A Multimodal Data Fusion Framework for Riverine Macro-Debris Monitoring: Integrating Crowdsourced Data, Edge-AI, and Spatio-Temporal RFID Tracking

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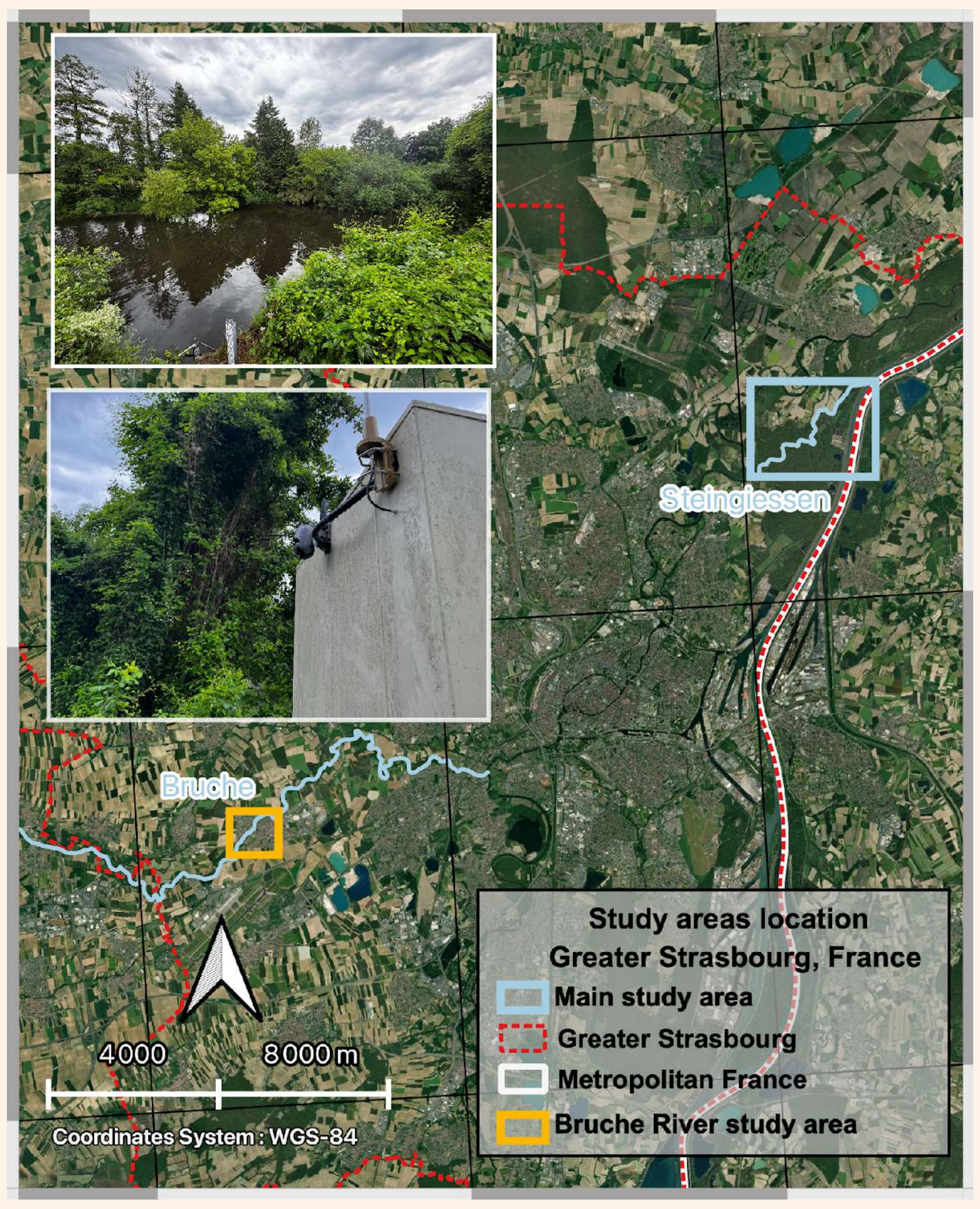
Introduction



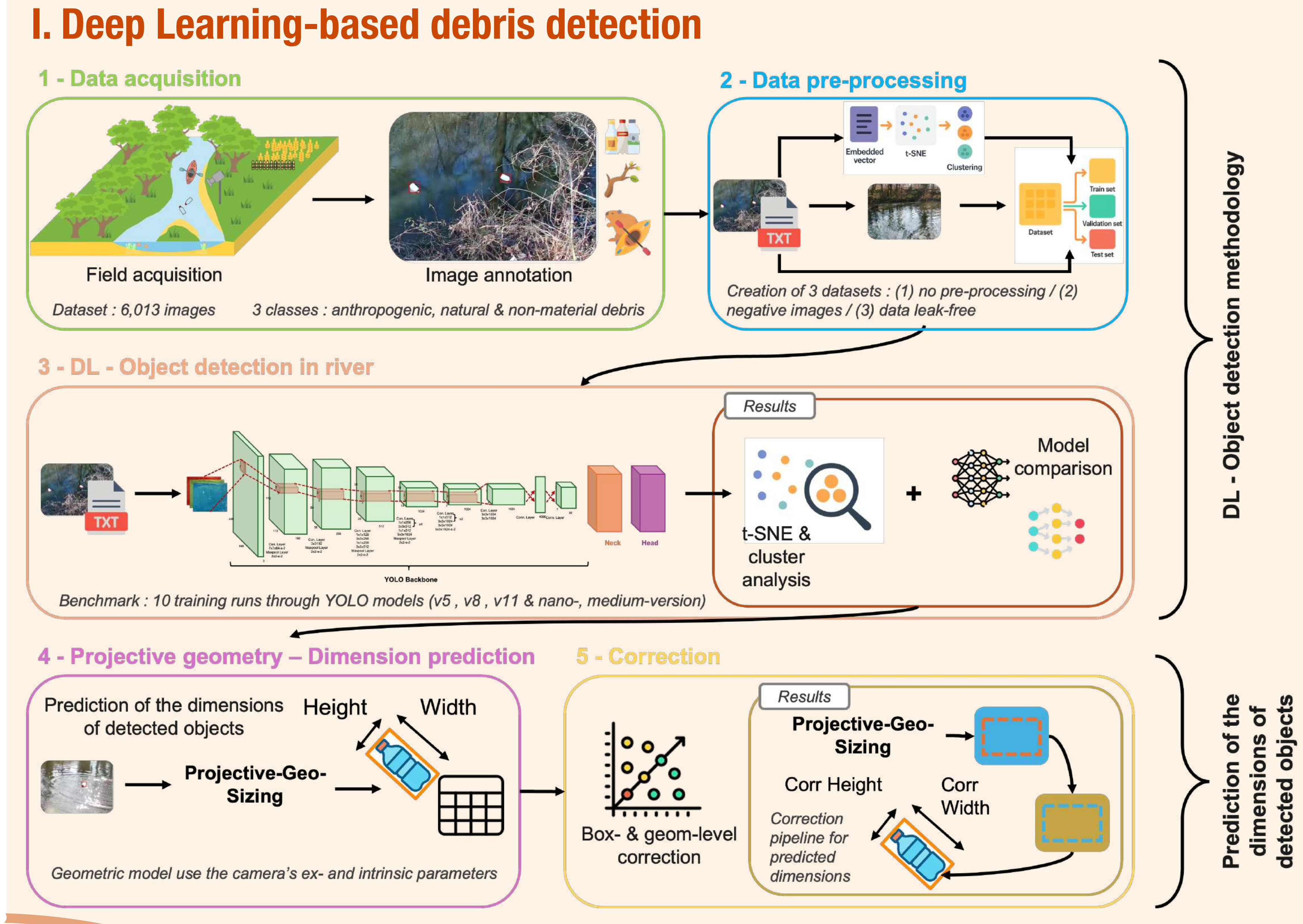
Issue : Rivers carry **millions of tons of plastic** to oceans, generating **microplastics**. They interact with logjams—altering **hydro-morphological dynamics**—and impact **flora and fauna**.

Challenge : current monitoring methods remain **sporadic, expensive, and difficult to replicate**.

Need : Developing **continuous, automated, and low-cost methods** to better understand plastic transport.

Methodology

I. Deep Learning-based debris detection

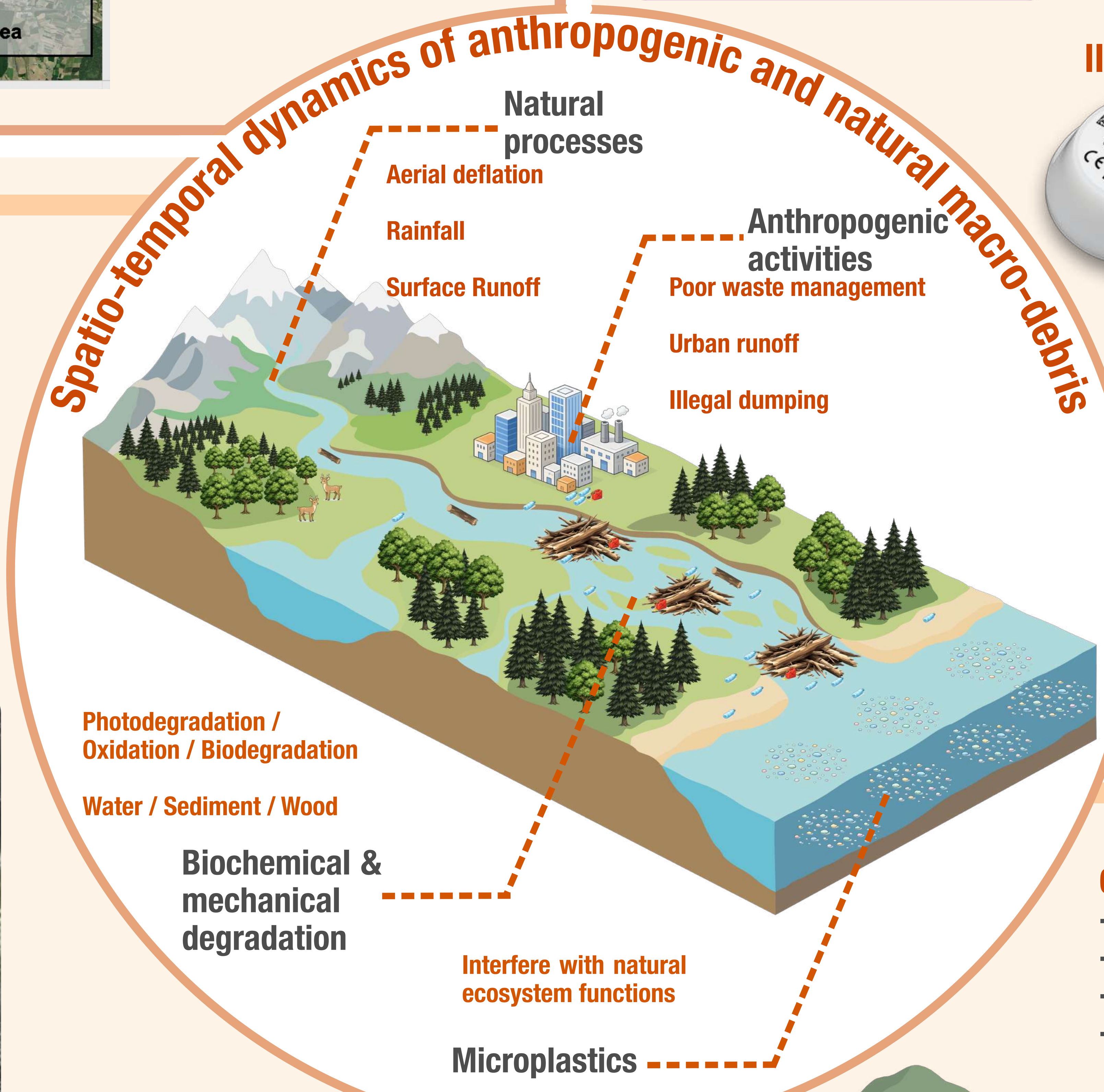


II. Spatio-Temporal RFID Tracking

Setup: **RFID tags** (433 MHz, 2.2s emission, 3-year battery) in **plastic bottles** to track their **spatio-temporal dynamics**.

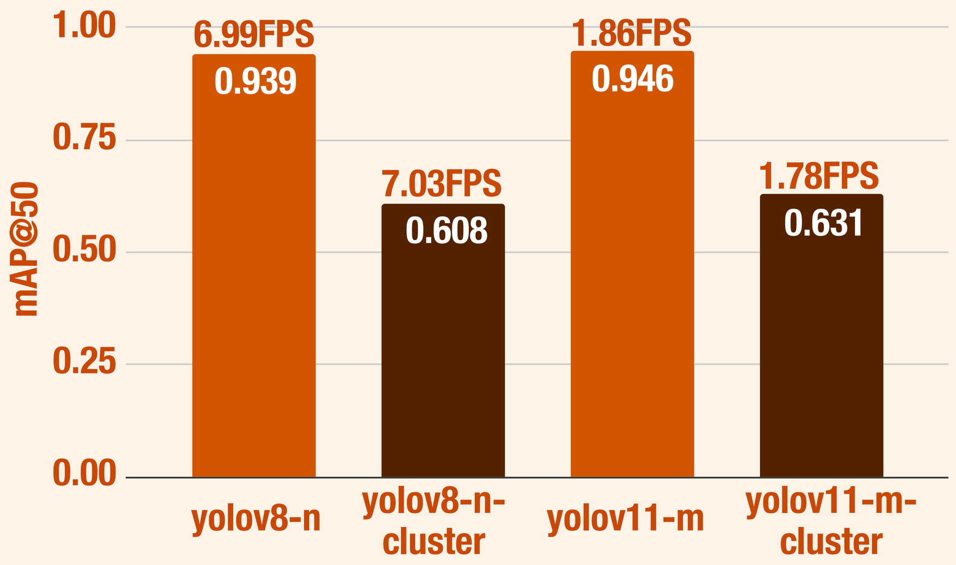
Deployment: Dropped in **Steingiessen River** on April 10th, 2025 (low flow velocity).

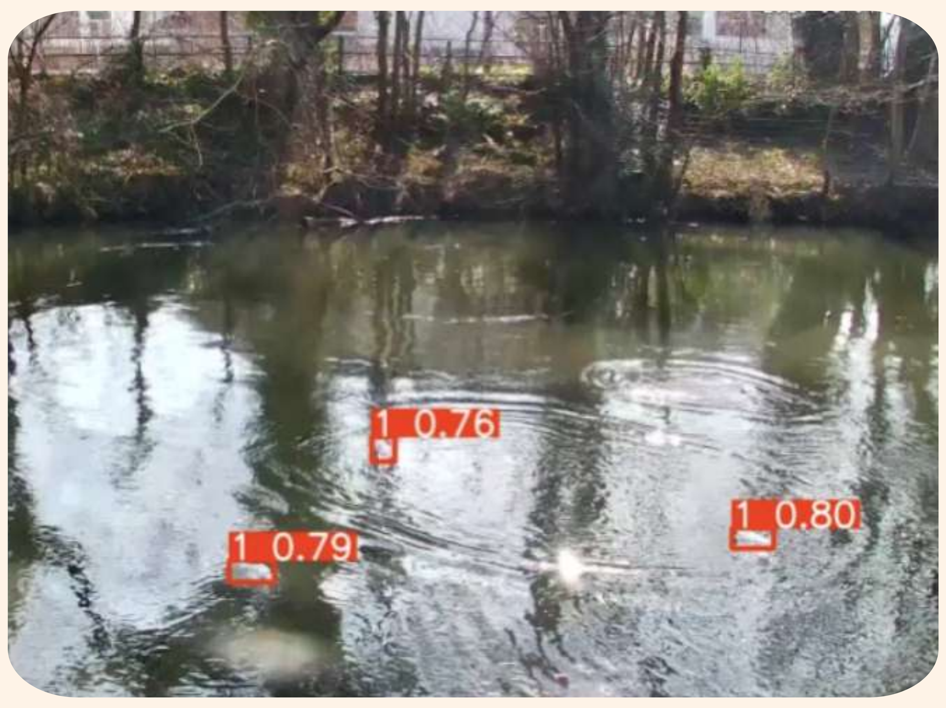
Monitoring: **Kayak** equipped with **RFID antenna** to map tag **positions** via signal strength.



Results

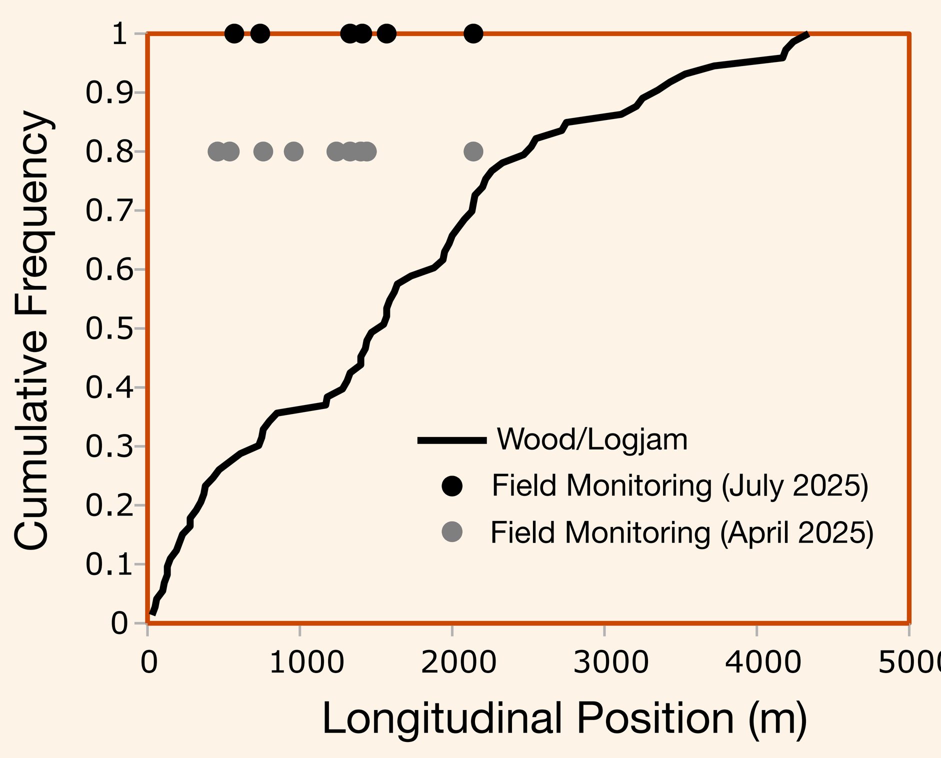
I. Deep Learning-based debris detection

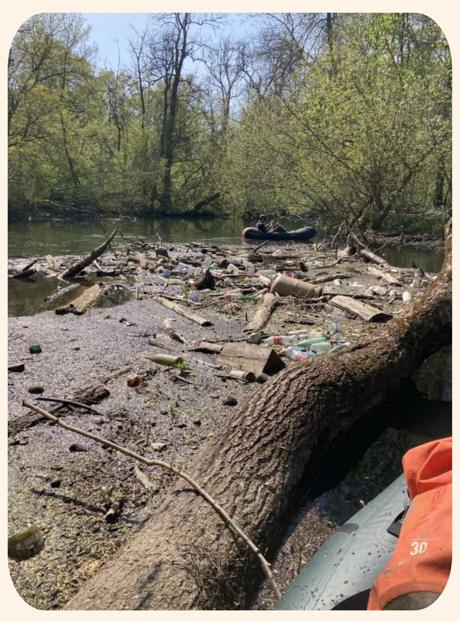




Robust detection under **complex river conditions**
YOLOv11-m achieves the **highest accuracy**
YOLOv8-n offers **best accuracy-efficiency trade-off** for embedded deployment.

II. Spatio-Temporal RFID Tracking





Travel distance: between 380 and 2060 m (low flow velocity)

80% detection rate for RFID bottles

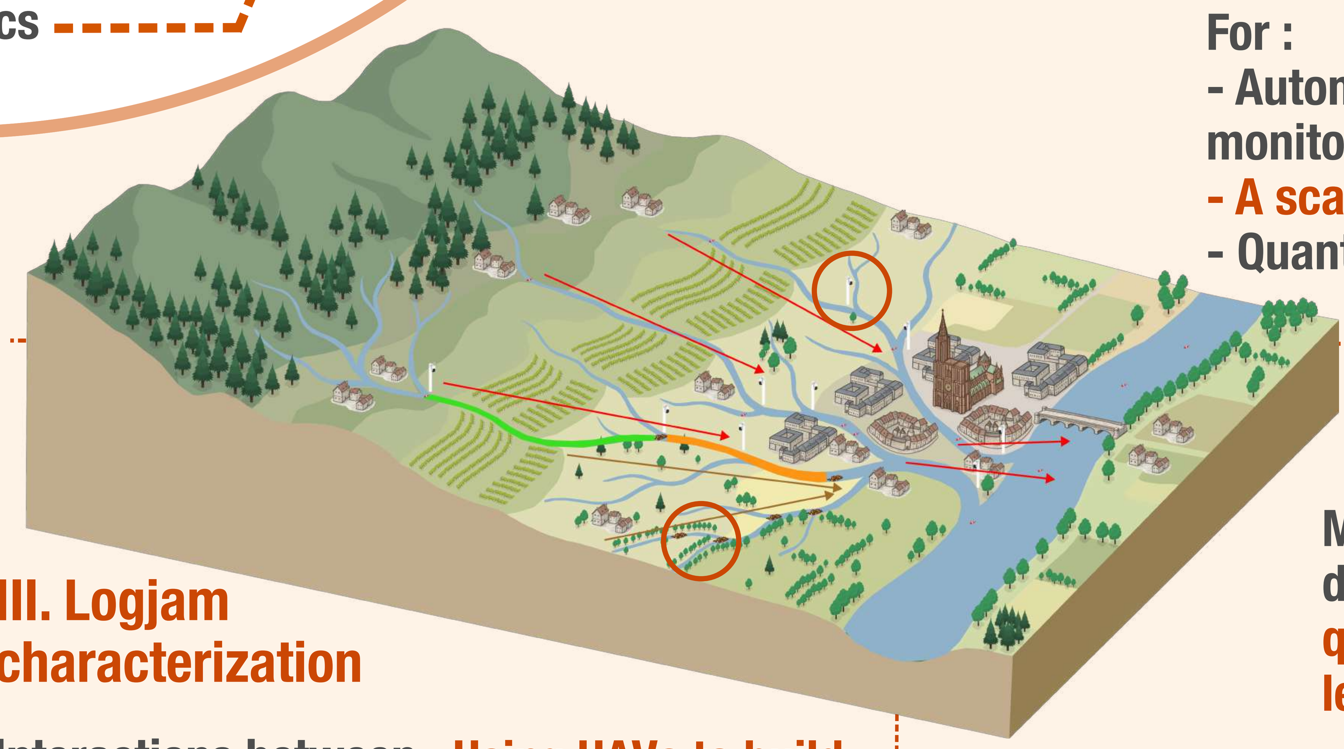
Trapping by natural logjams

Toward in-situ observatory

I. In-situ Edge-AI

Camera station with :
- Raspberry Pi 5
- RGB & IR cameras
- Embedded AI models
- Low-cost sensors

For :
- Automated & continuous monitoring
- **A scalable observatory**
- Quantifying debris



II. Crowdsourced data

Models performance depend on **dataset quality, balance and leakage control...**

How to acquire more data ? :
- Fieldwork
- Webscraping
- **Crowdsourcing**

streampic.eu :
- Based on citizen science
- Diverse sensors, veiwpoints, debris type

III. Logjam characterization

Interactions between logjams and plastics

Using UAVs to build 3D models via SfM

Develop a **logjam typology** based on river channel and logjam morphological metrics

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