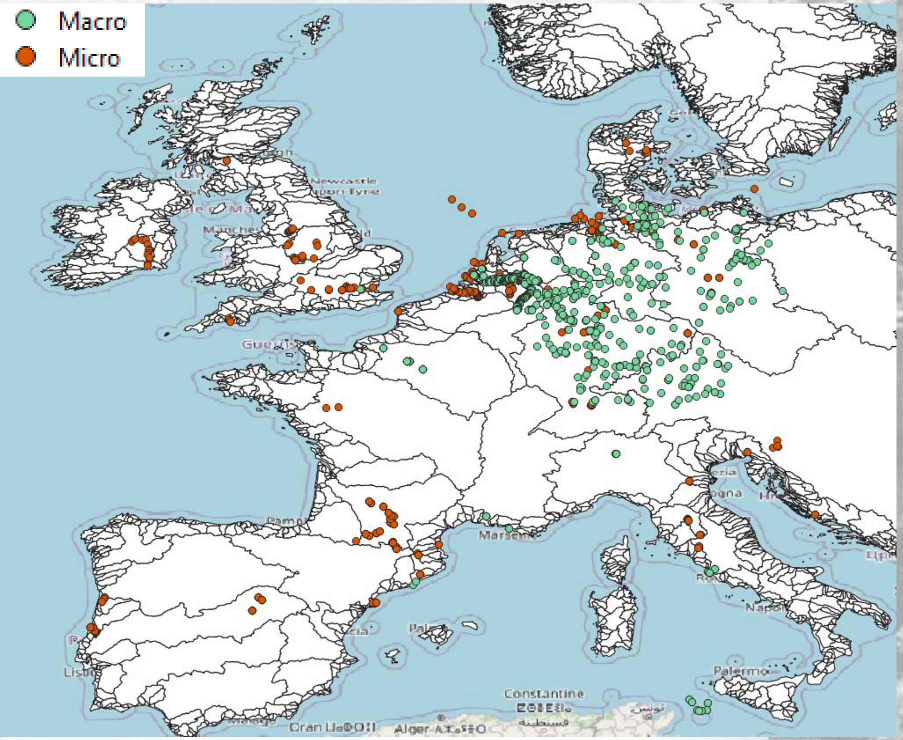

Based on the 1st round of the RLDB

Europe	Surface	Water column	River bed sediment	River bank sediment
103	71	21	21	15

Model calibration

Riverine Litter Database (RLDB)

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Data harmonization

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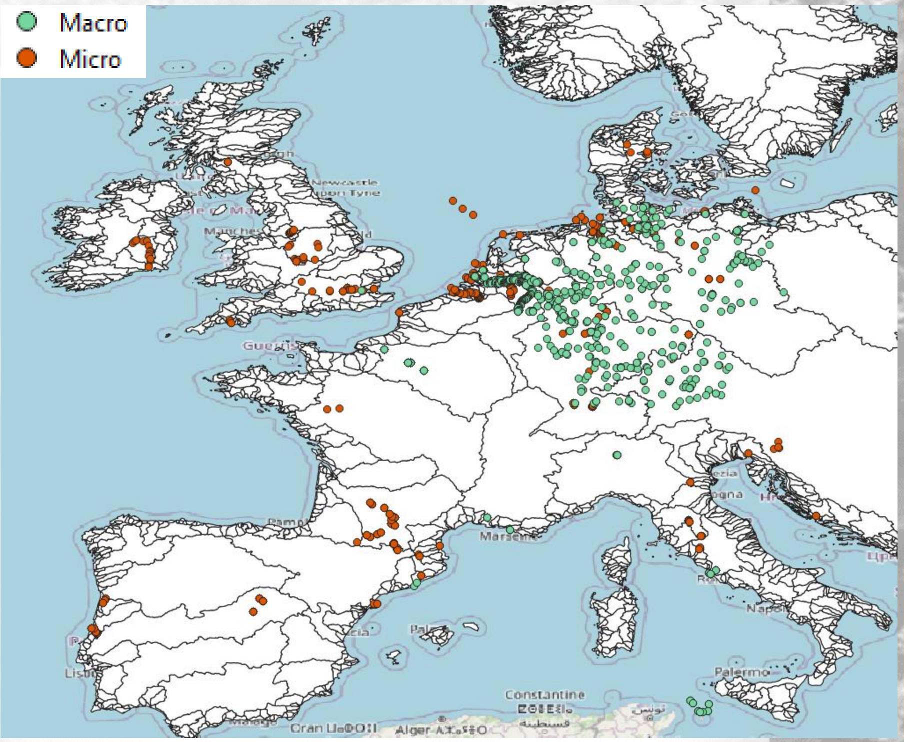

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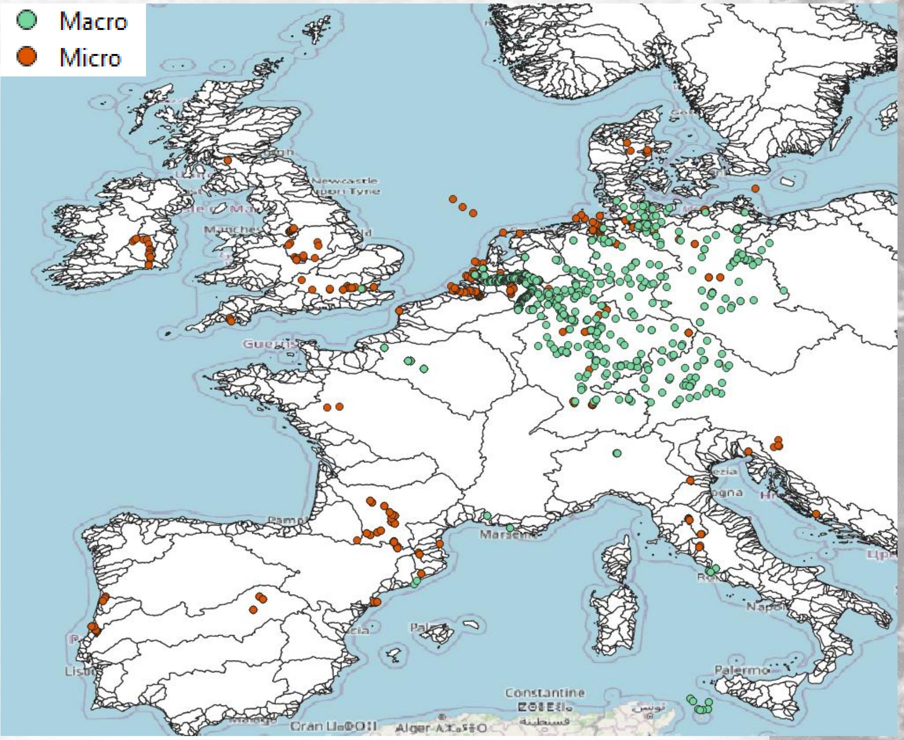

Based on the 1st round of the RLDB

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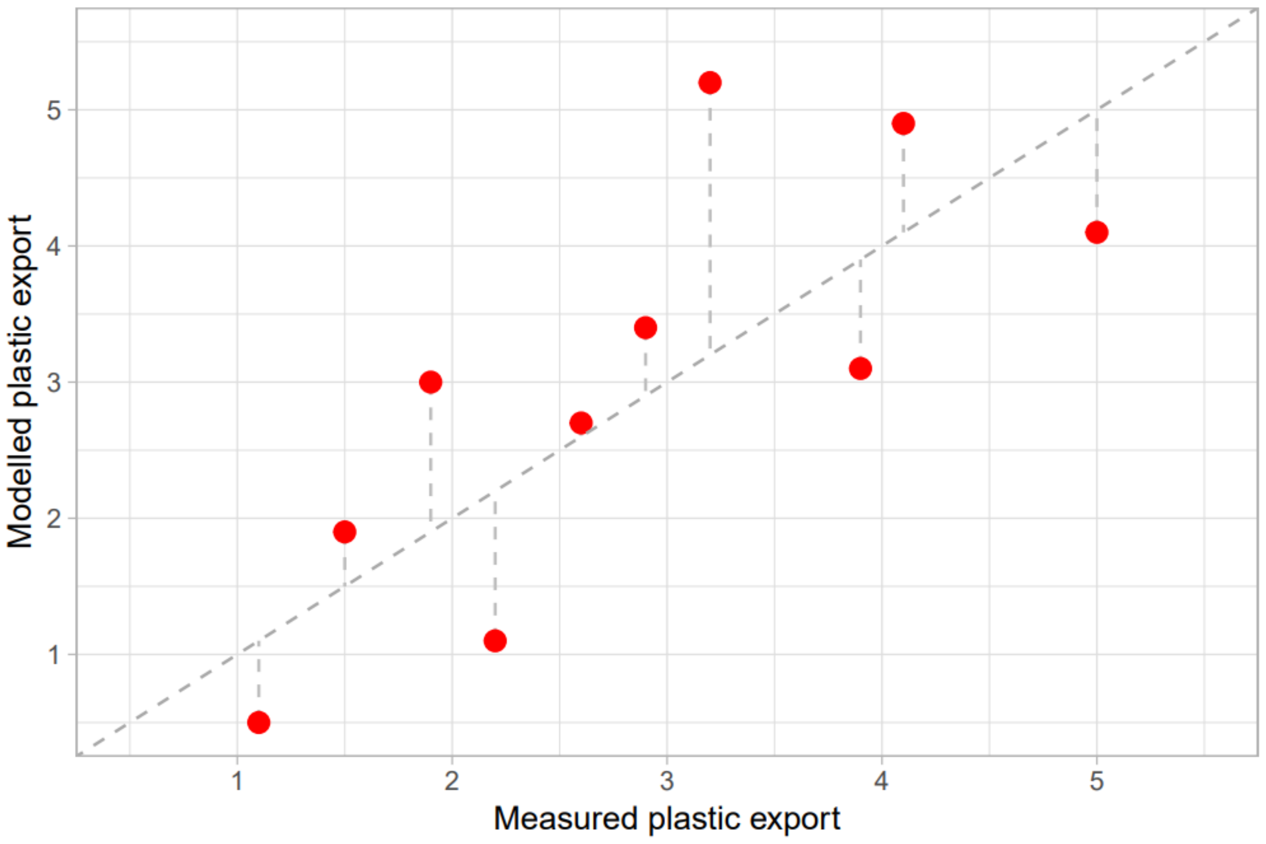
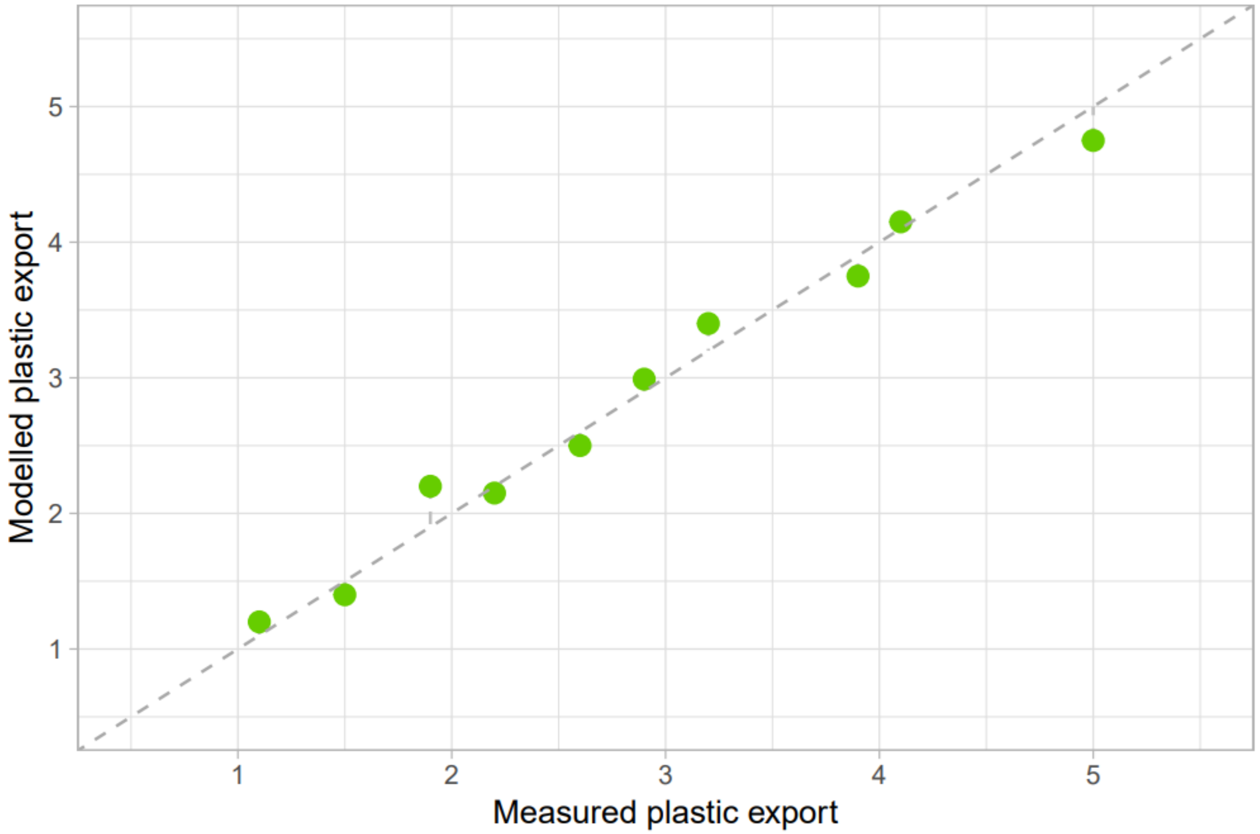
Model calibration: plastic export



Performance metric: R^2

modelled plastic export = f(measured plastic export)

Model calibration: plastic export



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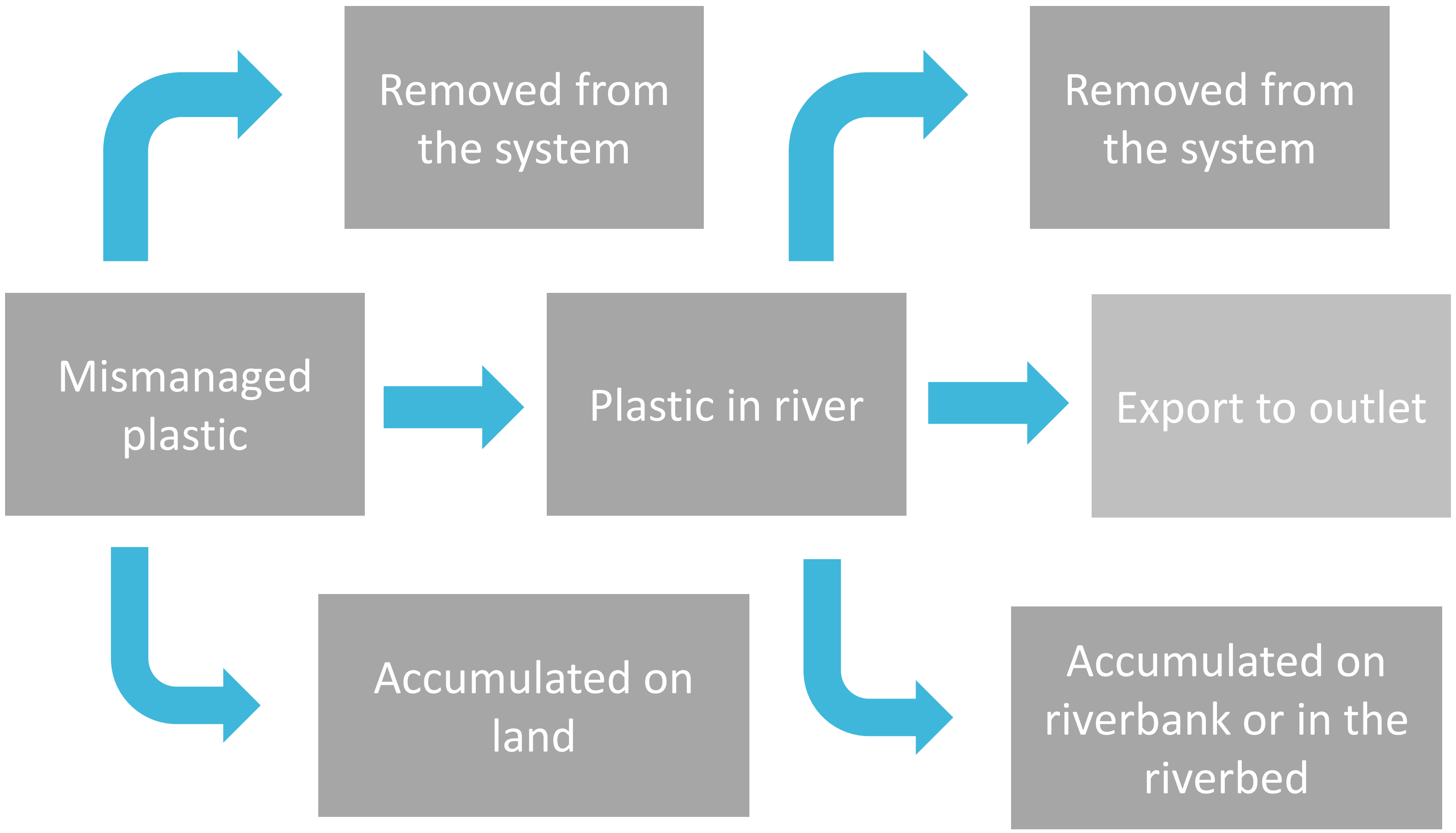

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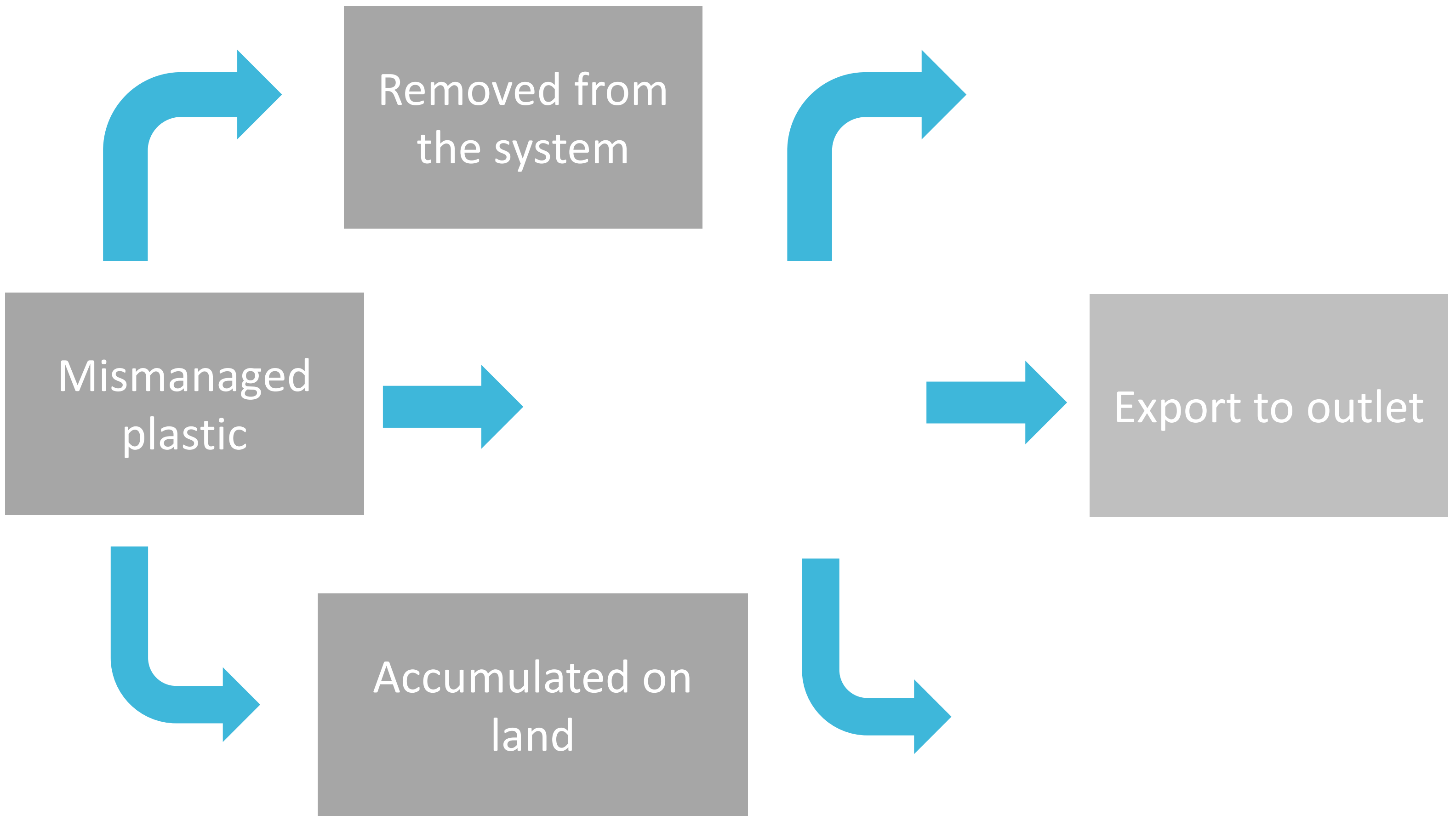
Model framework



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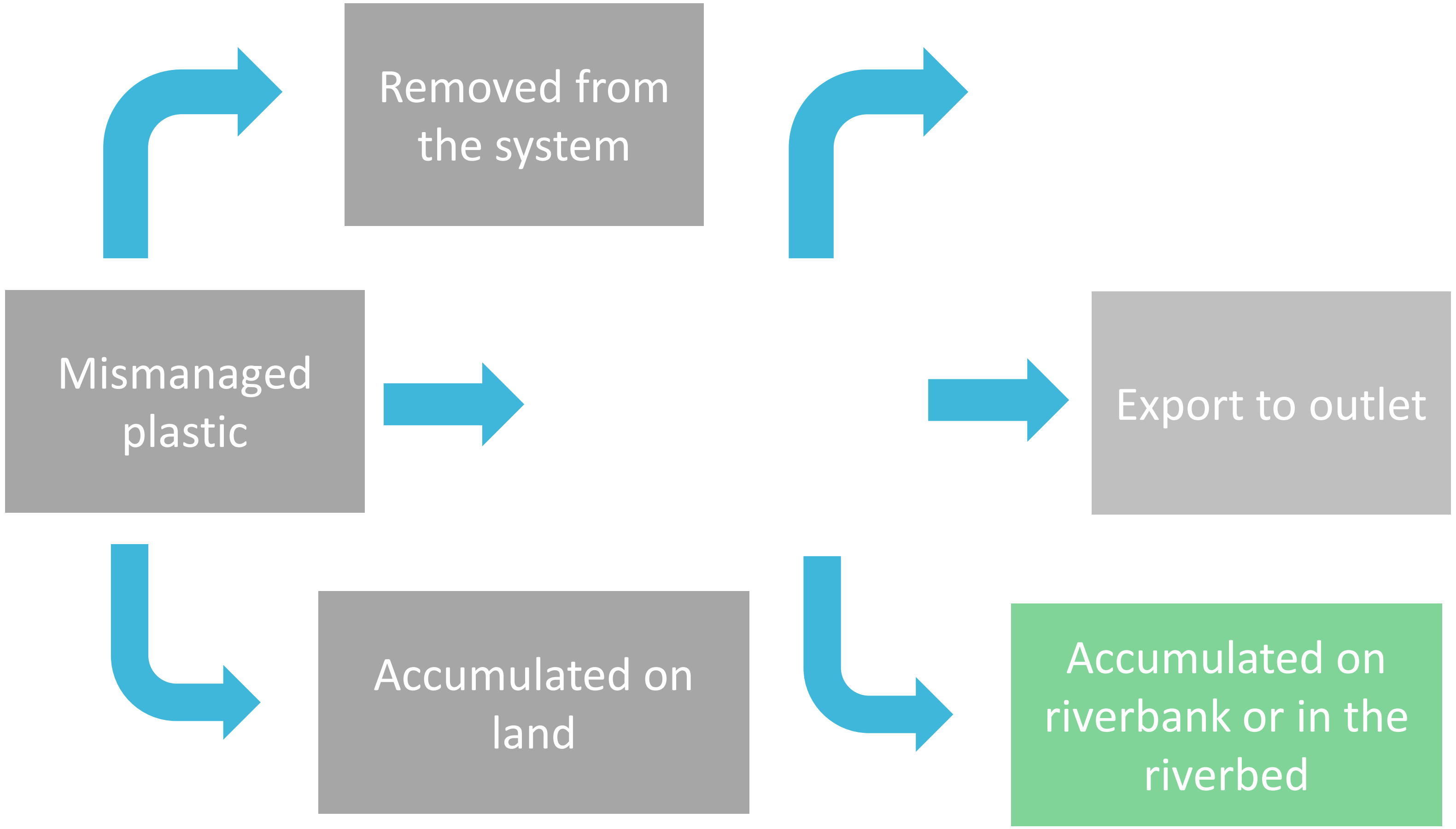

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Model calibration: riverbed and riverbank sediment

Compartment	River bed sediment	River bank sediment
Percentage	?	?

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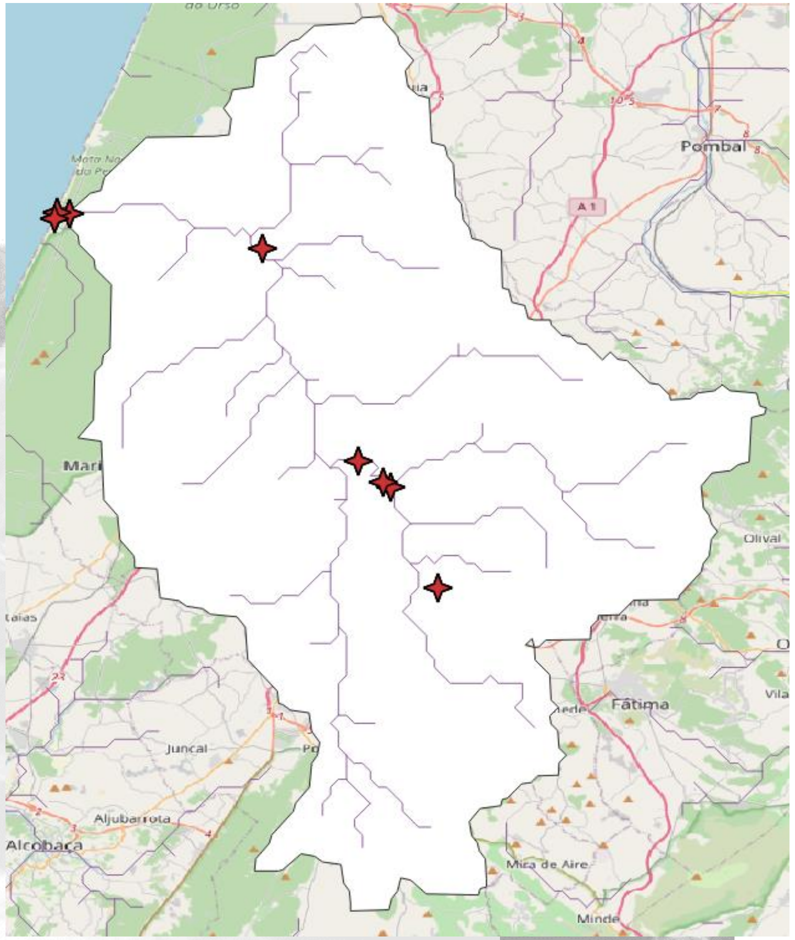
Model calibration: riverbed and riverbank sediment

Compartment	River bed sediment	River bank sediment
Percentage	?	?

Example: Riverbank data (macroplastics)



River basin: Lis (Portugal)

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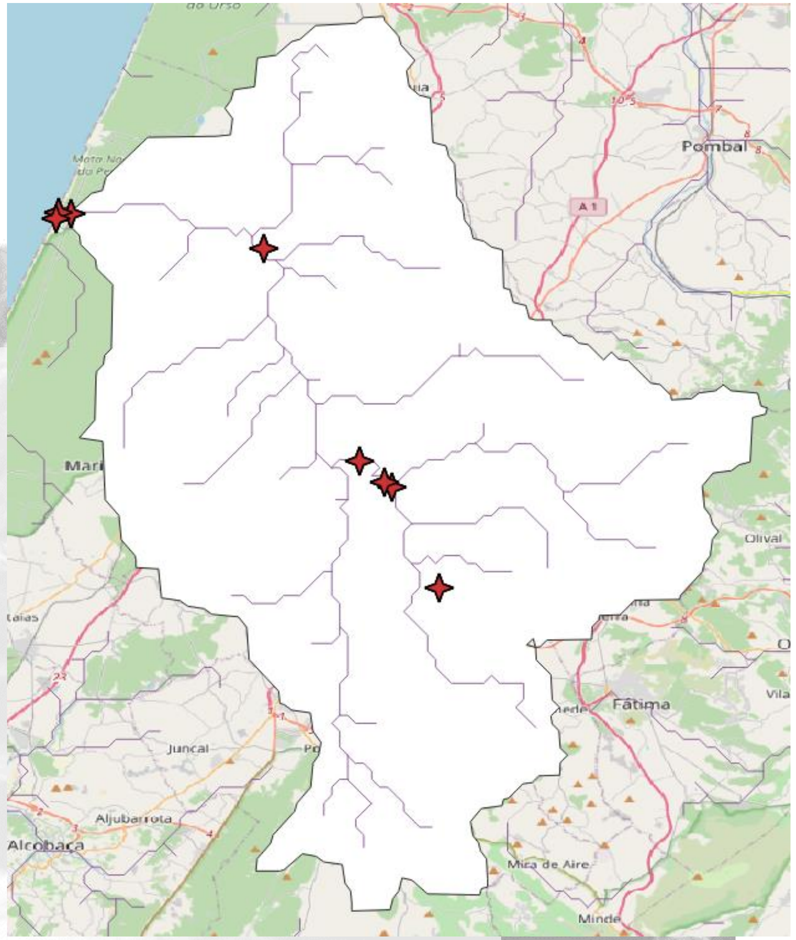
Model calibration: riverbed and riverbank sediment

Compartment	River bed sediment	River bank sediment
Percentage	?	?

Example: Riverbank data (macroplastics)

RLDB units: items/m2 or items/km



River basin: Lis (Portugal)

$$\frac{(Total\ plastic\ entering\ river\ -\ Plastic\ exported\ to\ outlet)}{Length\ of\ river} = \frac{1}{n}\sum_{i=1}^{n} Measured\ riverbank\ plastic_i$$

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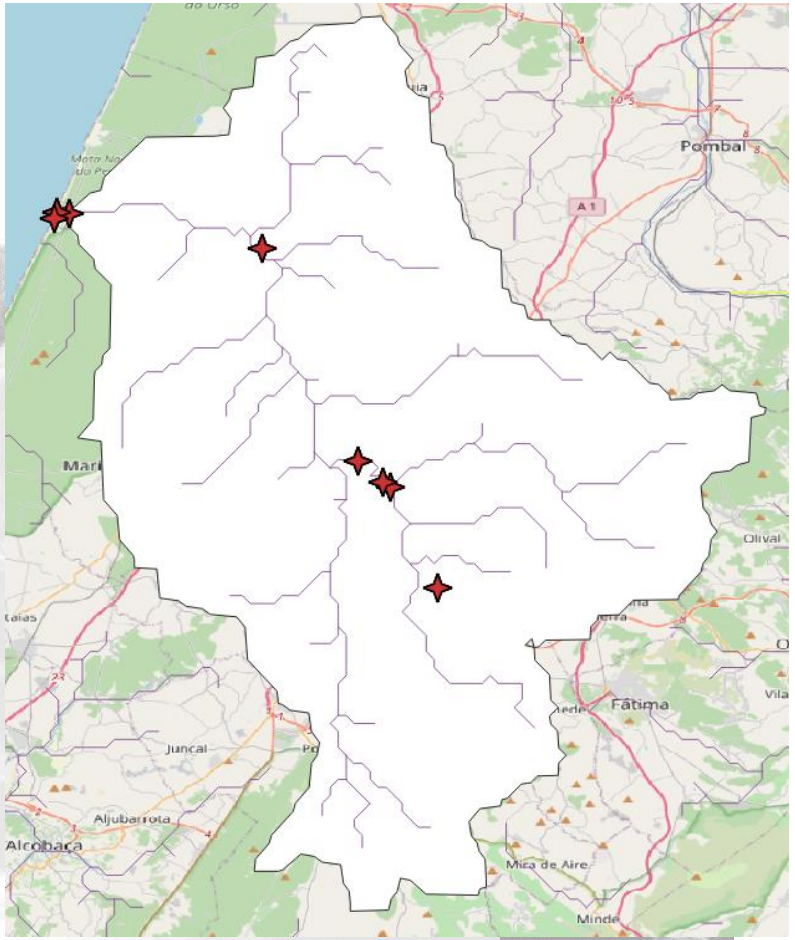

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Model output

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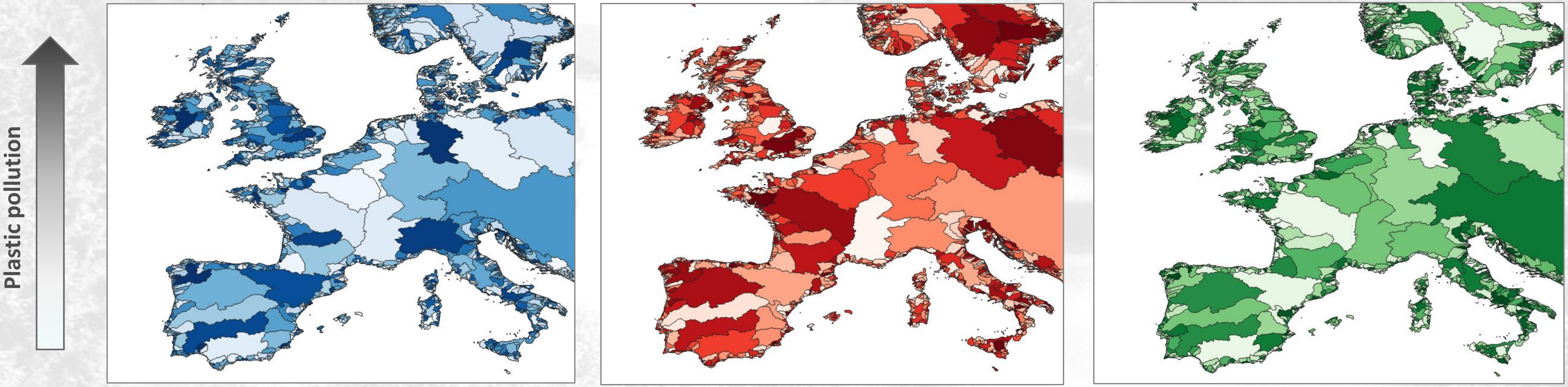
Model output



Plastic export to outlet

Plastic accumulation on riverbank

Plastic accumulation in riverbed sediment

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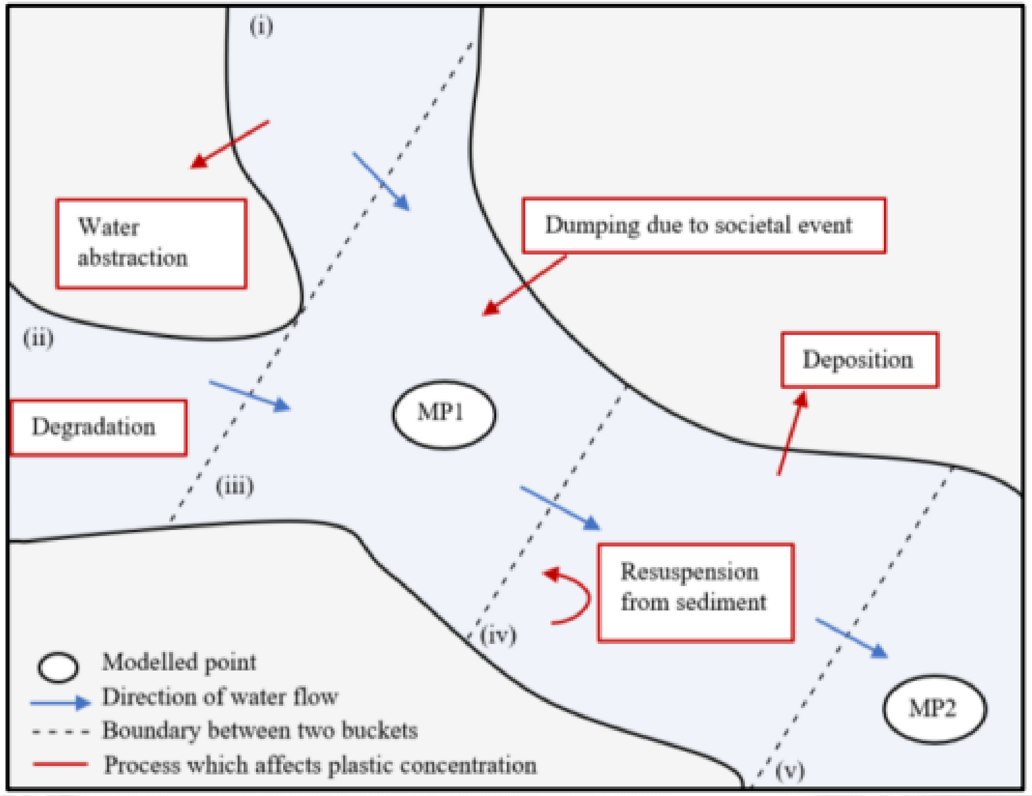
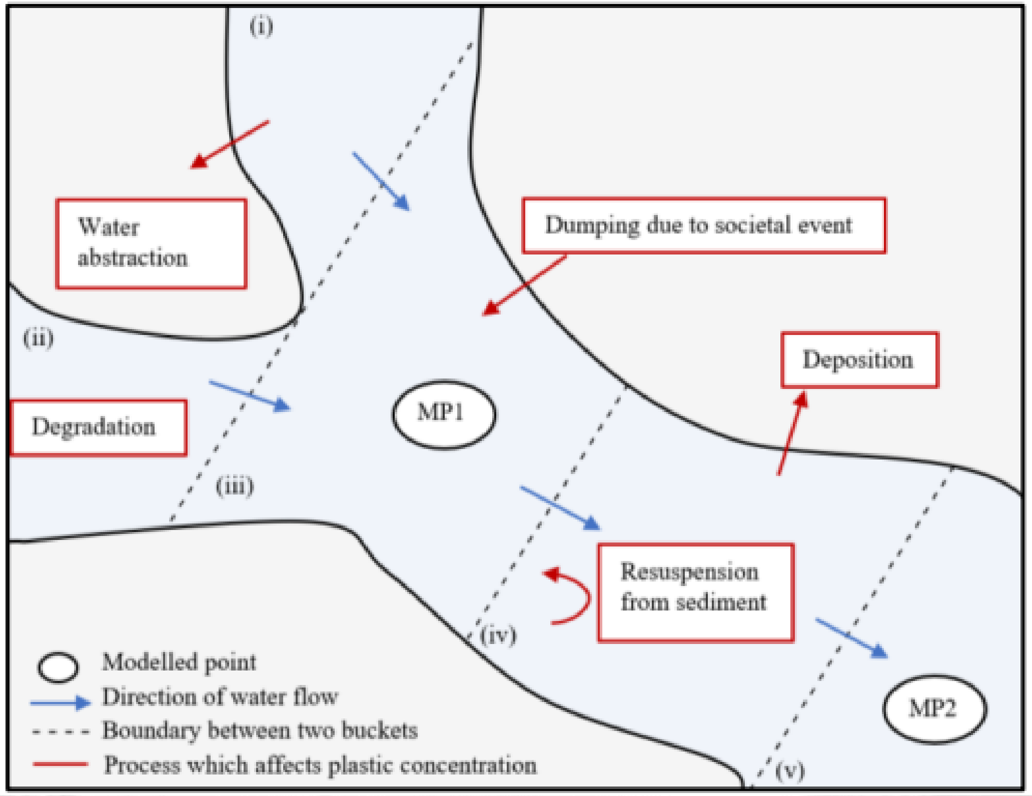
Future steps



Future steps

wflow_sbm

DELWAQ



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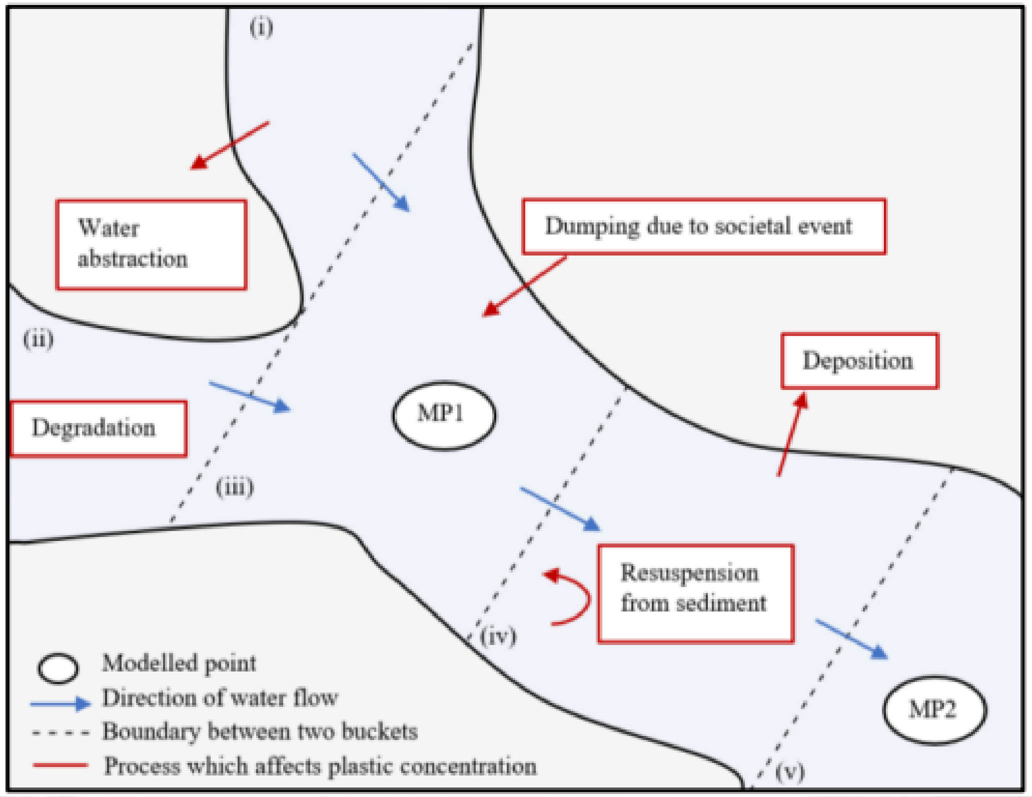
Future steps

wflow_sbm

DELWAQ

Aim: Integrate results from **in-situ** experiments of **mitigation measure efficiency** into hydrological models to assess the downstream and catchment level effect of **INSPIRE plastic reduction measures**



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Contact: Miranda.Stibora@wur.nl

Supervisors: Kryss Waldschläger
Tim van Emmerik

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Q&A

Please ask your question via the Q&A (toolbar)
or later via s
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