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Using artificial intelligence for automated detection of flooded areas in Côte d'Ivoire and Senegal

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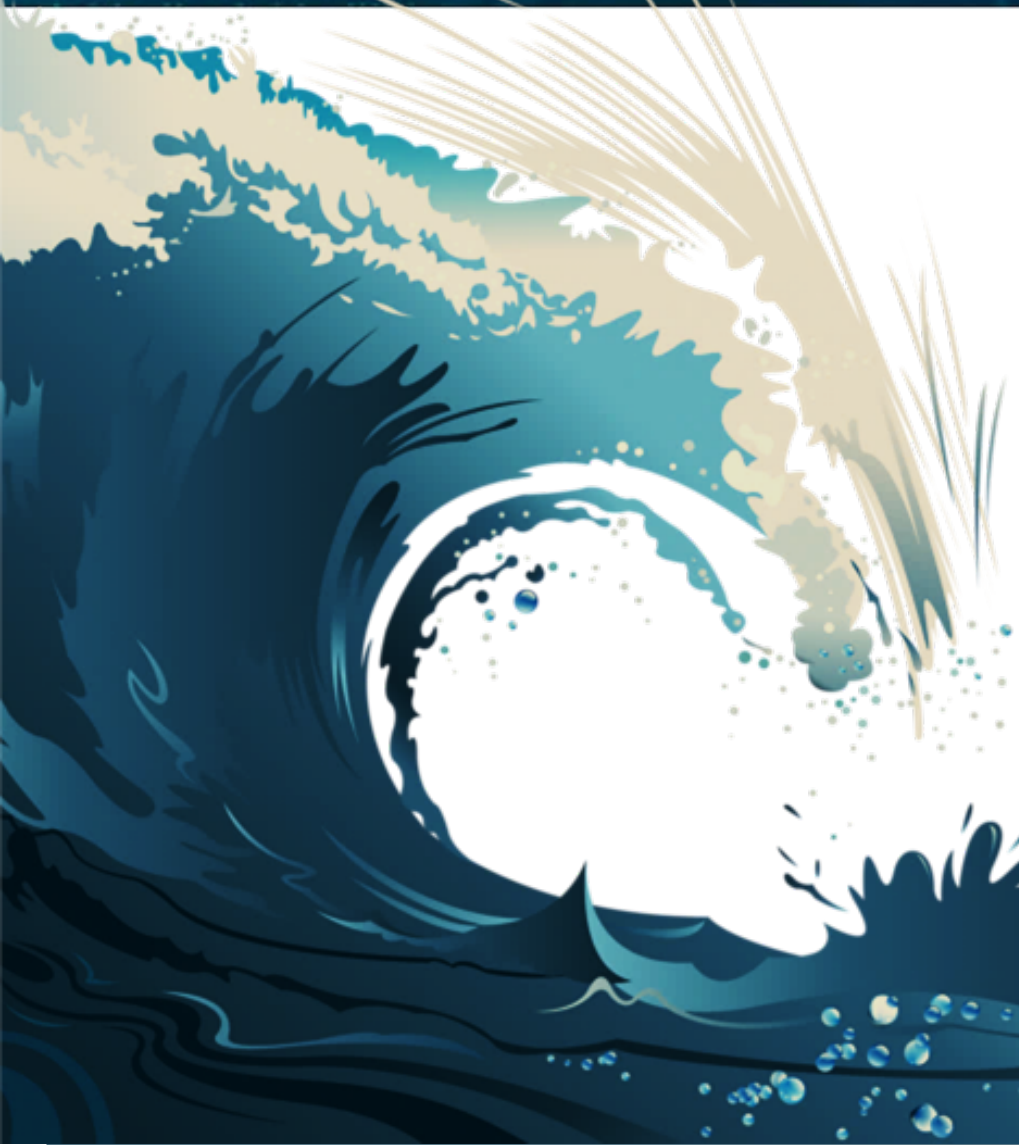
Plan



1 | CONTEXT

2 | OBJECTIVE

3 | METHODS

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Context

The coastal regions of Côte d'Ivoire and Senegal are regularly hit by floods, causing considerable damage to local populations, agriculture and infrastructure

- Space morphology;
- Rapid population growth;
- Unplanned urban expansion;

- Climate change ;
- Occupation of flood-prone areas;
- Weakness and/or absence of a densified drainage network

Early detection and accurate mapping of flooded areas are still major challenges

Helping decision-makers in sustainable development programs

- Raise public awareness
- Define monitoring and vigilance strategies

The lack of reliable data on the history of flooded areas is a reality

In this context, the use of deep learning methods offers promising prospects for improving early detection and management of floods.

Objective

- Automatically detect flooded areas
- Spatialize and quantify affected areas
- Estimate damage build area, crops lands and roads

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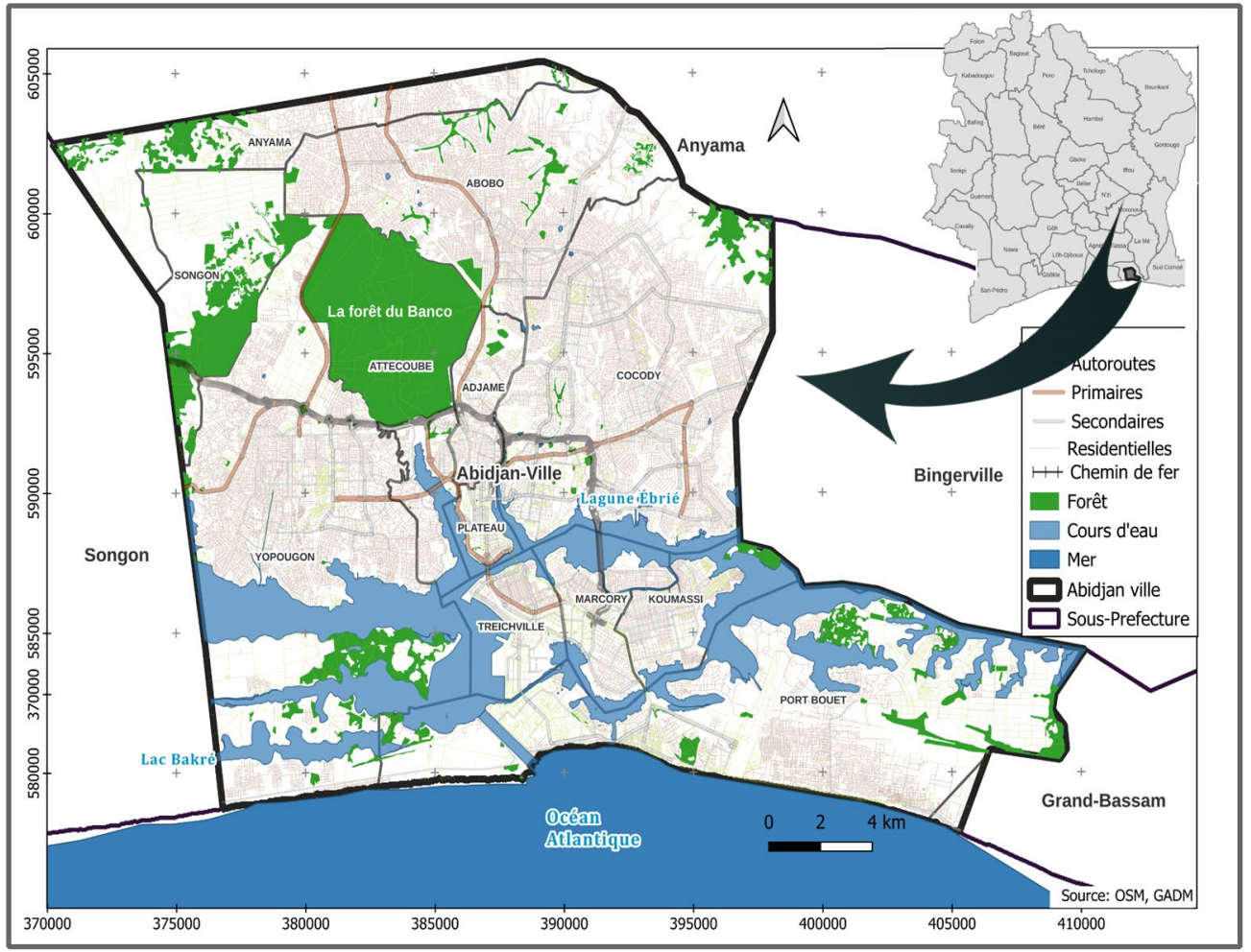
Location of study area

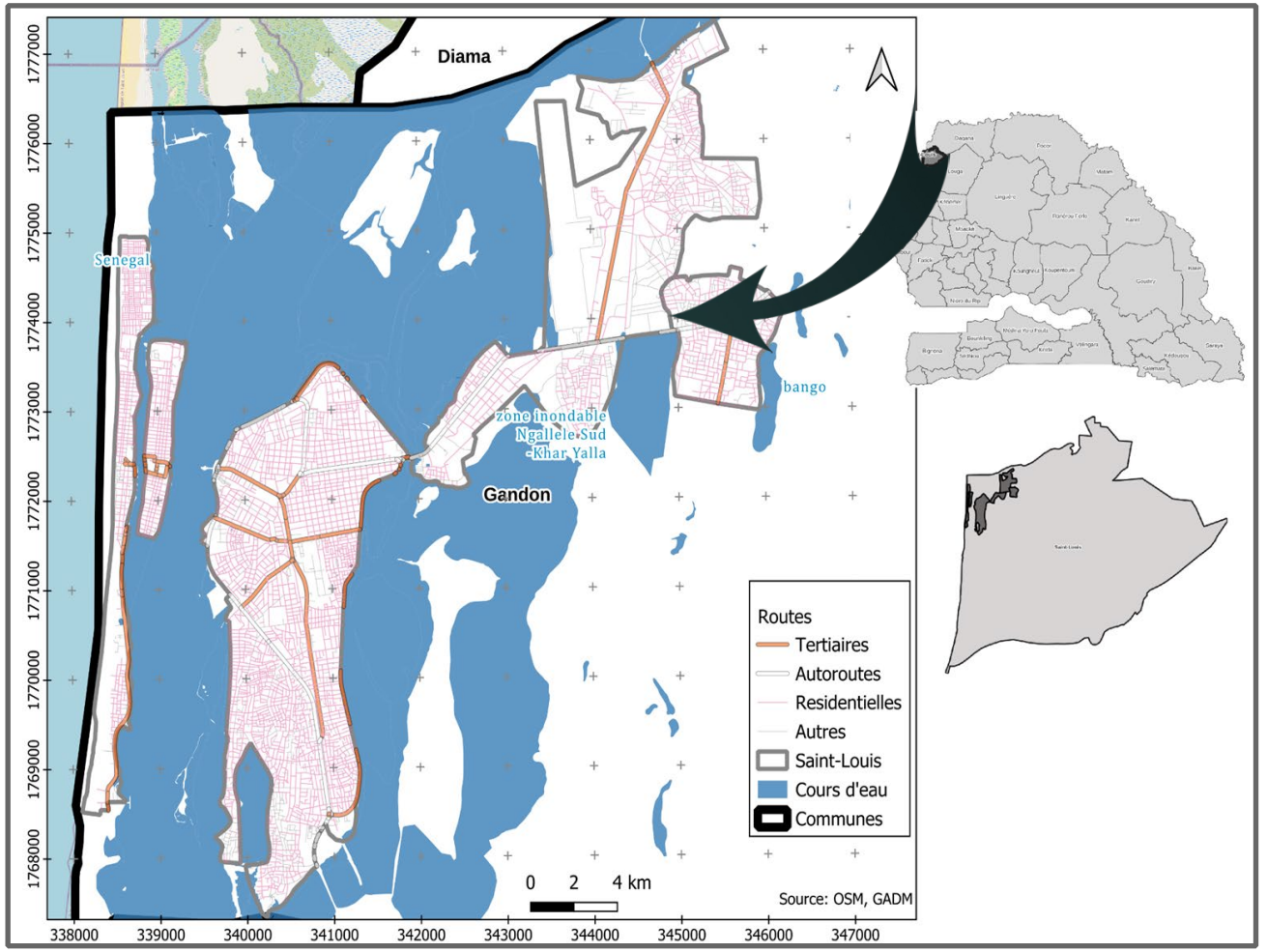
Abidjan (Ivory Coast)



- Abidjan is located in the south of Ivory Coast, along the Atlantic coast.
- It is the country's largest city and main economic and commercial center.

Location of study area

Saint- Louis (Senegal)



- Located in the north-western part of Senegal in the department of Saint-Louis
- Built on several islands (Saint-Louis, Sor and Ndar) and peninsulas at the mouth of the Senegal River
- Connected to the Langue de Barbarie (a narrow strip of sand separating the river from the Atlantic Ocean)

Material and Methods

Materials used in this study: Data and software

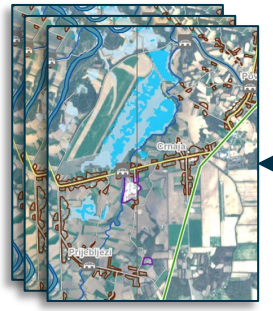
sentinel-2

25 /05/2024 – 31/07/2024

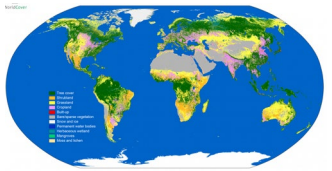
GOOGLE EARTH ENGINE

Cloud computing

Word Flood Data



Global world cover



Field Validation

Google Drive

Data storage space

Automatic flood processing and modeling and damage

python + colab

QGIS

GIS processing and thematic mapping

Material and Methods

Four (04) main steps define the approach :

STEP 1: Remote sensing data collection	**STEP 2:** Setting up the convolutional and calibration	**STEP 3:** Detecting flooded areas	**STEP 4:** Damage generated

Model database

- Sentinel-2 data from GEE
- Download WordFlood data

Data processing

- Ampsheric correction of optical images
- Opening WordFlood data

Neural convolutional model and hyperparameterization

- Architecture of the U-NET model
- Parameters

Learning U-NET

- Calibration U-NET avec les données WordFlood

Testing and validating the U-NET model

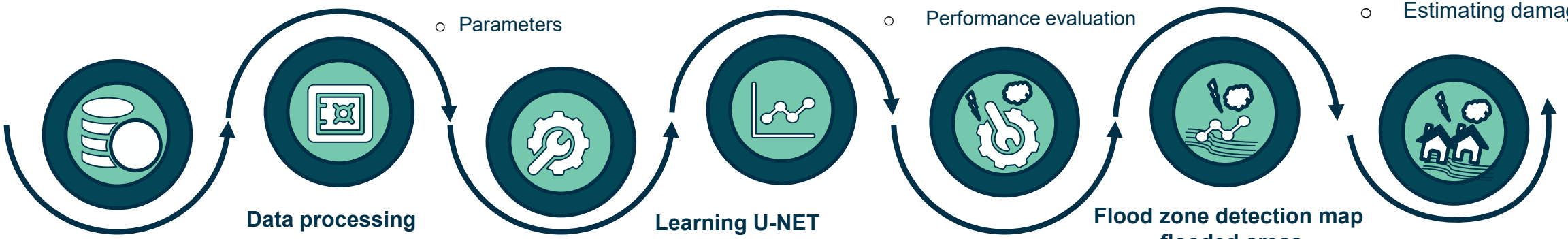
- Application to the study area
- Performance evaluation

Flood zone detection map flooded areas

- Using the classes recognized by the model

Stakes and damages

- Stakes assessment
- Estimating damage



Material and Methods

The quality of results is assessed using statistical measures of Precision (PR), Recall (RE) and F1 score

Précision	$\frac{\text{True positive}}{\text{True positive} + \text{false positive}}$
Recall	$\frac{\text{True positive}}{\text{True positive} + \text{false negative}}$
Score F1	$2 \times \frac{\text{Precision} \times Recall}{\text{Precision} + Recall}$

Results

Statistical performance of U-NET in each locality

	U-NET (Saint Louis)			U-NET (Abidjan)		
	PR	RE	F1	PR	RE	F1
Permanent waters	91 %	89 %	90 %	91 %	83 %	87 %
Flooded areas	90 %	88 %	89 %	89 %	87 %	88 %
Others	86 %	91 %	88 %	82 %	89 %	85 %
Clouds	85 %	81 %	83 %	83 %	83 %	83 %

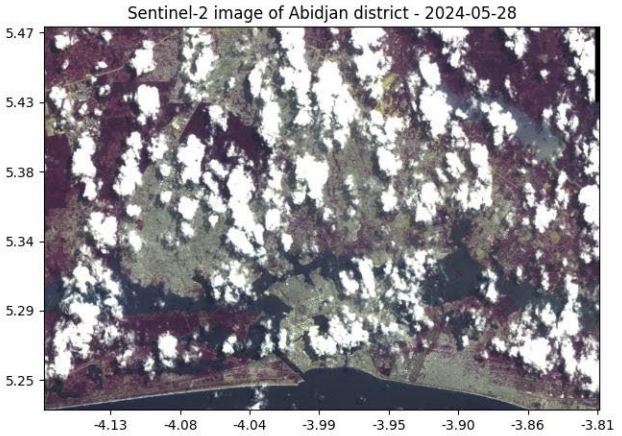
PRECISION : Over 82% in in Saint Louis and Abidjan

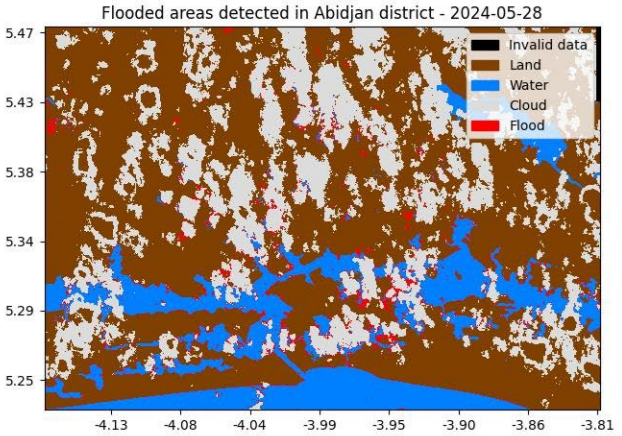
RECALL : Over 81 % in in Saint Louis and Abidjan

F1 score: above 83 % in Saint Louis and Abidjan

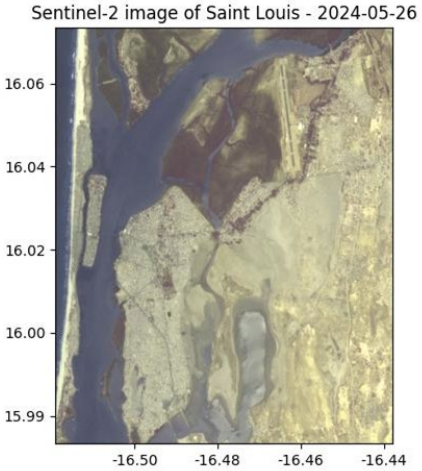
Results

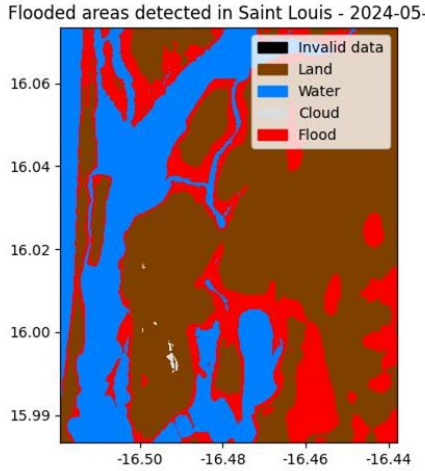
✓ Identification and labelling in Abidjan 2024-05-28



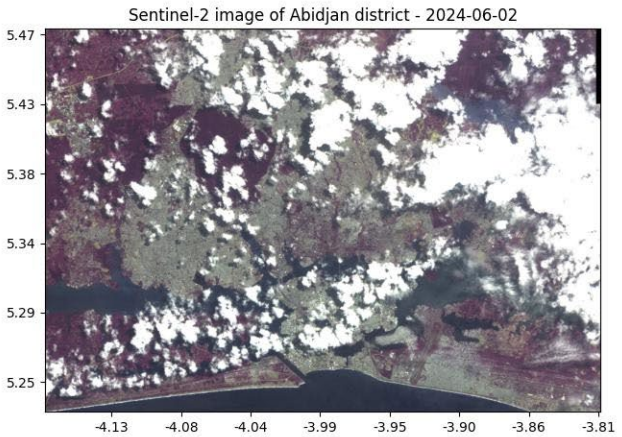


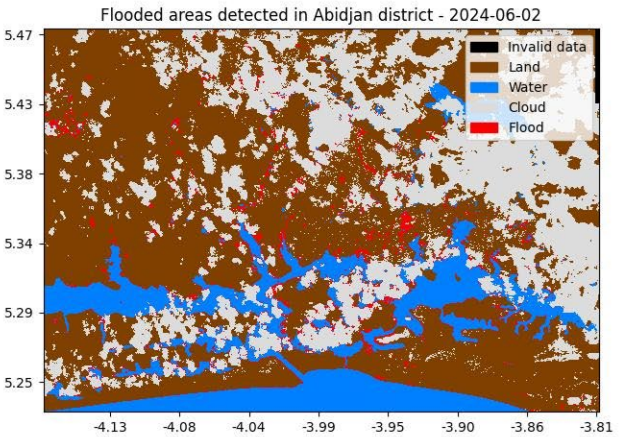
✓ Identification and labeling in Saint Louis 2024-05-26



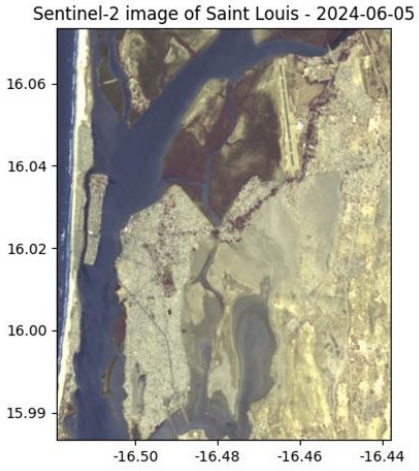


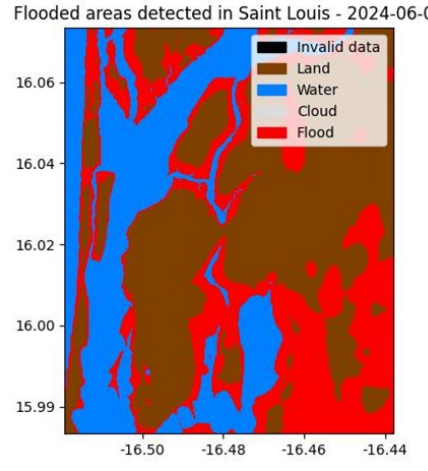
✓ Identification and labelling in Abidjan 2024-06-02





✓ Identification and labeling in Saint Louis 2024-06-05

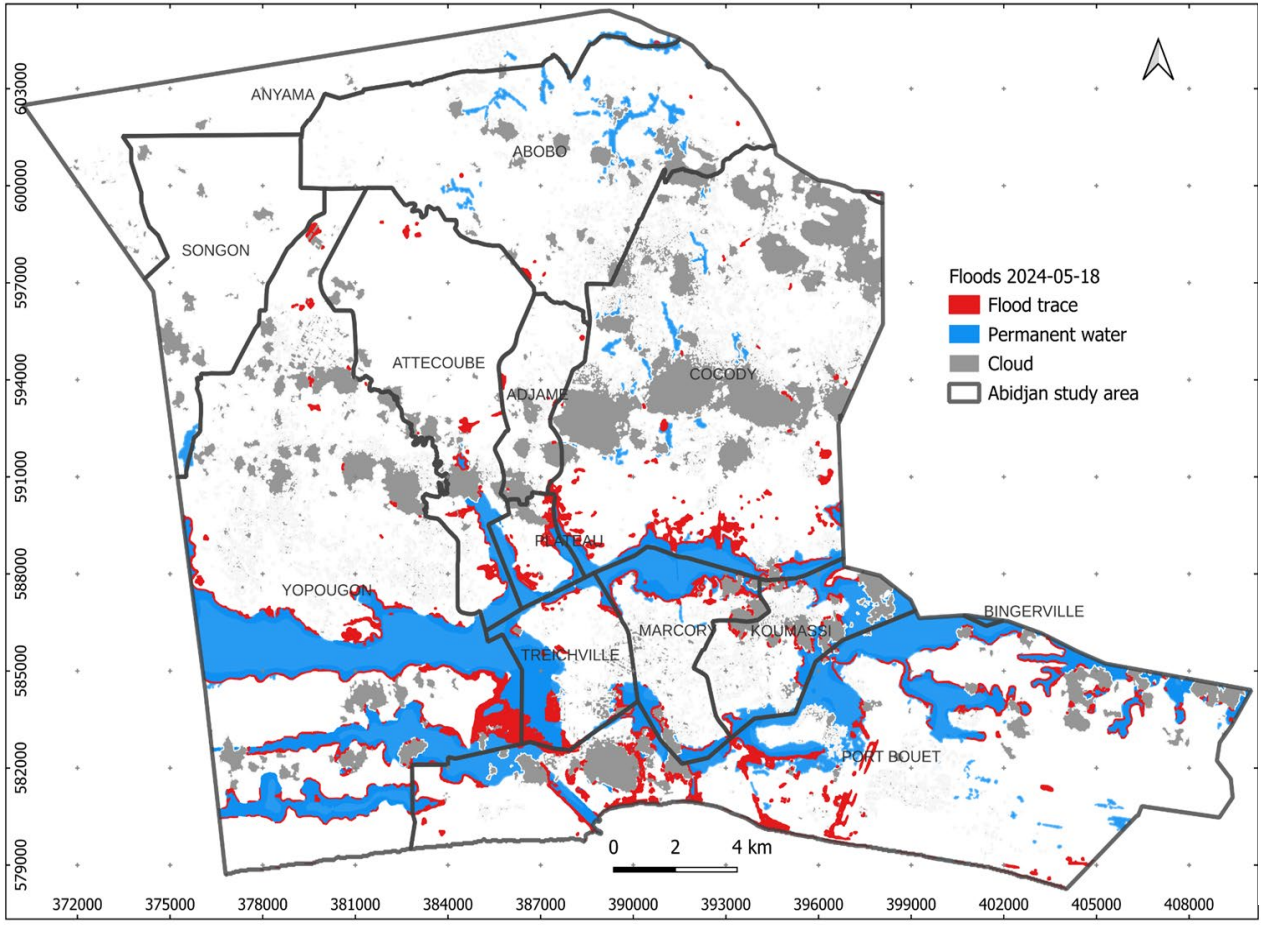




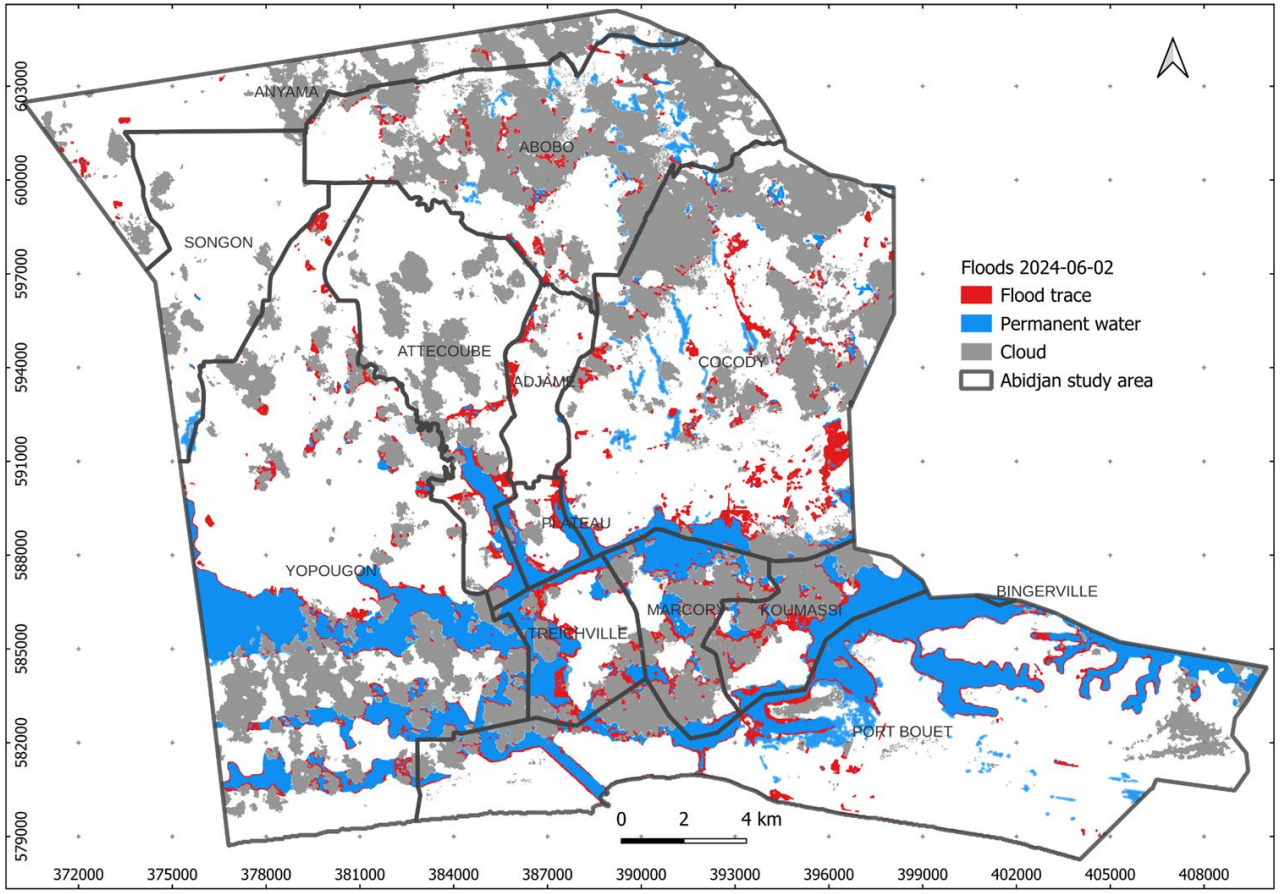
Results

Flood maps for Abidjan in 2024

Map of flooded areas in Abidjan 2024-05-18



Map of flooded areas in Abidjan 2024-06-02

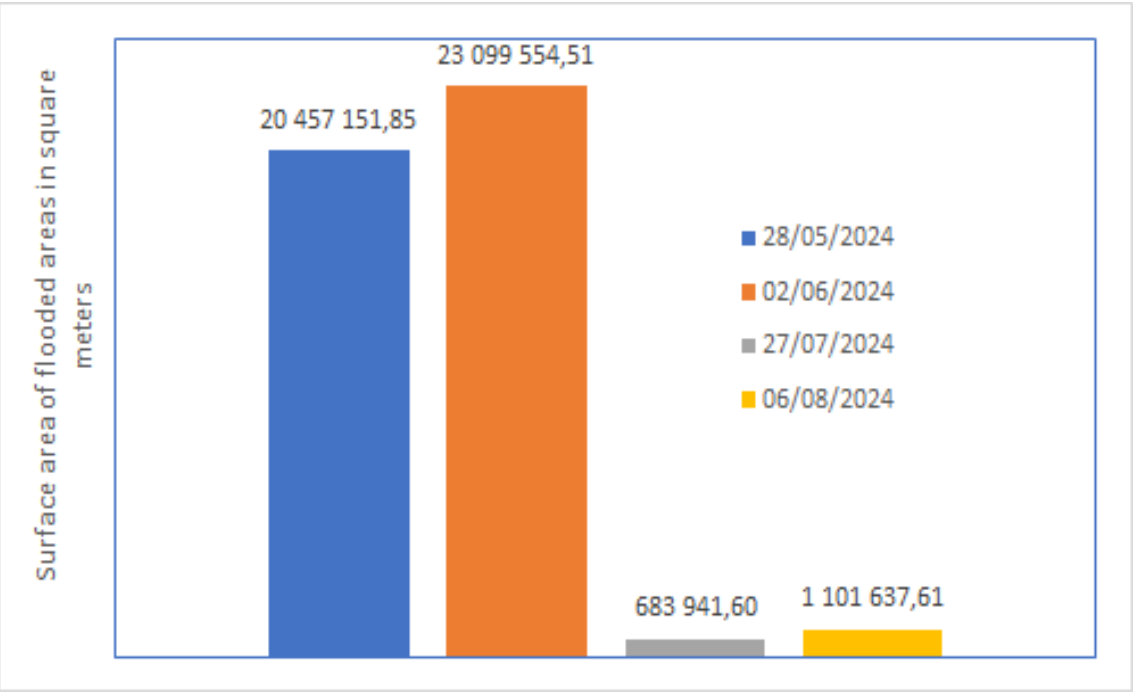


Results

Flood maps for Abidjan in 2024

Map of flooded areas in Abidjan 2024-06-02

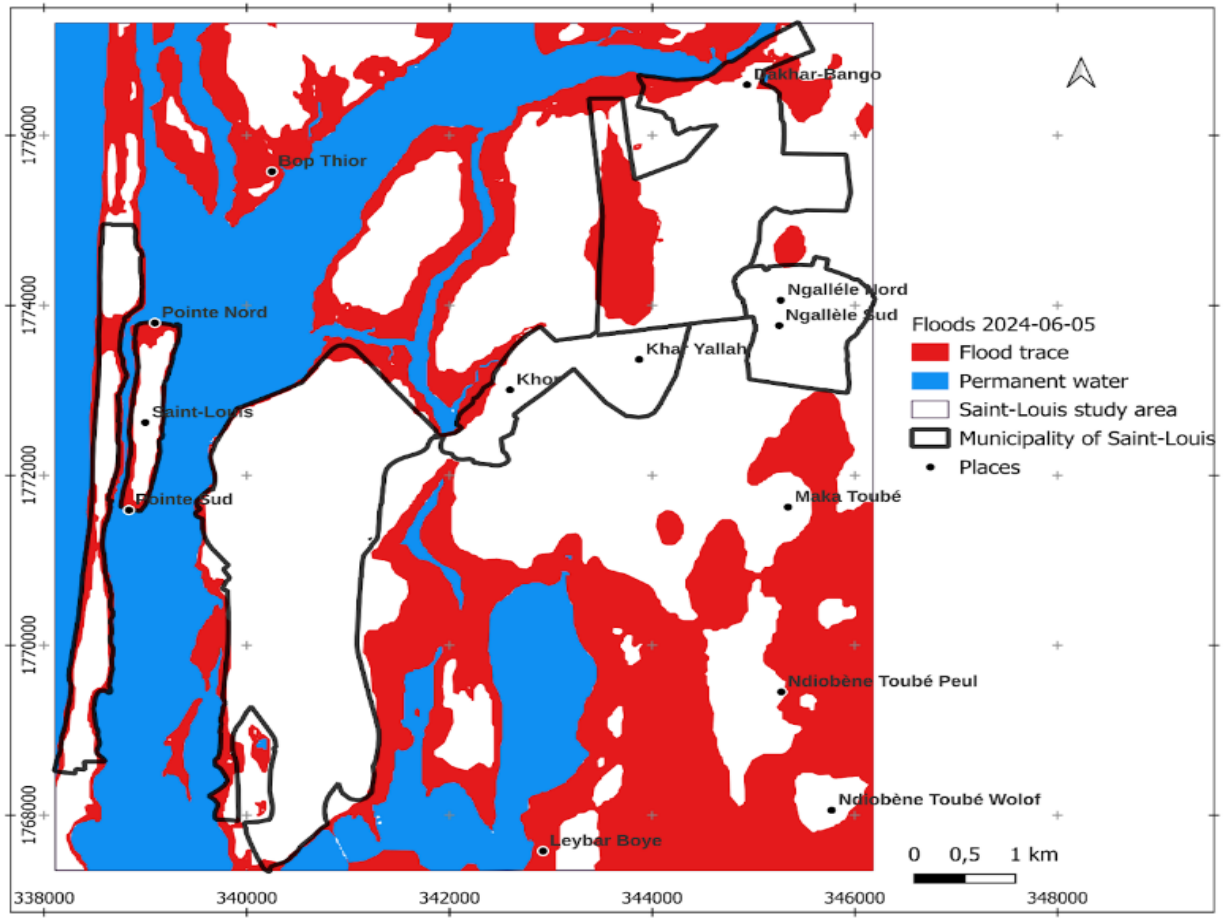
	28/05/2024		02/06/2024		27/07/2024		06/08/2024	
	Sup (m²)	(%)	Sup (m²)	(%)	Sup (m²)	(%)	Sup (m²)	(%)
Nuages	167816546	27,1	157276794	25,4	414314606	66,8	386552823	62,4
Espace inondé	20457151,9	3,3	23099554,5	3,7%	683941,6	0,11	1101637,61	0,2
Autre	431723376	69,6	439620725	70,9 %	204998526,1	33,06	232342613	37,5
Zone d'étude	619997074	100	619997074	100	619997073,7	100	619997074	100



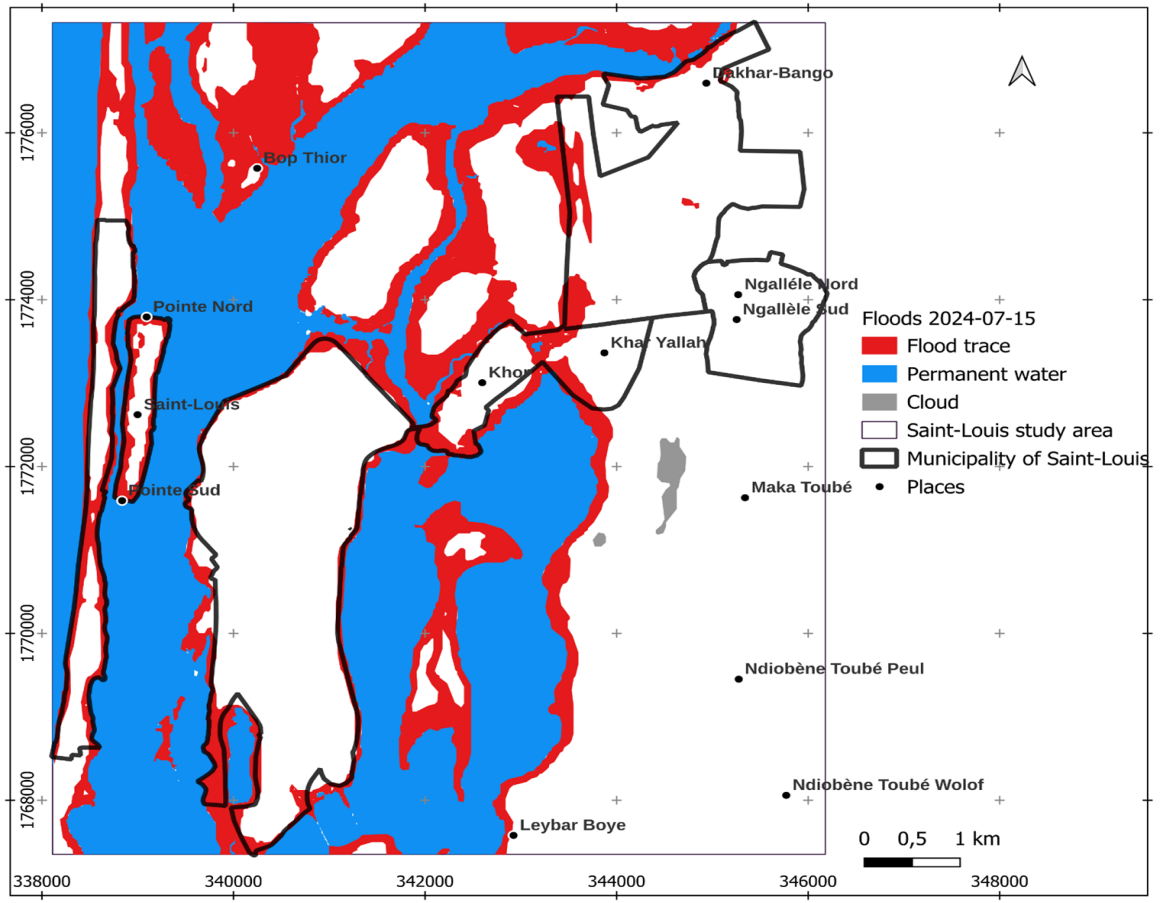
Results

Flood maps for Saint Louis in 2024

Map of flooded areas in Saint Louis 2024-06-05



Map of flooded areas in Saint Louis 2024-07-15

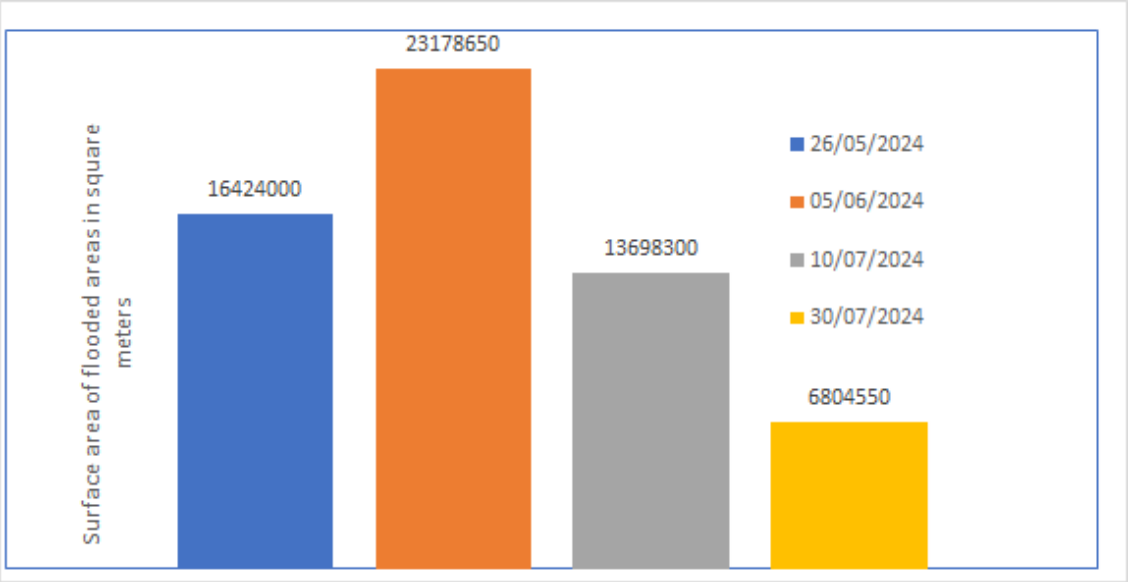


Results

Flood maps for Saint Louis in 2024

Map of flooded areas in Saint Louis 2024-06-05

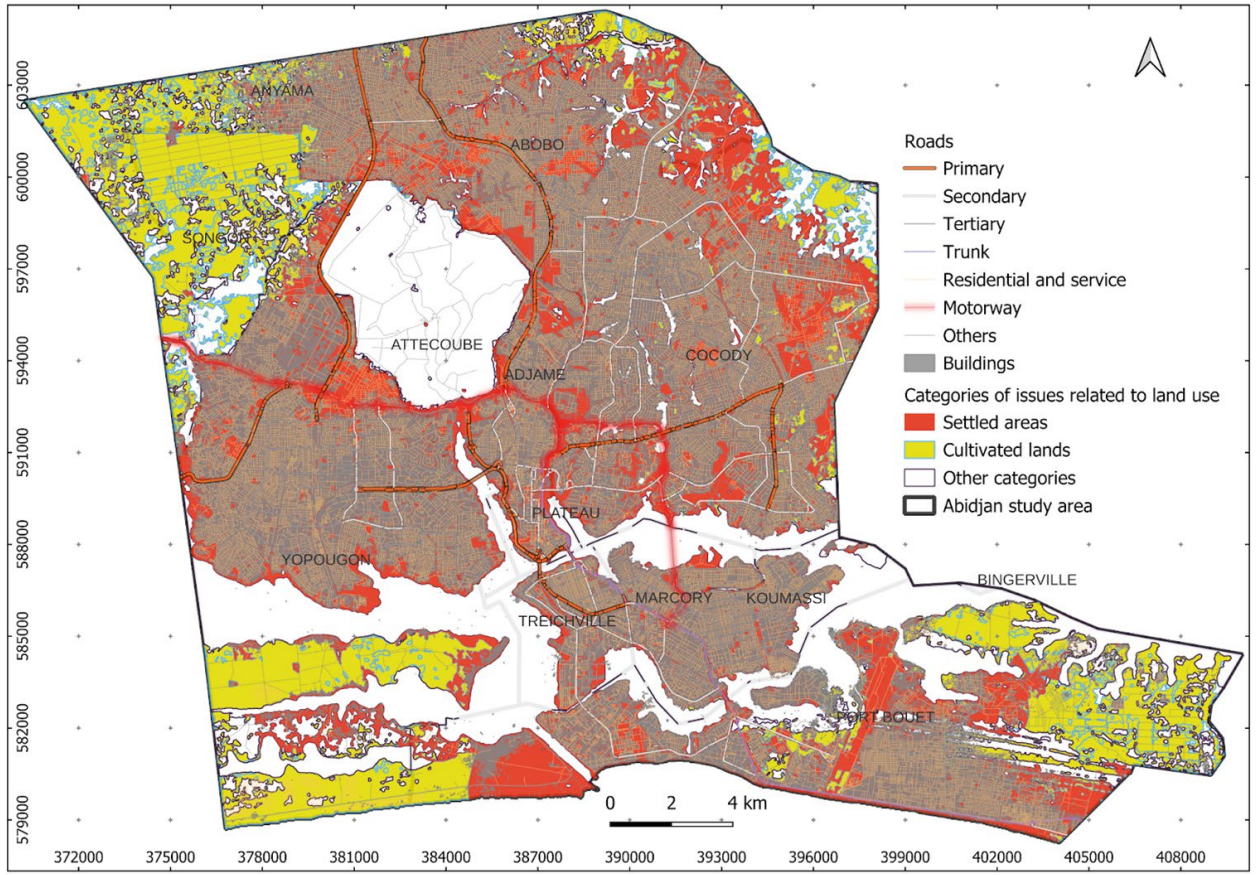
	26/05/2024		05/06/2024		10/07/2024		30/07/2024	
	Sup (m²)	(%)	Sup (m²)	(%)	Sup (m²)	(%)	Sup (m²)	(%)
Nuages	77000	0,1		0	1895900	2,4	37252000	46,3
Espace inondé	16424000	20,4	23178650	28,8	13698300	17,03	6804550	8,5
Autre	63956900	79,5	57279250	71,2	64863700	80,6	36401350	45,2
Zone d'étude	80457900	100	80457900	100	80457900	100	80457900	100



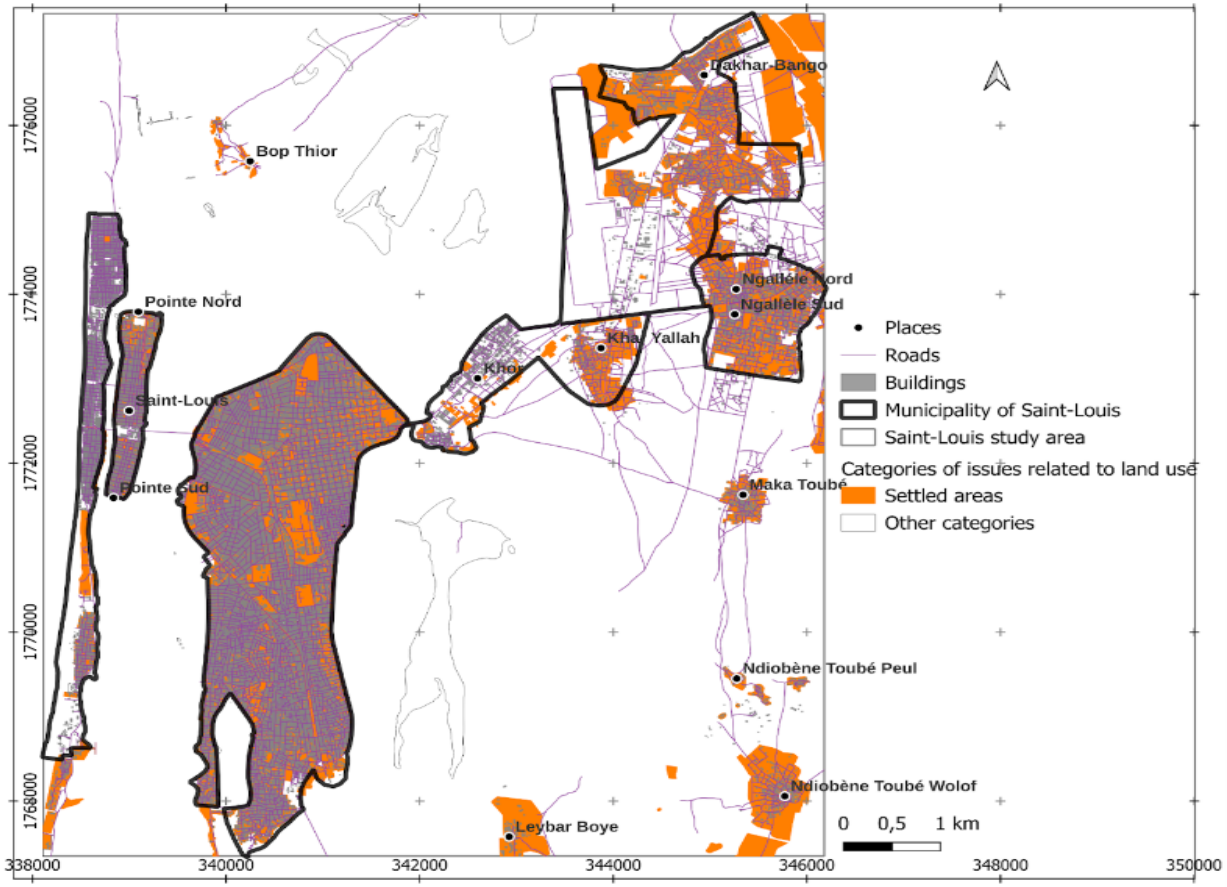
Results

Maps of issues in Abidjan and Saint Louis

Map of issues in Abidjan



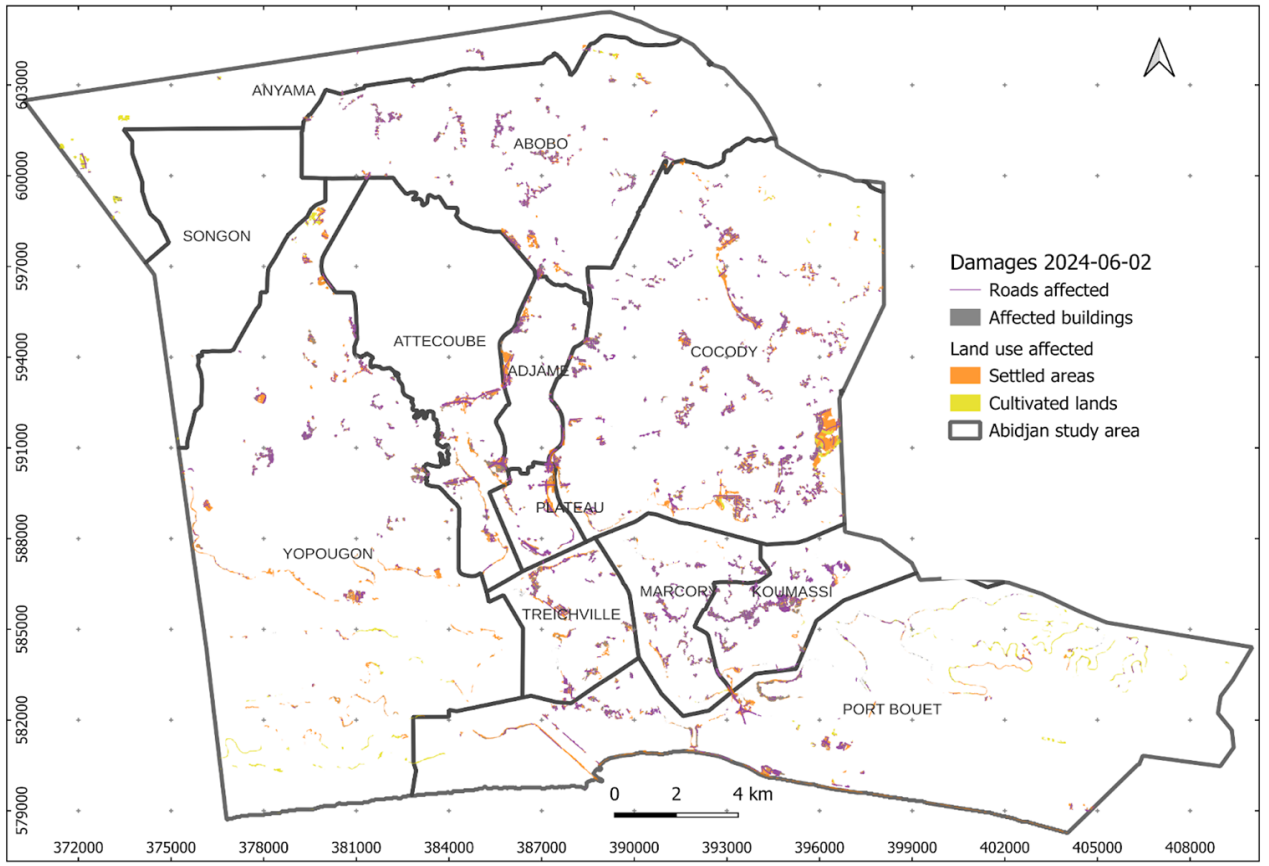
Map of issues in Saint Louis



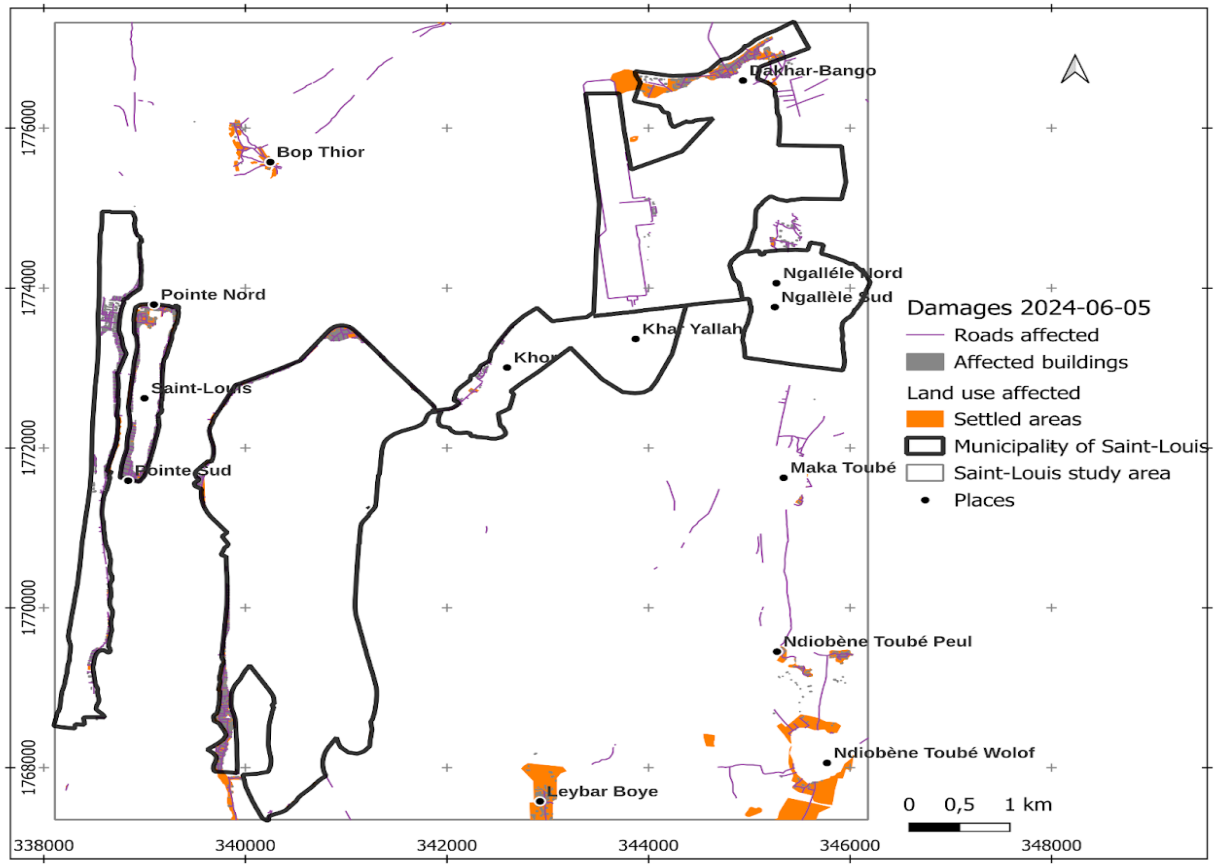
Results

Maps of potential damage in Abidjan and Saint Louis in 2024

Abidjan damage map 2024-06-02



Saint Louis damage map 2024-06-05



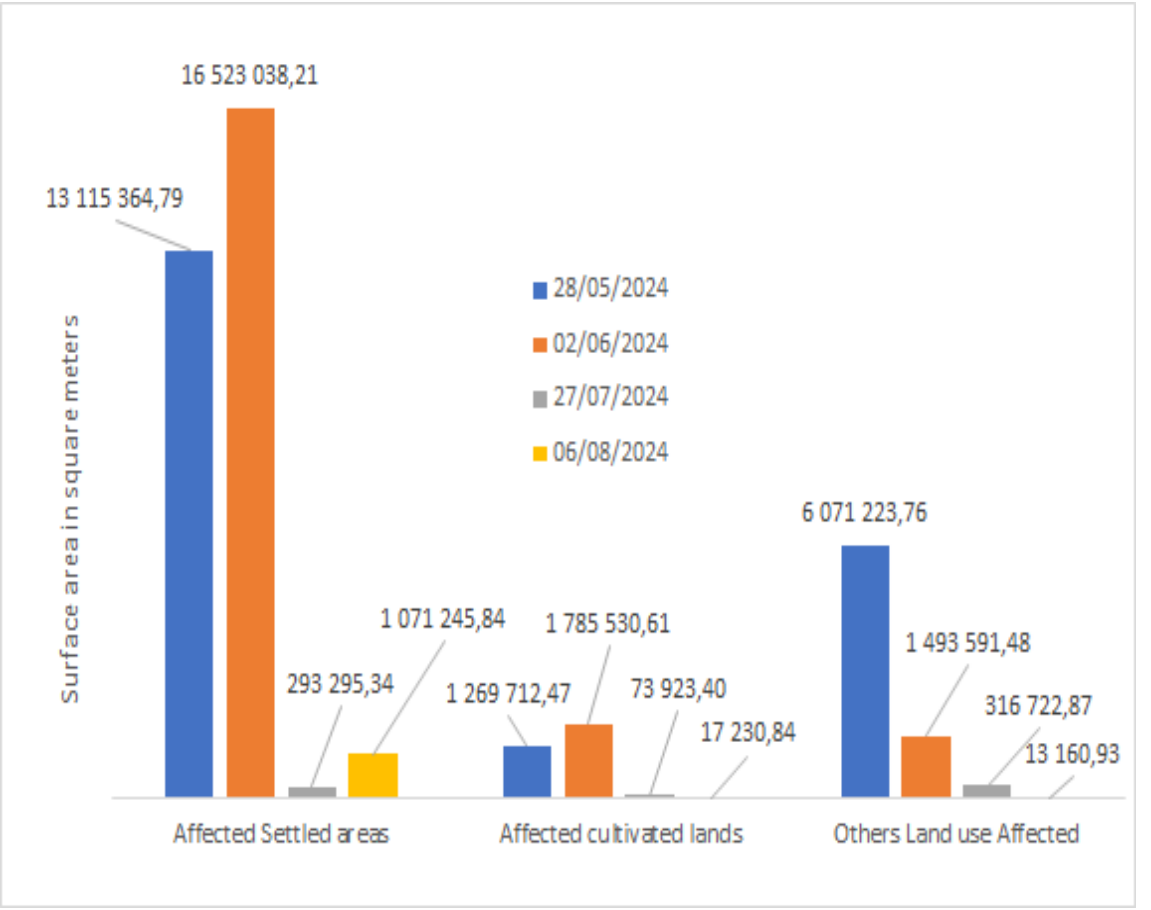
Results

Proportion of issues related to land use

Issues affected by flooding in Abidjan

	28/05/2024		02/06/2024		27/07/2024		06/08/2024	
	Sup (m²)	(%)	Sup (m²)	(%)	Sup (m²)	(%)	Sup (m²)	(%)
Habitats affected	13 115 364,8	64,1%	16 523 038,2	71,5%	293 295,3	42,9%	1 071 245,8	97,2%
Crops affected	1 269 712,5	6,2%	1 785 530,6	7,7%	73 923,4	10,8%	17 230,8	1,6%
Others	6 071 223,8	29,7%	1 493 591,5	6,5%	316 722,9	46,3%	13 160,9	1,2%
Flooded area	20 457 151,9	100%	23 099 554,5	100%	683 941,6	100%	1 101 637,6	100%

	28/05/2024	02/06/2024	27/07/2024	06/08/2024
	Sup (m²)	Sup (m²)	Sup (m²)	Sup (m²)
Affected building	2 670 999,21	2 611 748,62	1 608 512,08	262 036,30



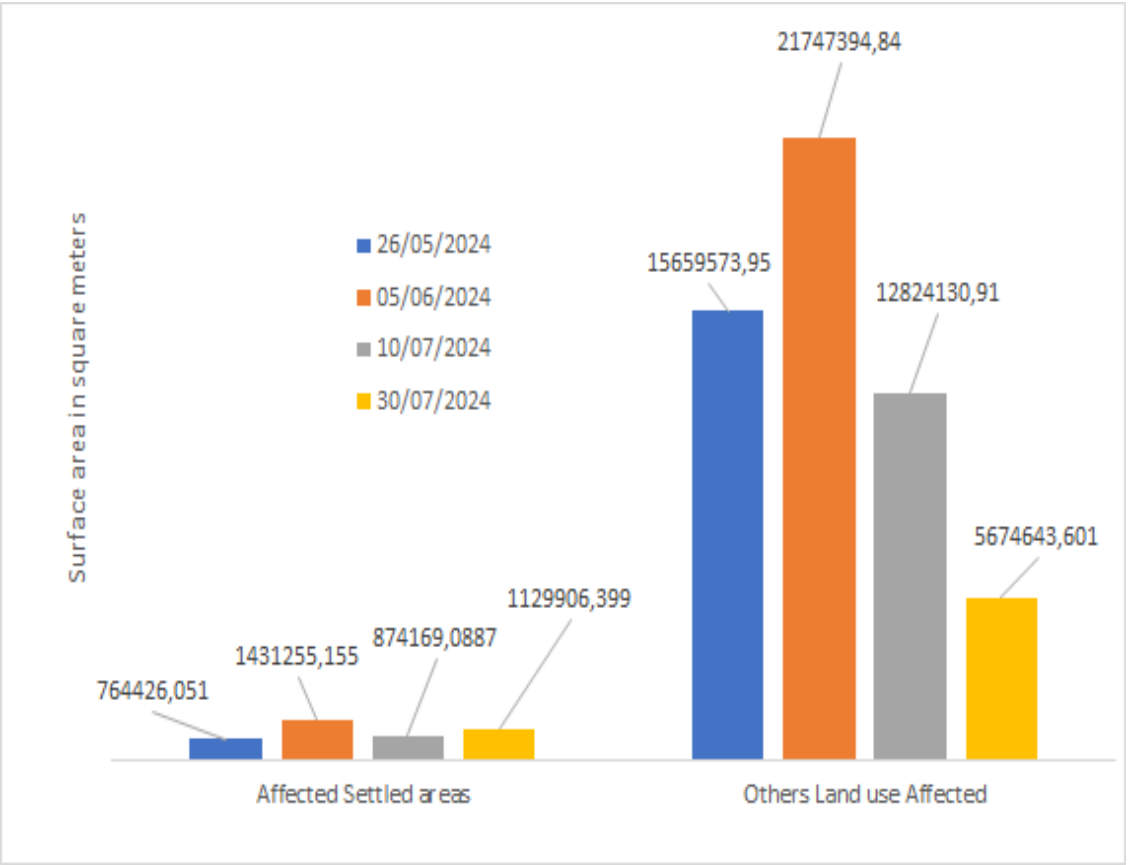
Results

Proportion of issues related to land use

Issues affected by floodingin Saint-Louis

	26/05/2024		05/06/2024		10/07/2024		30/07/2024	
	Sup (m²)	(%)	Sup (m²)	(%)	Sup (m²)	(%)	Sup (m²)	(%)
Habitats affected	764426,1	4,7%	1431255,2	6,2%	874169,1	6,4%	1129906	16,6%
Crops affected								
Others	15659573,9	95,3%	21 668 299,4	93,8%	12824130,9	93,6%	5674644	83,4%
Flooded area	16424000	100%	23 099 554,5	100%	13698300	100%	6804550	100%

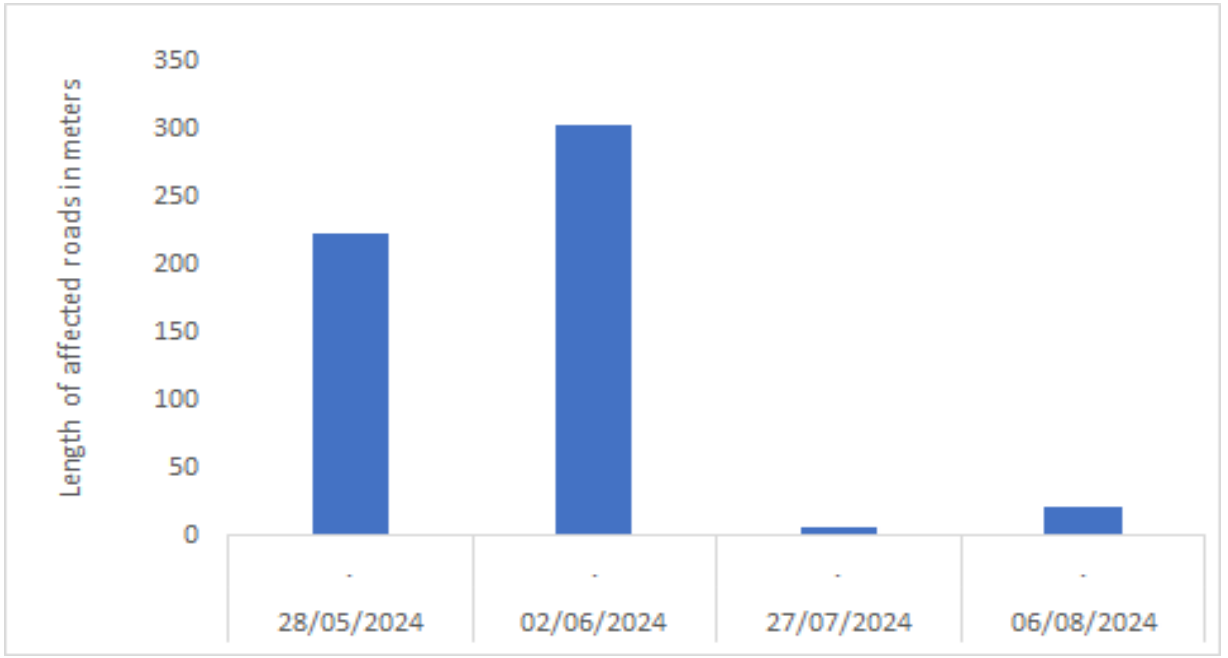
	26/05/2024	05/06/2024	10/07/2024	30/07/2024
	Sup (m²)	Sup (m²)	Sup (m²)	Sup (m²)
Affected building	149036,4908	247088,72	241054,803	388084,052



Results

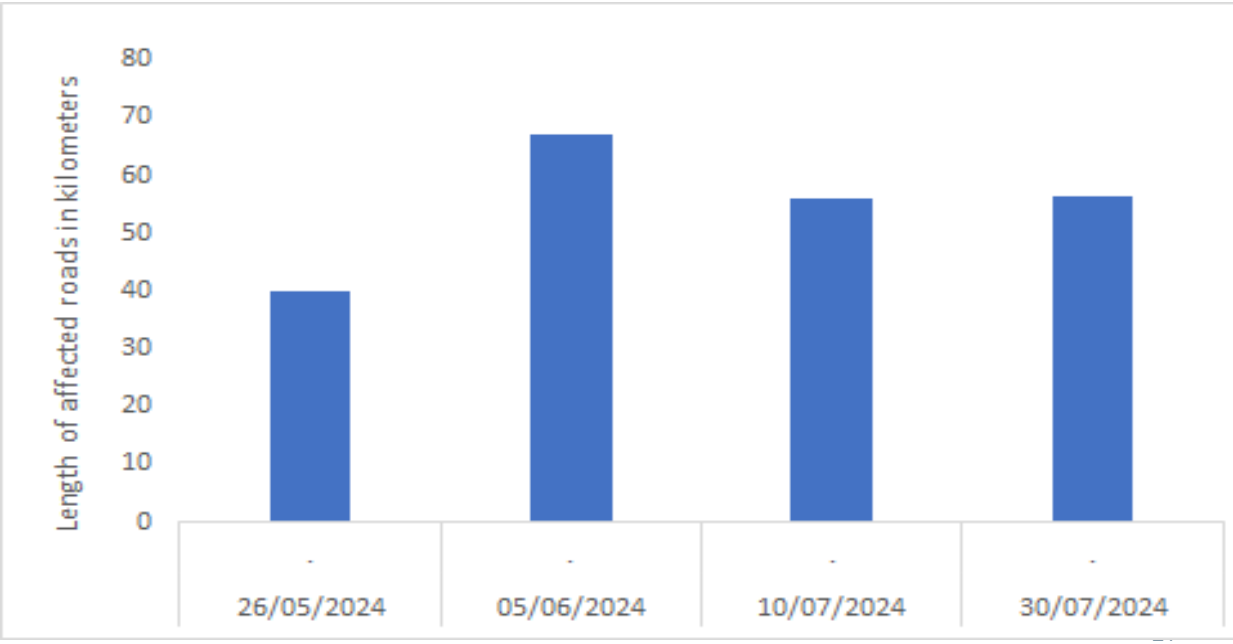
Roads affected by flooding in Abidjan

	28/05/2024	02/06/2024	27/07/2024	06/08/2024
	Longueur (km)	Longueur (km)	Longueur (km)	Longueur (km)
Affected roads	222,58	302,78	5,45	20,96



Roads affected by flooding in Saint Louis

26/05/2024	05/06/2024	10/07/2024	30/07/2024
Longueur (km)	Longueur (km)	Longueur (km)	Longueur (km)
39,9	67,1	55,92	56,36



Conclusion

- This study demonstrated the effectiveness of the U-Net model for **mapping flooded areas in Abidjan and Saint Louis, with remarkable statistical performance.**
- The results indicate a high accuracy in identifying land cover classes, including water, flooded areas, and dry land. However, persistent confusions, particularly between clouds and water surfaces, highlight the need to **improve the model to optimize recognition under conditions of heavy cloud cover.**
- The analysis of the flood maps **revealed that vulnerable areas, often located downstream, are particularly affected by flooding.**
- This study has the advantage of facilitating the **automation of temporal monitoring of floods and the estimation of damages in a given area, with a frequency of every 5 days, after each month, by season, or after each year..**
- Finally, this study calls for interdisciplinary collaboration to better understand flood dynamics and to develop prevention strategies tailored to local contexts. **The results obtained provide a solid foundation for informed decision-making in urban planning and flood risk management.**

THANK YOU FOR YOUR ATTENTION

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