Flood susceptibility mapping based on Fuzzy-AHP model and earth observations: case study of Comoe Basin, Côte d'Ivoire

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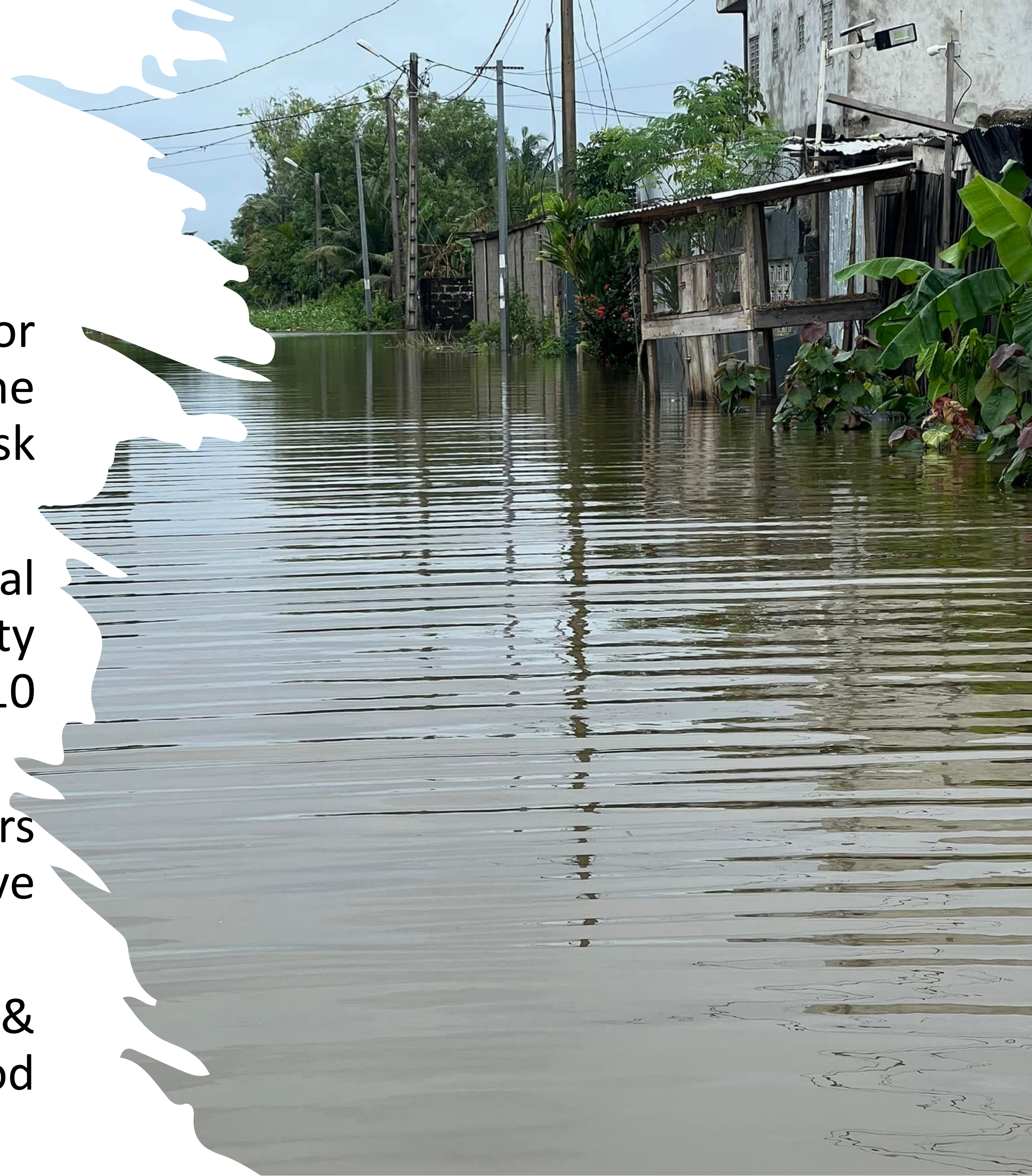
EO AFRICA

BACKGROUND

- Hydroclimatic hazards (floods, storms or droughts) are a global threat according to the United Nations Office for Disaster Risk Reduction (UNISDR, 2015).
- Flooding is one of the most destructive natural hazards claiming lives and causing property damage across the world (Yahaya et al., 2010 and Ouma et al., 2014).
- In Comoe River, Cote d'Ivoire, in recent years frequent catastrophic flood events have occurred
- Riverbed development, high rainfall & geomorphology are important sources of flood risk to agricultural areas and homes



Recent floods in Comoe catchment

Alepe, octobre 2019

Bonoua, octobre 2020

Bassam, octobre 2021

Bassam, juin 2023

Bassam, juin 2023

Considering

- The recurrence of river flooding in the Comoe basin and the resulting damages
- Monitoring and modelling flood damage is still not well developed due to limited access and applications of EO datasets to flood management

OBJECTIVE

➔ Develop a treatment chain to map flood patterns and hazards from Earth Observations

→ Map flood patterns and hazards using a multicriteria analysis approach through Fuzzy-Analytic Hierarchy Process (FAHP)

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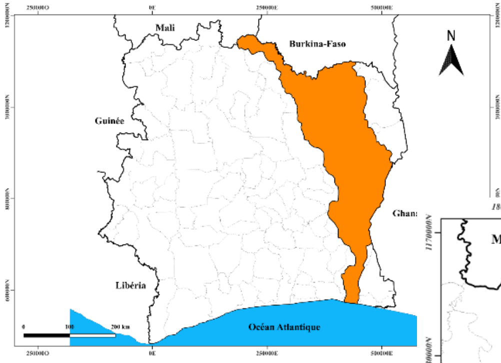
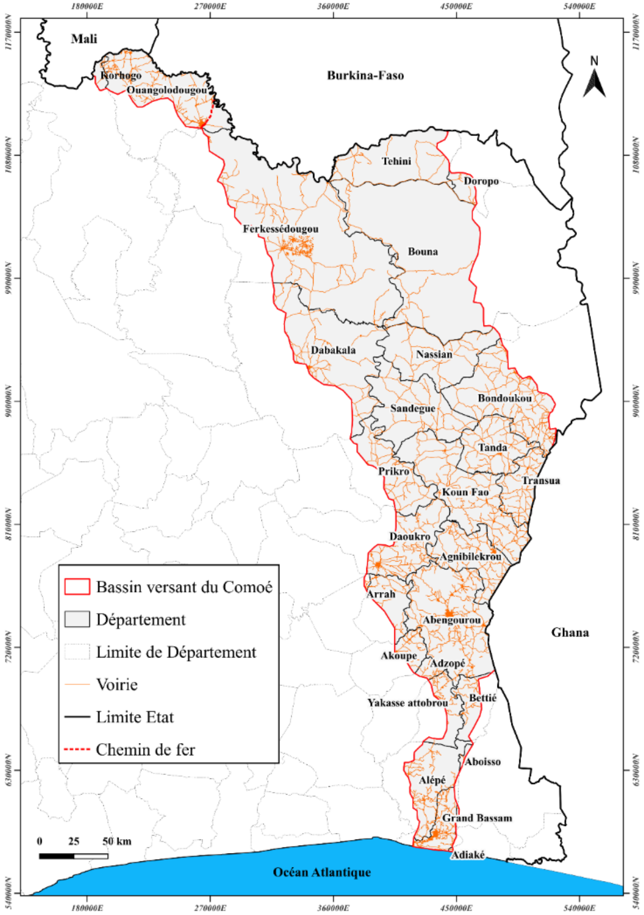
STUDY AREA

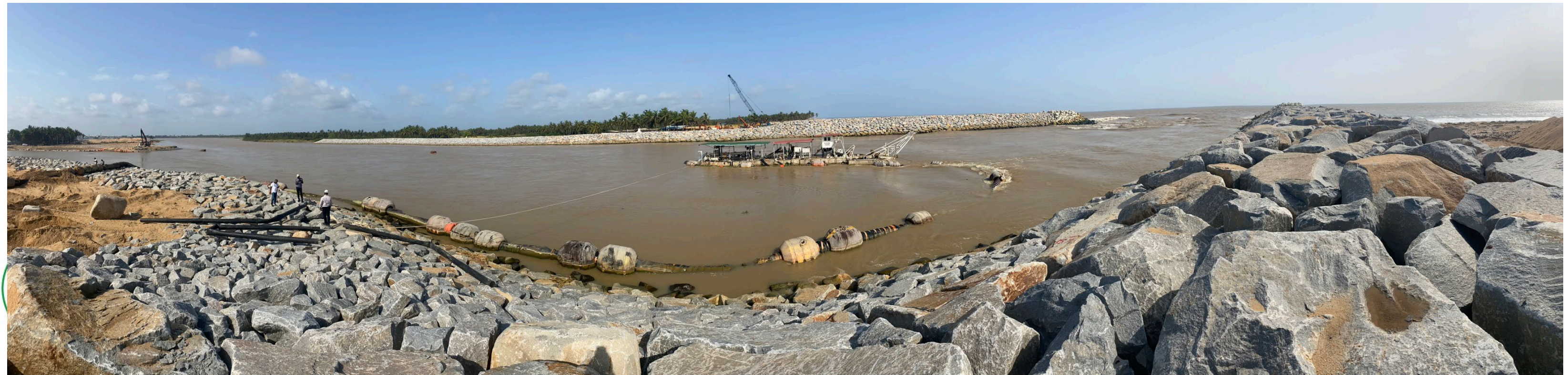
The Comoé national basin is a cross-border basin originating in south-west Burkina Faso, shared mainly between Côte d'Ivoire (80%) and Burkina Faso (18%), with Ghana (2%) and Mali (less than 1%) playing a very minor role.

The River Comoé crosses Côte d'Ivoire from north to south, lying between longitudes West of 3°43'20 to 4°28'57" and latitudes North of 5°11'30" to 10°56'16".

This area partially covers eleven (11) regions and twenty-six administrative departments in Côte d'Ivoire. It has a surface area of **78,100 km²**, including 17,610 km² in Burkina (Hydromet, 2020) and 60,490 km² in Côte d'Ivoire







With a length of **1,160 km** this river emerges at the eastern end of the Ebrié lagoon system at Grand-Bassam.

DATA

- **Data**
  - Satellite Images
    - Sentinel-2 MSI (resolution 10m)
    - DEM from ALOS palsar (12.5m)
  - Maps
    - Administrative
    - Soil
  - Climatic
    - IRI
  - Population
    - Global Human Settlement
    - https://ghsl.jrc.ec.europa.eu/download.php

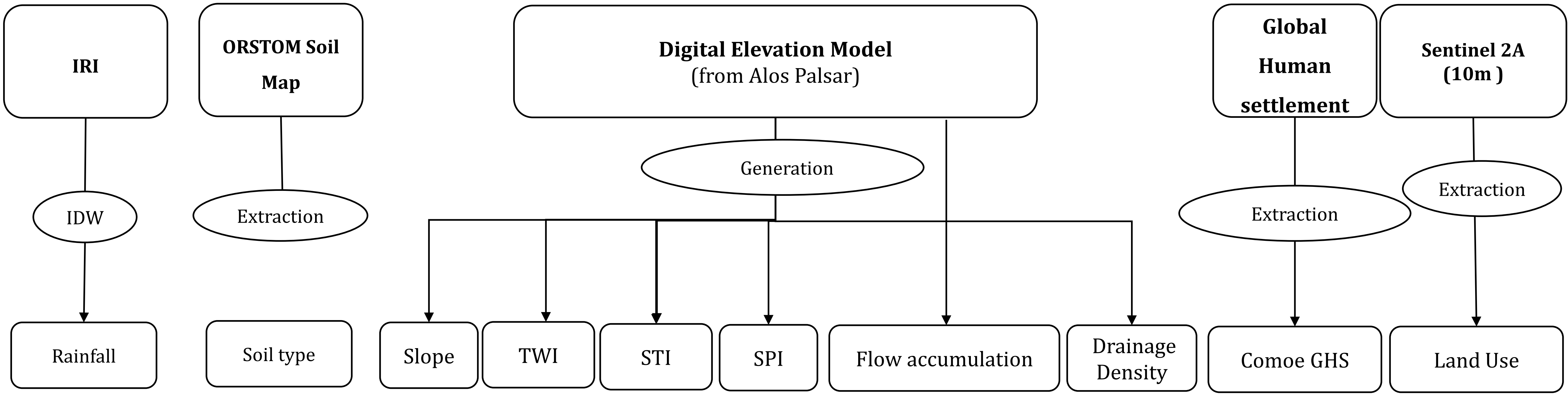
METHODS

Step: factors Selected

10 parameters were considered

- ❖ DEM
  - Slope
  - Flow accumulation
  - Drainage density
  - Soil Type
  - Topographic Wetness Index (TWI)
  - Sediment Transport Index (STI
  - Stream Power index (SPI)
- ❖ Anthropic Factor
  - Land Use
  - Gobal Human Settkement
- ❖ Climatic Factor
  - Rainfall

METHODS



TWI : Topographic Wetness Index

STI : Sediment Transport Index

SPI : Stream Power Index (SPI)

METHODS

Table : AHP Flood susceptibility parameters matrix [A].

	Rainfall	Slope	LULC	Drainage Density		Soil type	flow accuma	GHS settlem	TWI	SPI	STI	∑ rank	Vp	Cp
			k=	10										
Rainfall	1	2	3	4		6	7	8	9	10	11	21,00	1,356	0,109
Slope	1/2	1	2	3		5	6	7	8	9	10	19,00	1,342	0,108
LULC	1/3	1/2	1	2		4	5	6	7	8	9	17,00	1,328	0,107
Drainage Density	1/4	1/3	1/2	1		3	4	5	6	7	8	15,00	1,311	0,106
Soil type	1/6	1/5	1/4	1/3		1	2	3	4	5	6	11,00	1,271	0,102
flow accumation	1/7	1/6	1/5	1/4		1/2	1	2	3	4	5	9,00	1,246	0,100
GHS settlement	1/8	1/7	1/6	1/5		1/3	1/2	1	2	3	4	7,00	1,215	0,098
TWI	1/9	1/8	1/7	1/6		1/4	1/3	1/2	1	2	3	5,00	1,175	0,095
SPI	1/10	1/9	1/8	1/7		1/5	1/4	1/3	1/2	1	2	3,00	1,116	0,090
STI	1/11	1/10	1/9	1/8		1/6	1/5	1/4	1/3	1/2	1	1,50	1,041	0,084
∑	2,82	4,68	7,50	11,22		20,45	26,28	33,08	40,83	49,50	59,00	108,50	12,40	1,00

Table : AHP Flood susceptibility parameters Normalized matrix

	Rainfall	Slope	LULC	Drainage Density		Soil type	flow accuma	GHS settlem	TWI	SPI	STI	∑ rank		[C]	[D] =[A]*[C]	[E]=[D]/[C]	λmax	Ic	Rc
Rainfall	0,35	0,43	0,40	0,36		0,29	0,27	0,24	0,22	0,20	0,19	2,95		0,295	3,289	11,151			
Slope	0,18	0,21	0,27	0,27		0,24	0,23	0,21	0,20	0,18	0,17	2,16		0,216	2,436	11,294			
LULC	0,12	0,11	0,13	0,18		0,20	0,19	0,18	0,17	0,16	0,15	1,59		0,159	1,679	10,564			
Drainage Density	0,09	0,07	0,07	0,09		0,15	0,15	0,15	0,15	0,14	0,14	1,19		0,119	1,319	11,089	10,578	0,064	0,043
Soil type	0,06	0,04	0,03	0,03		0,05	0,08	0,09	0,10	0,10	0,10	0,68		0,068	0,724	10,627			Soit
flow accumation	0,05	0,04	0,03	0,02		0,02	0,04	0,06	0,07	0,08	0,08	0,50		0,050	0,514	10,347			
GHS settlement	0,04	0,03	0,02	0,02		0,02	0,02	0,03	0,05	0,06	0,07	0,36		0,036	0,363	10,144			4,31%
TWI	0,04	0,03	0,02	0,01		0,01	0,01	0,02	0,02	0,04	0,05	0,26		0,026	0,258	10,072			
SPI	1/28	0,02	0,02	0,01		0,01	0,01	0,01	0,01	0,02	0,03	0,18		0,018	0,187	10,153			
STI	0,03	0,02	0,01	0,01		0,01	0,01	0,01	0,01	0,01	0,02	0,14		0,014	0,143	10,333			
∑	1,00	1,00	1,00	1,00		1,00	1,00	1,00	1,00	1,00	1,00	10,00		1,000		105,775			

METHODS

FUZZIFICATION

- Determining the universe of discourse
- Determining language variables
- Define the membership function from 0 to 1

Fuzzy inference engine

- List all inference rules

Defuzzification

- Moving from a linguistic result to a numerical result

METHODS

Table : Flood susceptibility parameters fuzzy matrix [A].

	Rainfall	Slope	LULC	Drainage Density	Soil type	flow accuma	GHS settleme	TWI	SPI	STI
Rainfall	(1,1,1)	(1,2,3)	(2,3,4)	(3,4,5)	(5,6,7)	(6,7,8)	(7,8,9)	(8,9,10)	(9,10,11)	(11,11,11)
Slope	(1/3,1/2,1)	(1,1,1)	(1,2,3)	(2,3,4)	(4,5,6)	(5,6,7)	(6,7,8)	(7,8,9)	(8,9,10)	(9,10,11)
LULC	(1/4,1/3,1/2)	(1/3,1/2,1)	(1,1,1)	(1,2,3)	(3,4,5)	(4,5,6)	(5,6,7)	(6,7,8)	(7,8,9)	(8,9,10)
Drainage Density	(1/5,1/4,1/3)	(1/4,1/3,1/2)	(1/3,1/2,1)	(1,1,1)	(2,3,4)	(3,4,5)	(4,5,6)	(5,6,7)	(6,7,8)	(7,8,9)
Soil type	(1/7,1/6,1/5)	(1/6,1/5,1/4)	(1/5,1/4,1/3)	(1/4,1/3,1/2)	(1,1,1)	(1,2,3)	(2,3,4)	(3,4,5)	(4,5,6)	(5,6,7)
flow accumation	(1/8,1/7,1/6)	(1/7,1/6,1/5)	(1/6,1/5,1/4)	(1/5,1/4,1/3)	(1/3,1/2,1)	(1,1,1)	(1,2,3)	(2,3,4)	(3,4,5)	(4,5,6)
GHS settlement	(1/9,1/8,1/7)	(1/8,1/7,1/6)	(1/7,1/6,1/5)	(1/6,1/5,1/4)	(1/4,1/3,1/2)	(1/3,1/2,1)	(1,1,1)	(1,2,3)	(2,3,4)	(3,4,5)
TWI	(1/10,1/9,1/8)	(1/9,1/8,1/7)	(1/8,1/7,1/6)	(1/7,1/6,1/5)	(1/5,1/4,1/3)	(1/4,1/3,1/2)	(1/3,1/2,1)	(1,1,1)	(1,2,3)	(2,3,4)
SPI	(1/11,1/10,1/9)	(1/10,1/9,1/8)	(1/9,1/8,1/7)	(1/8,1/7,1/6)	(1/6,1/5,1/4)	(1/5,1/4,1/3)	(1/4,1/3,1/2)	(1/3,1/2,1)	(1,1,1)	(1,2,3)
STI	(1/11,1/11,1/11)	(1/11,1/10,1/9	(1/10,1/9,1/8	(1/9,1/8,1/7)	(1/7,1/6,1/5)	(1/6,1/5,1/4)	(1/5,1/4,1/3)	(1/4,1/3,1/2)	(1/3,1/2,1)	(1,1,1)

Table : Flood susceptibility parameters fuzzy normalized weight .

10 parameters were considered

	Fuzzy weight [W̃i =t̃i * ((∑t̃i)^-1)]			Weight (wi)	**Normalized weight**
Rainfall	0,189	0,279	0,396	0,288	**0,27**
Slope	0,140	0,212	0,321	0,224	**0,21**
LULC	0,104	0,158	0,245	0,169	**0,16**
Drainage Density	0,079	0,118	0,183	0,127	**0,12**
Soil type	0,047	0,069	0,104	0,073	**0,07**
flow accumation	0,033	0,053	0,085	0,057	**0,05**
GHS settlement	0,027	0,040	0,061	0,043	**0,04**
TWI	0,020	0,030	0,047	0,032	**0,03**
SPI	0,015	0,022	0,035	0,024	**0,02**
STI	0,012	0,017	0,026	0,018	**0,02**
∑				1,06	**1,00**

METHODS

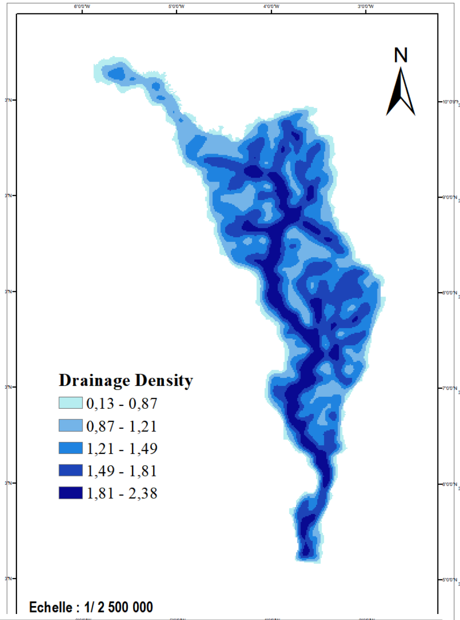
0.12 x Drainage density
+
0.21 x Slope
+
0.07 x Soil type
+
0.03 x TWI
+
0.02 x STI
+
0.02 x SPI
+
0.05 x Flow accumulation

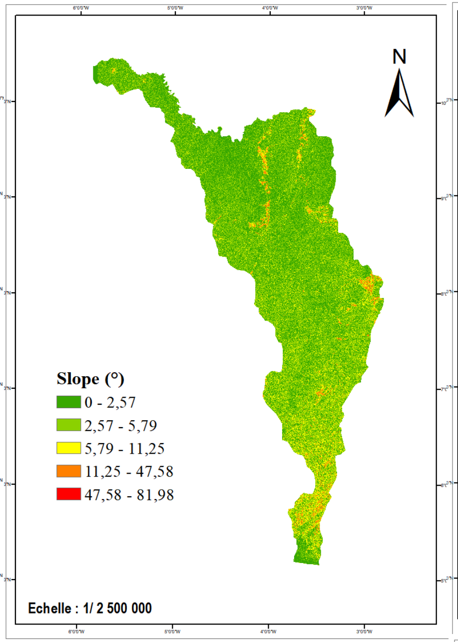
0.27 x Rainfal
+
0.16 x Land Use
+
0.04 x Global Human settlement

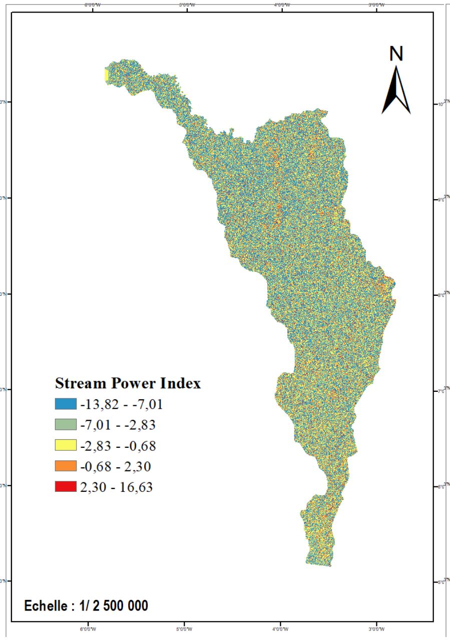
AHP-fuzzy process

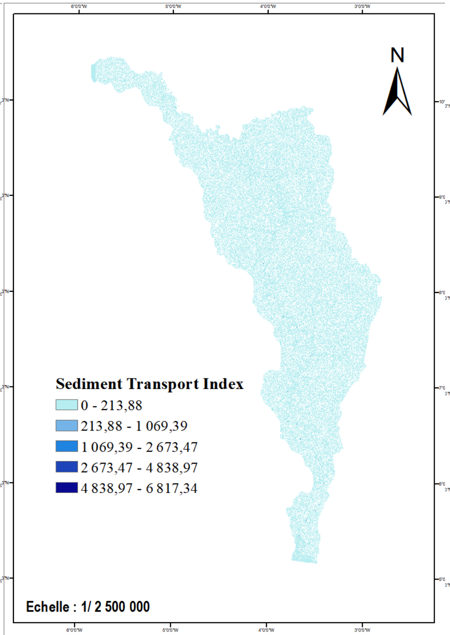
Flood risk map

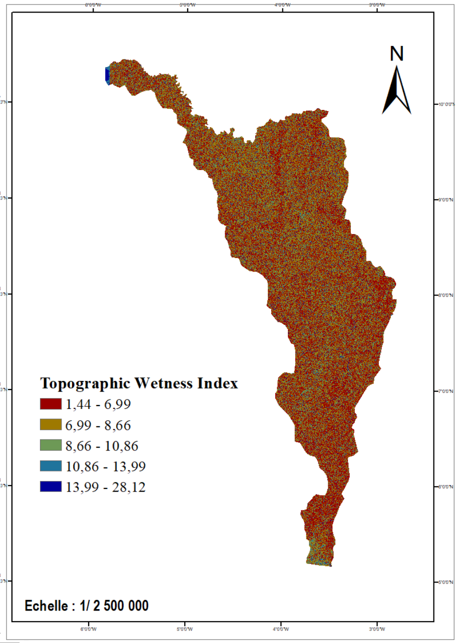
RESULTS

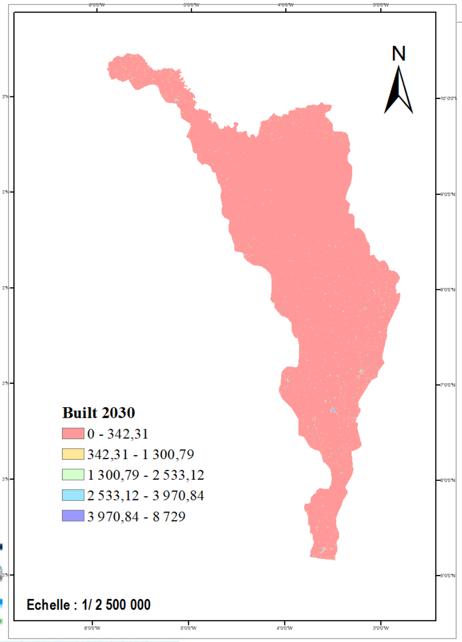

N
Drainage Density
0,13 - 0,87
0,87 - 1,21
1,21 - 1,49
1,49 - 1,81
1,81 - 2,38
Echelle : 1/ 2 500 000

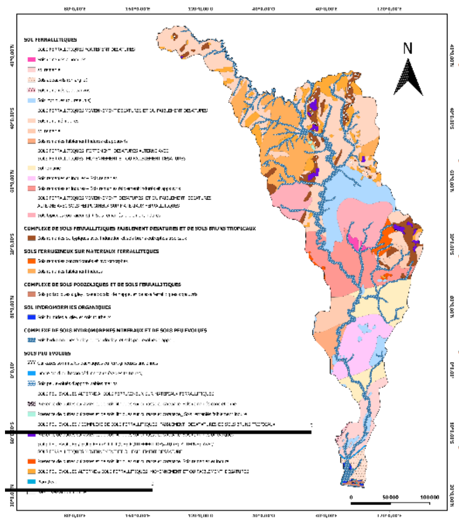

N
Slope (°)
0 - 2,57
2,57 - 5,79
5,79 - 11,25
11,25 - 47,58
47,58 - 81,98
Echelle : 1/ 2 500 000

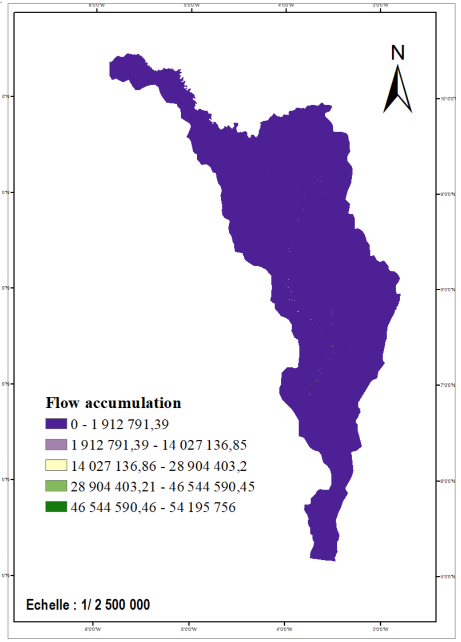

N
Stream Power Index
-13,82 - -7,01
-7,01 - -2,83
-2,83 - -0,68
-0,68 - 2,30
2,30 - 16,63
Echelle : 1/ 2 500 000

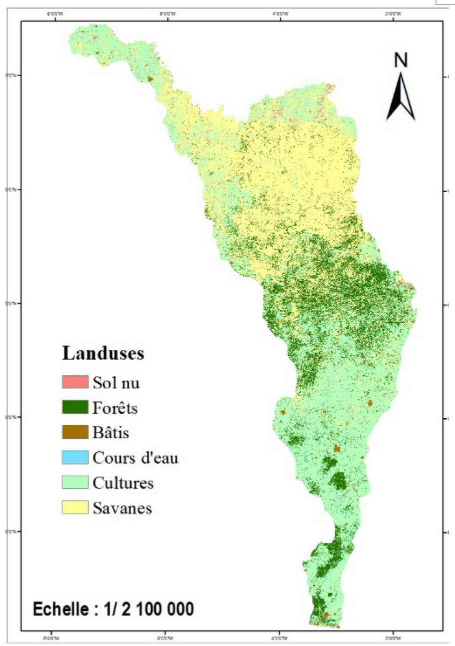

N
Sediment Transport Index
0 - 213,88
213,88 - 1 069,39
1 069,39 - 2 673,47
2 673,47 - 4 838,97
4 838,97 - 6 817,34
Echelle : 1/ 2 500 000

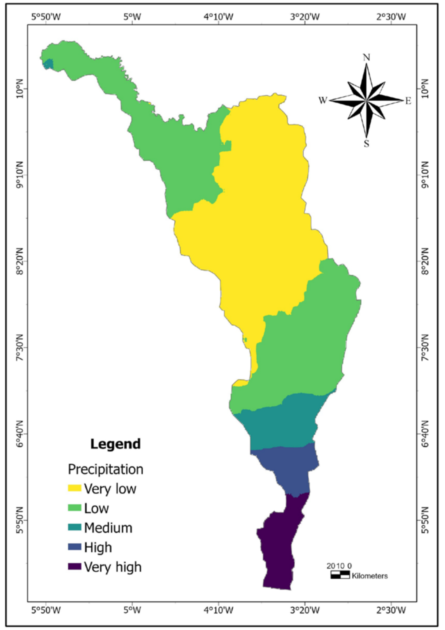

N
Topographic Wetness Index
1,44 - 6,99
6,99 - 8,66
8,66 - 10,86
10,86 - 13,99
13,99 - 28,12
Echelle : 1/ 2 500 000


N
Built 2030
0 - 342,31
342,31 - 1 300,79
1 300,79 - 2 533,12
2 533,12 - 3 970,84
3 970,84 - 8 729
Echelle : 1/ 2 500 000

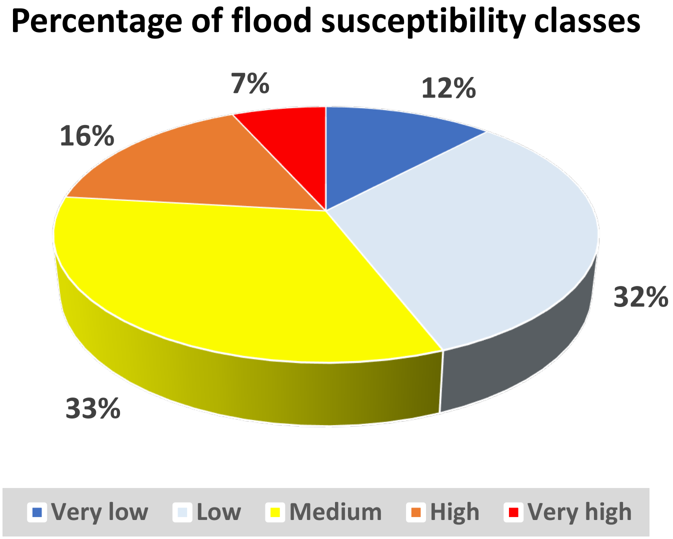

N

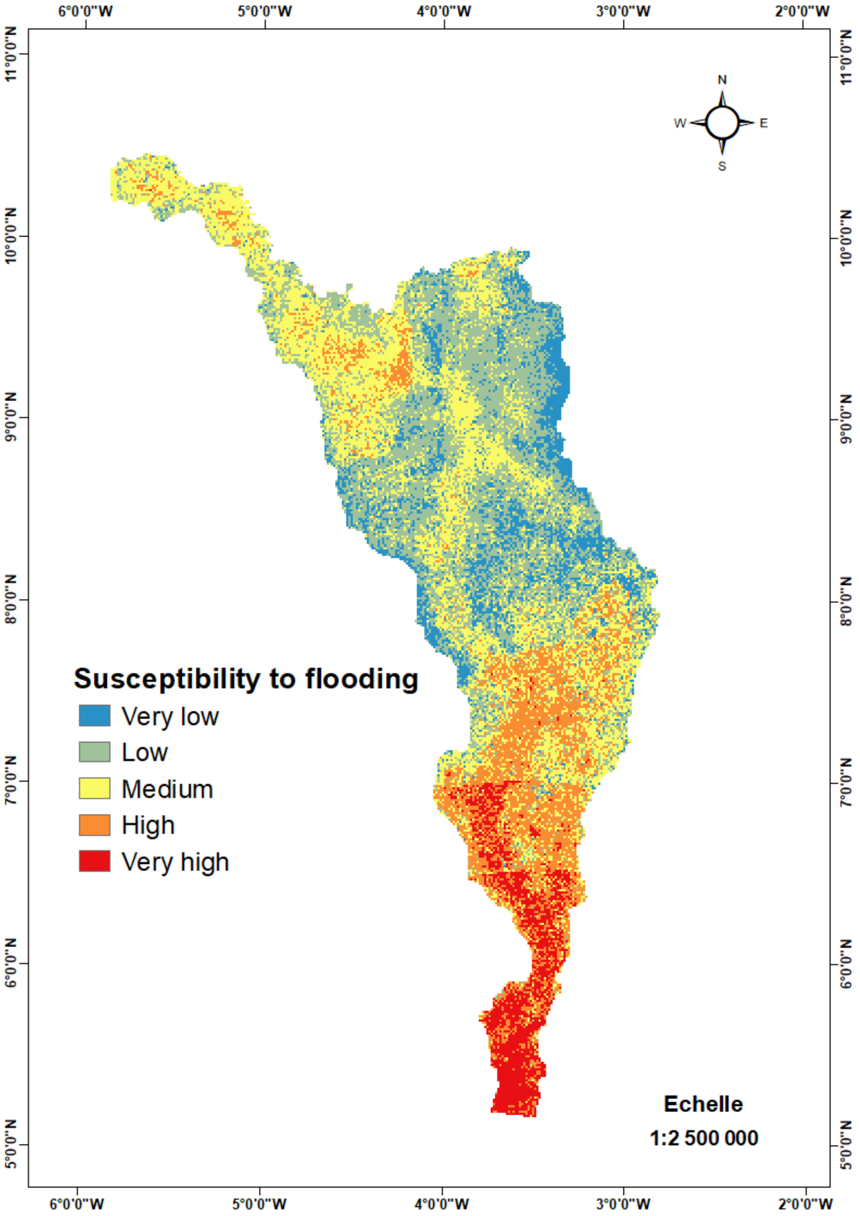

N
Flow accumulation
0 - 1 912 791,39
1 912 791,39 - 14 027 136,85
14 027 136,86 - 28 904 403,2
28 904 403,21 - 46 544 590,45
46 544 590,46 - 54 195 756
Echelle : 1/ 2 500 000


N
Landuses
Sol nu
Forêts
Bâtis
Cours d'eau
Cultures
Savanes
Echelle : 1/ 2 100 000


5°50'W
5°W
4°10'W
3°20'W
2°30'W
10°N
9°10'N
8°20'N
7°30'N
6°40'N
5°50'N
N
W
E
S
Legend
Precipitation
Very low
Low
Medium
High
Very high
Kilometers

RESULTS





▪Comoe catchment is half dominated by areas at medium risk of flooding (33%) and high and very high risk of flooding (23%) with AHP method.

CONCLUSIONS

- The AHP multi-criteria method, combined with Fuzzy method, was used to map flood risk areas from ESA EO data in the Comoe catchment.
- Comoe catchment is half dominated by areas at medium, high and very high risk of flooding with AHP method.
- Results notably highlight the importance of multiple factors beyond rainfall and confirm the importance of slope, LULC and drainage density in the onset of floods in the Comoe catchment.
- These results can help operational partners identify existing and future area subject to flood risks and design strategies to reduce risks in Comoe catchment

BENEFICIARIES

National Stakeholders

Municipality

THANK YOU FOR YOUR ATTENTION

UNIVERSITÉ Félix HOUPHOUËT-BOIGNY

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