Monitoring climatic and environmental conditions of Dengue-2 virus outbreak in the Kedougou area (South-East Senegal, West Africa) using Earth Observation data and GIS: Preliminary results

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Dengue-2 virus

Introduction

- In the Kedougou area (South East Senegal, West Africa), entomological and virogical studies have often led to the isolation of Dengue-2 virus from *Aedes Aegypty* mosquitoes.

- Dengue-2 virus outbreaks happen almost regularly over this area and seem to be linked with climatic and environmental changes.

- These factors play a crucial role in the abundance and distribution of the mosquitoes, vectors of the disease.

- In the absence of vaccine and specific medical treatment, RS and GIS technologies are expected to play a key role in the strategy of control and surveillance of the disease.

- In numerous epidemiological studies, they have shown to be very efficient in identifying areas and periods at risk and have led to an amelioration of the prevention techniques.

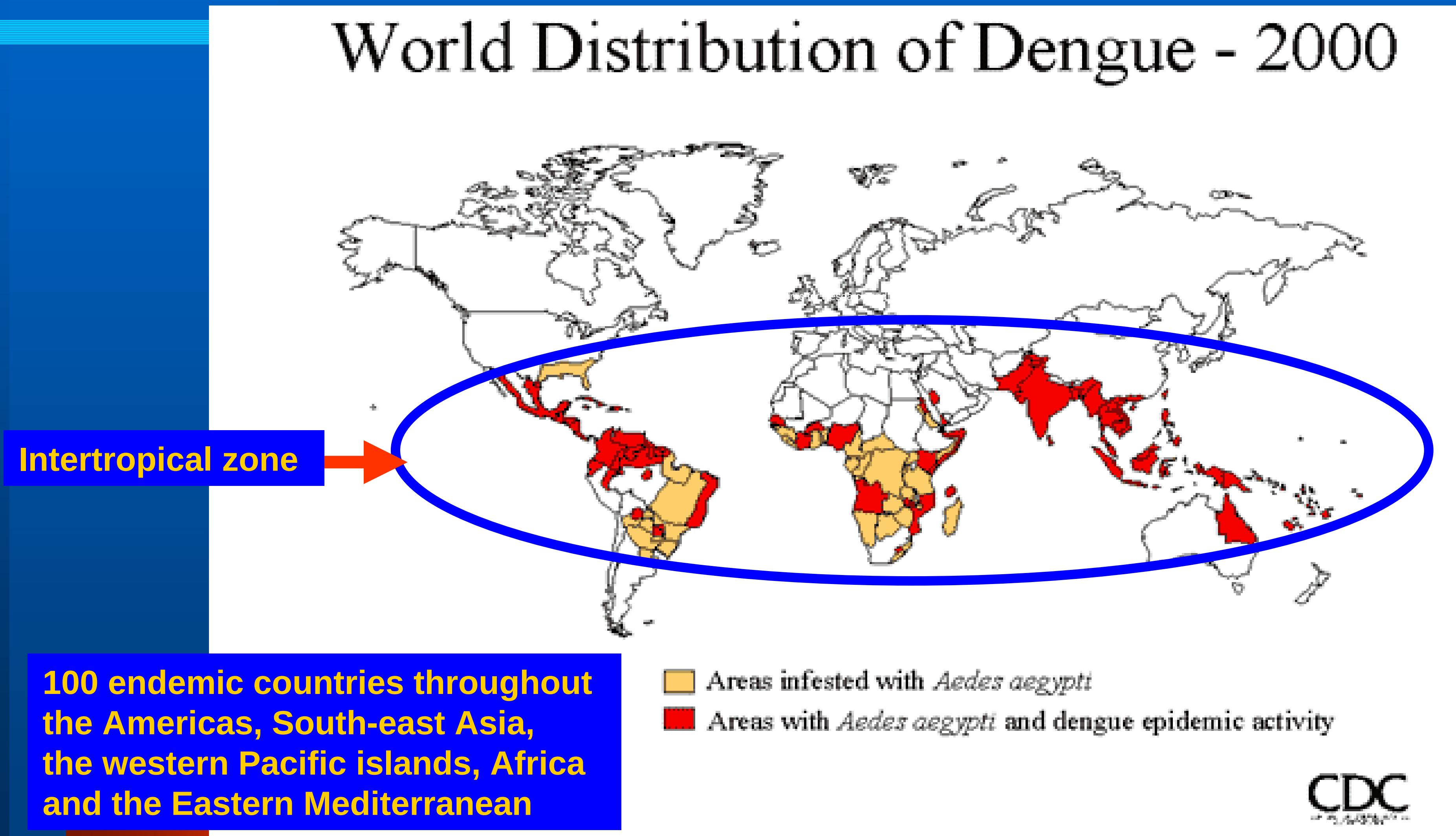
- What are the possible relationships between climatic/environmental factors and Dengue-2 virus outbreaks in the study area ? What contribution of RS and GIS?

General scope

✓Disease information

☞Distribution

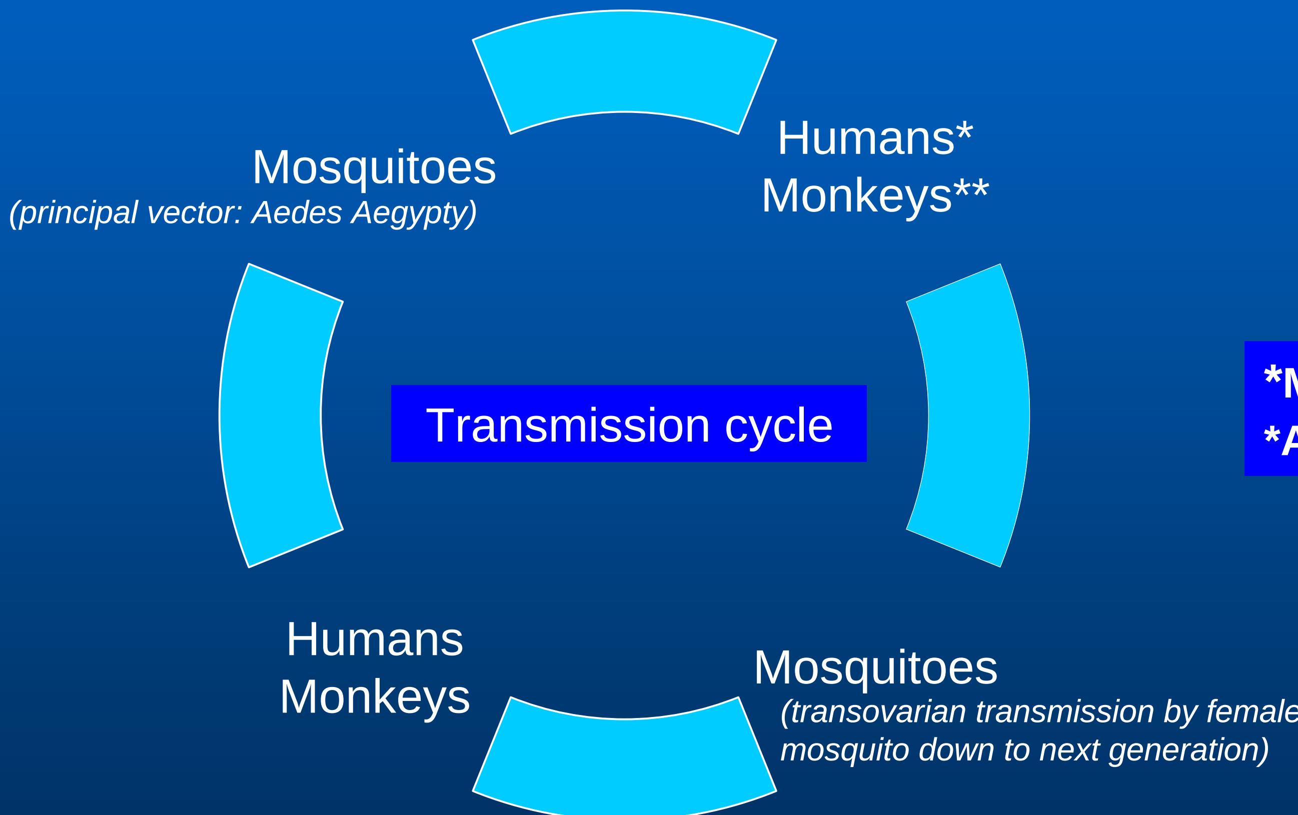
See the Website of the UNICEF-UNDP-World Bank-WHO Special Programme for Research and Training in Tropical Deseases http://www.who.int/tdr/index.html



100 endemic countries throughout the Americas, South-east Asia, the western Pacific islands, Africa and the Eastern Mediterranean

✓Causative agent: Arthropod-borne virus belonging to the family Flaviviridae
There are 4 known serotypes: DEN-1, DEN-2, DEN-2, DEN-4

✓Dengue virus is transmitted via the bite of various day-feeding mosquitoes



***Major targets**
***Accidental targets**

✓*Some monkeys may also serve as a source of the virus*

✓Various symptoms include:

- Flu-like illness
- Undifferentiated febrile disease with rash
- Mild febrile fever
- High fever, severe headache, pain behind the eyes, muscle and joint pains and rash
- Dengue haemorrhagic fever (DHF)

✓Prevention and control

- No specific treatment
- Close medical attention and clinical management to save the life of the patient
- Controlling dengue and DHF: combat the vector mosquito by clean-up campaigns, elimination of potential breeding sites for vector mosquitoes, treatment of larval habitats with insecticides

> *DHF responsible of* ***20 000 deaths/year***
>
> ***2,5 billions are exposed***
>
> *more than* ***100 millions*** *infected/year worldwide*

Dengue reported in Africa: some examples

✓In South Africa

☞*Durban (1926-1927): 40 000 persons infected*

✓In Nigeria

☞*Jos: Dengue-2 virus isolated from Aedes mosquitoes in 1969*

✓In Senegal

☞ *Evidence of Dengue-2 virus isolated from a human blood sample in Bandia village (Kedougou, South-Eastern region) in October 1970*

☞ *A montoring and control programme of Dengue and Yellow Fever: discovery of several outbreak cycles of Dengue-2 in 1970, 1980, 1981, 1982, 1989, 1990, 1999 and 2000*

☞*Our research focuses on the outbreaks of the period 1989-2000*

Monitoring environmental and climatic conditions of Dengue-2 outbreak

Study area

☞*Dengue-2 outbreak cycles are linked with climatic and environmental changes*

☞*Can RS and GIS technologies help in epidemiological studies as efficient tools in monitoring and evaluating those changes and helping build prevention strategies?*

Imagery and ancillary data

- ***Satellite imagery***

Year	1988	1990	1995	1999	2000	2001
Date	Dec. 10	Dec. 24	Oct. 11	Oct. 30	Dec. 19	Ap. 26
Sensor	TM	TM	TM	ETM+	ETM+	ETM+
Emergence	No	Yes	No	Yes	Yes	No

- ***Climatic data: rainfall, relative moisture, temperature***
- ***Biological data: entomological, virological***

Data processing

✓Pre-processing

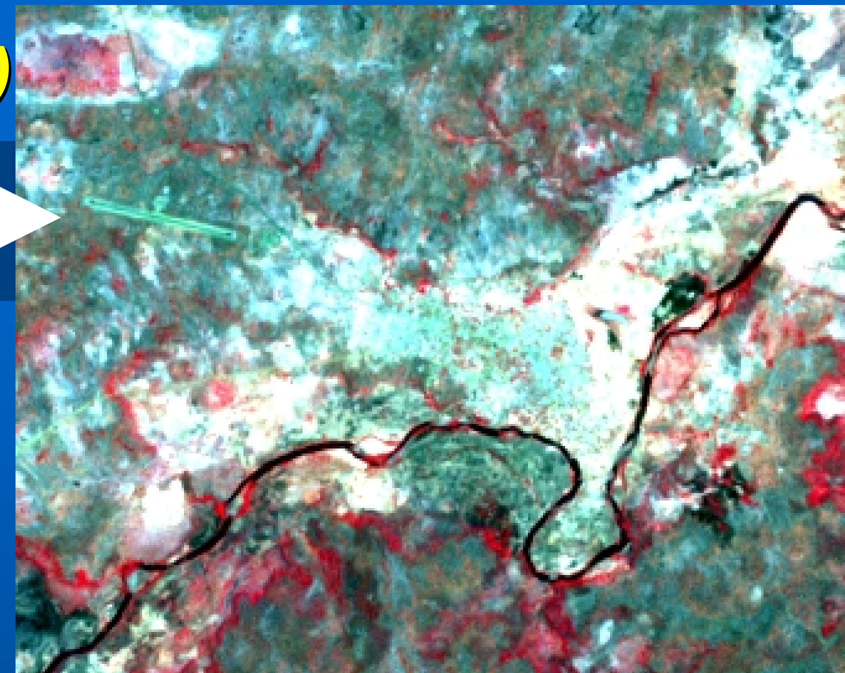
- ☞ *Geometric corrections*
- ☞ *Radiometric normalization*

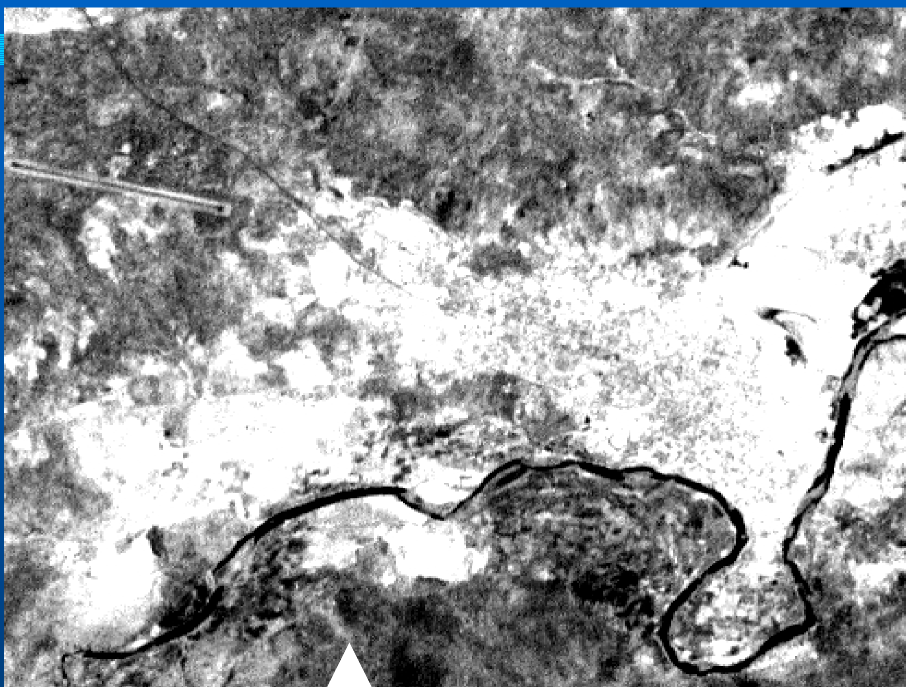
✓Processing

- ☞ *Spatial enhancement*
- ☞ *NDVI Calculation (Normalized Vegetation Index)*
- ☞ *Classification*
- ☞ *Fieldwork (ground truthing)*

Spatial enhancement (resolution merge)

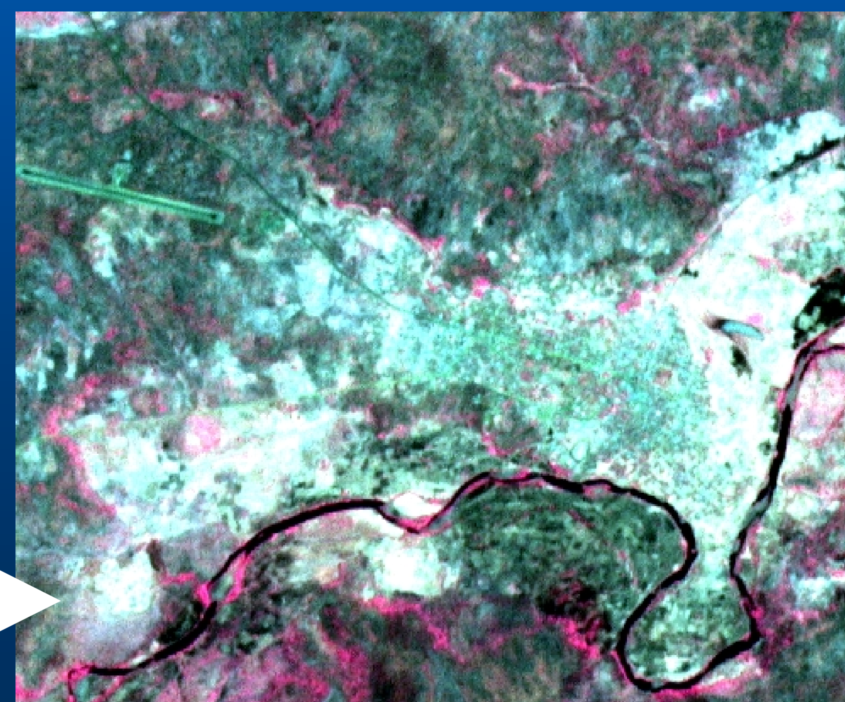
CIR 432 (RGB): 30m resolution



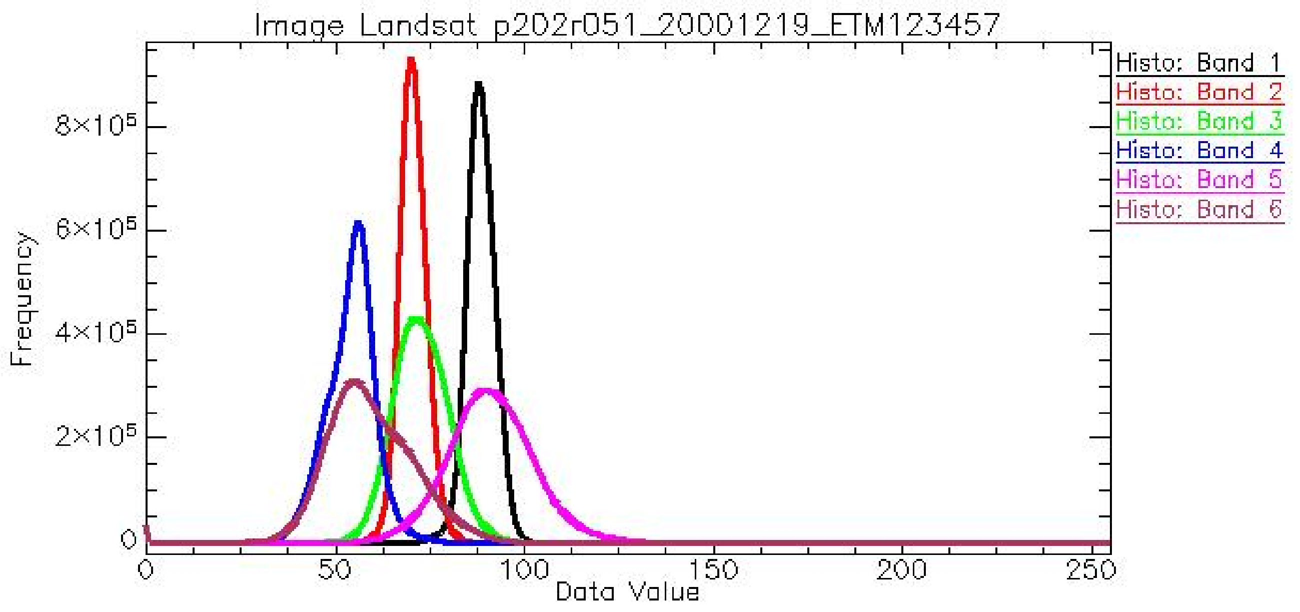


Panchromatic band: 15m resolution

CIR 432 (RGB): 15m resolution



Radiometric normalization (homogenization of pixels distribution)

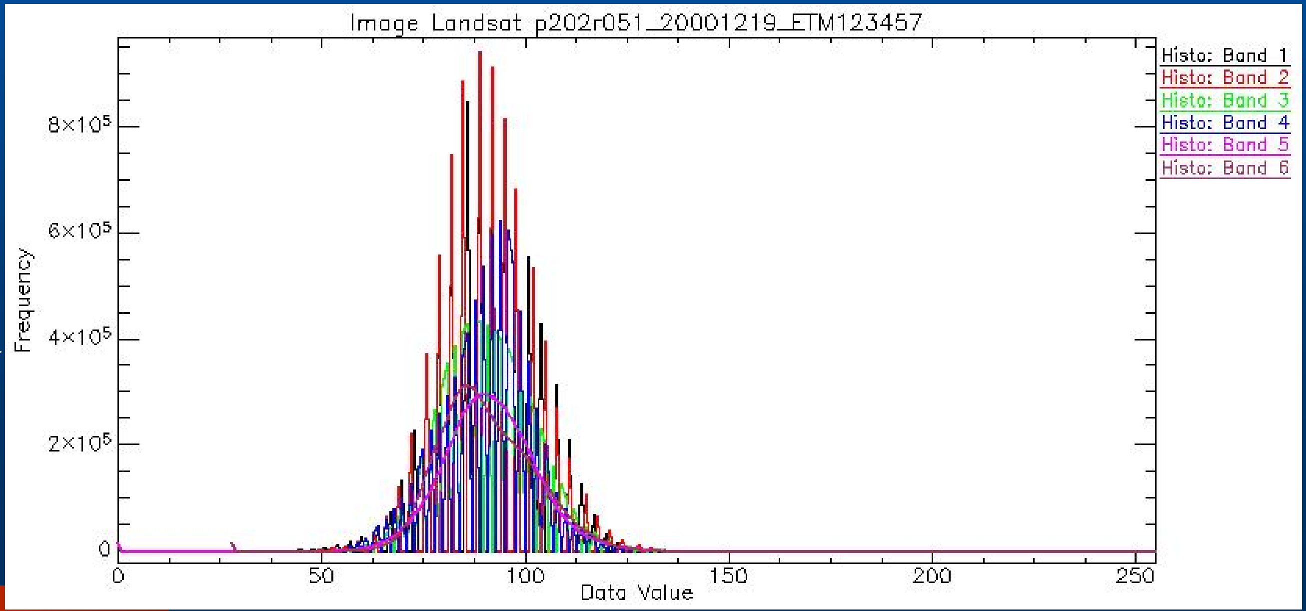


Raw data statistics

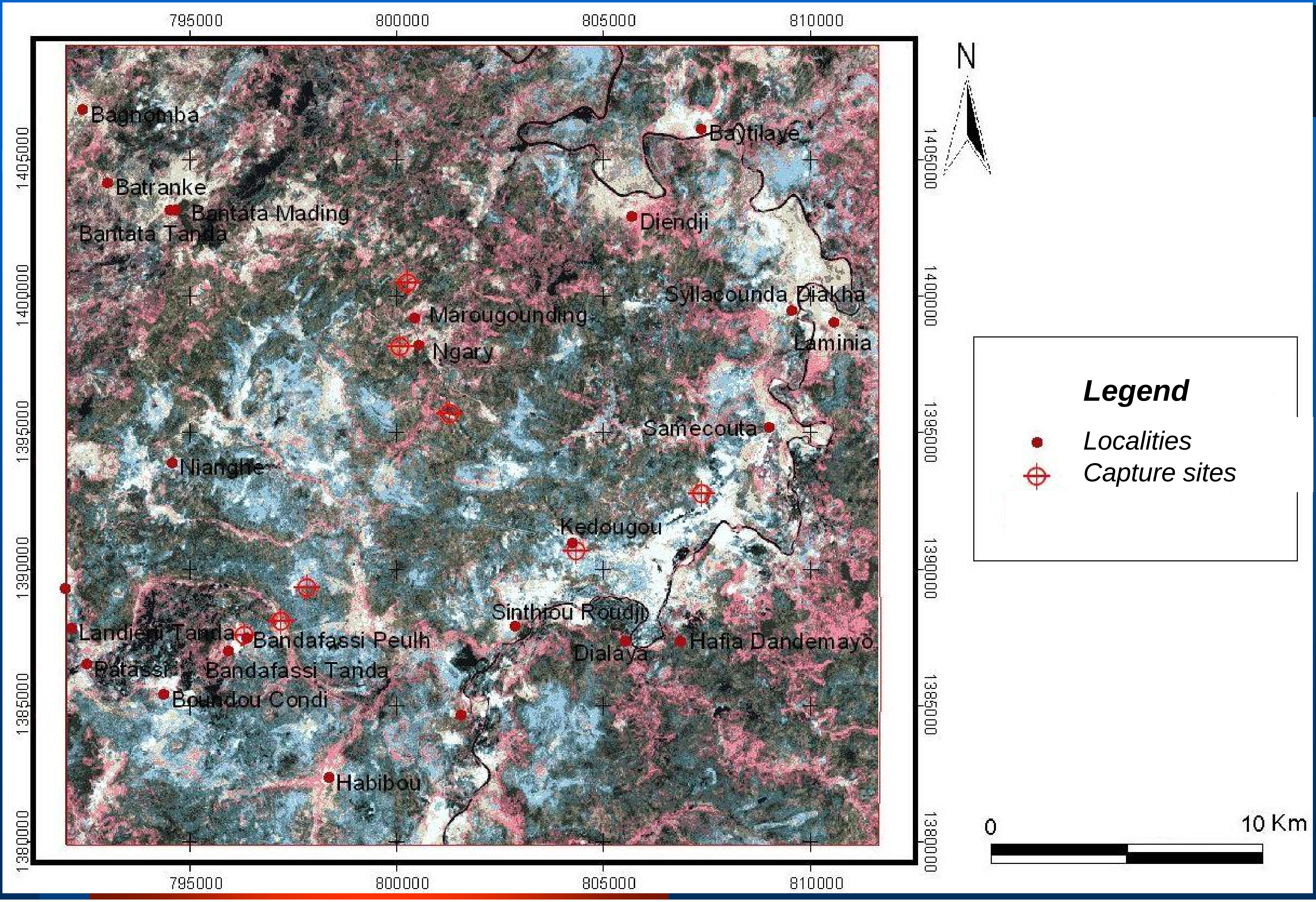
Bands	Min	Max	Mean	St. dev.
ETM 1	70	102	89	3.723
ETM 2	53	91	71	3.592
ETM 3	46	119	72	7.336
ETM 4	28	88	55	6.409
ETM 5	36	175	91	11.703
ETM 7	25	251	58	11.239

Normalized data statistics

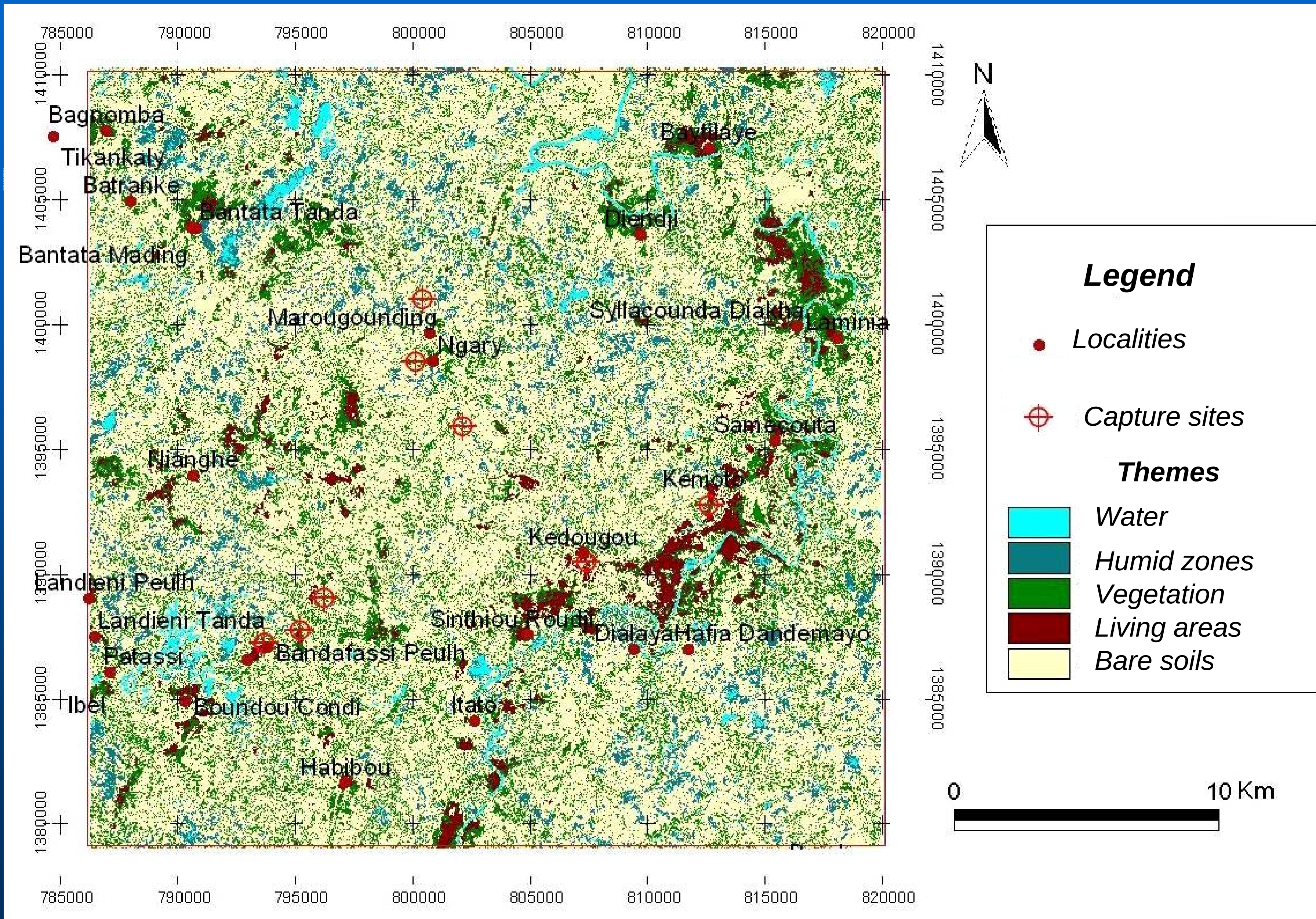
Bands	Min	Max	Mean	St. dev.
ETM 1	32	133	92	11.714
ETM 2	33	157	92	11.683
ETM 3	48	164	89	11.706
ETM 4	43	152	92	11.716
ETM 5	36	175	91	11.703
ETM 7	55	255	89	11.638



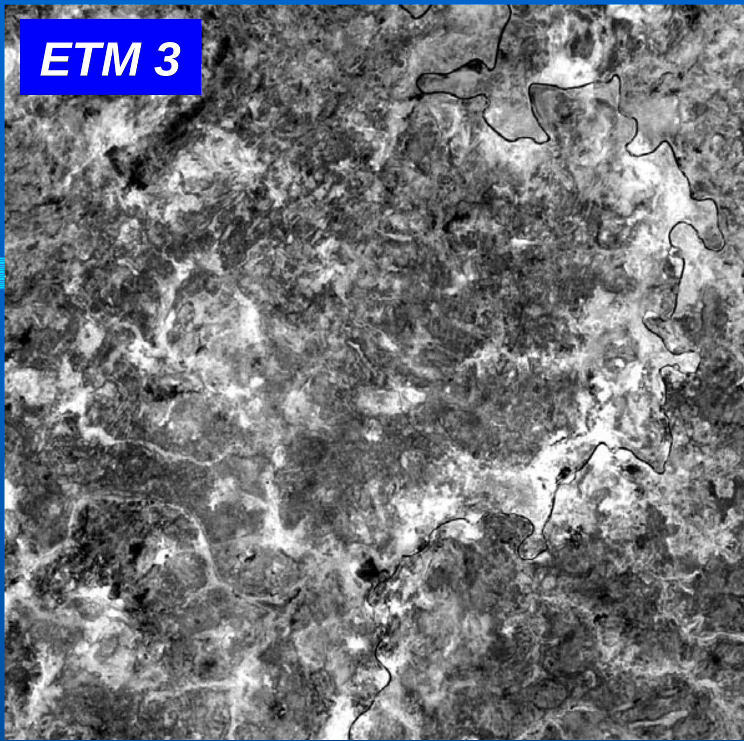
☞ *Unsupervised classification (for field studies)*

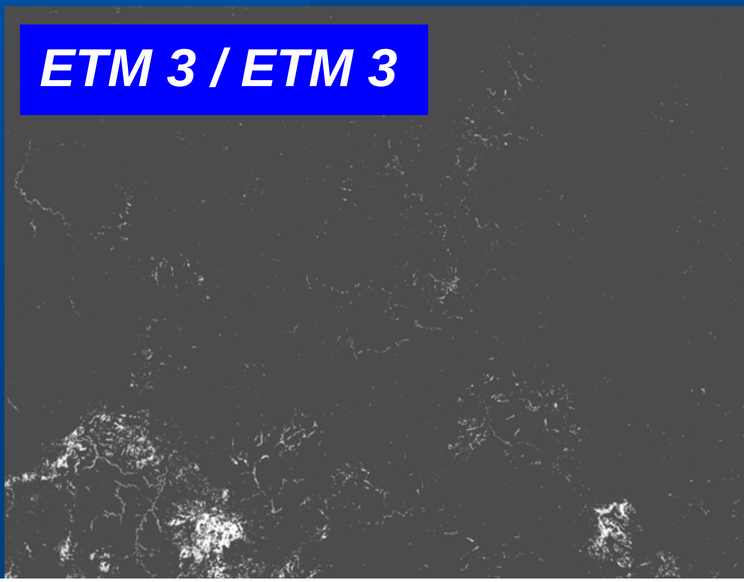


Supervised classification



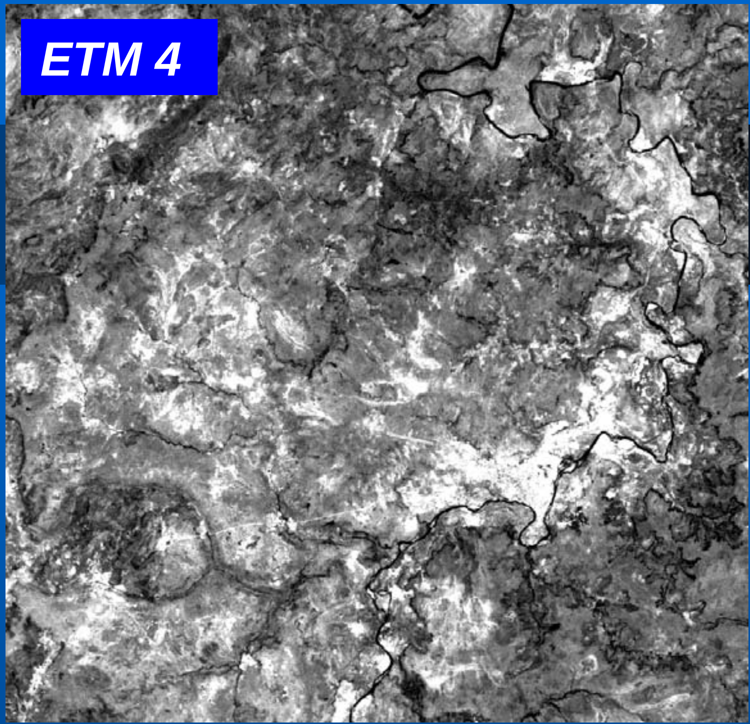
☞ Vegetation Index

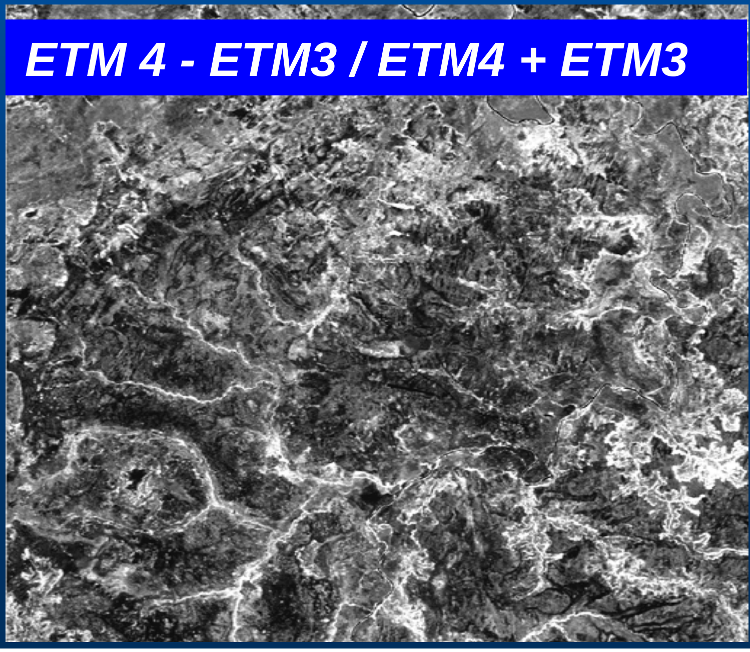




$$NDVI = \frac{PIR - R}{PIR + R}$$

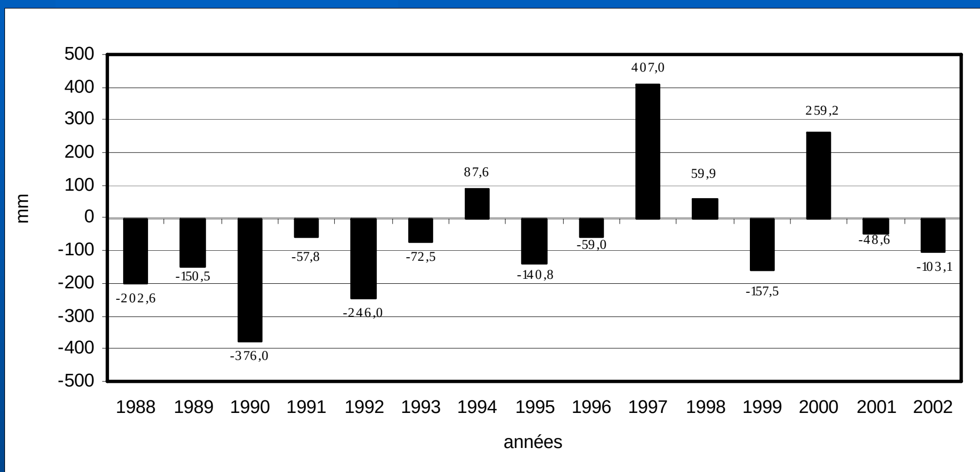
$$= \frac{ETM\,4 - ETM\,3}{ETM\,4 + ETM\,3}$$



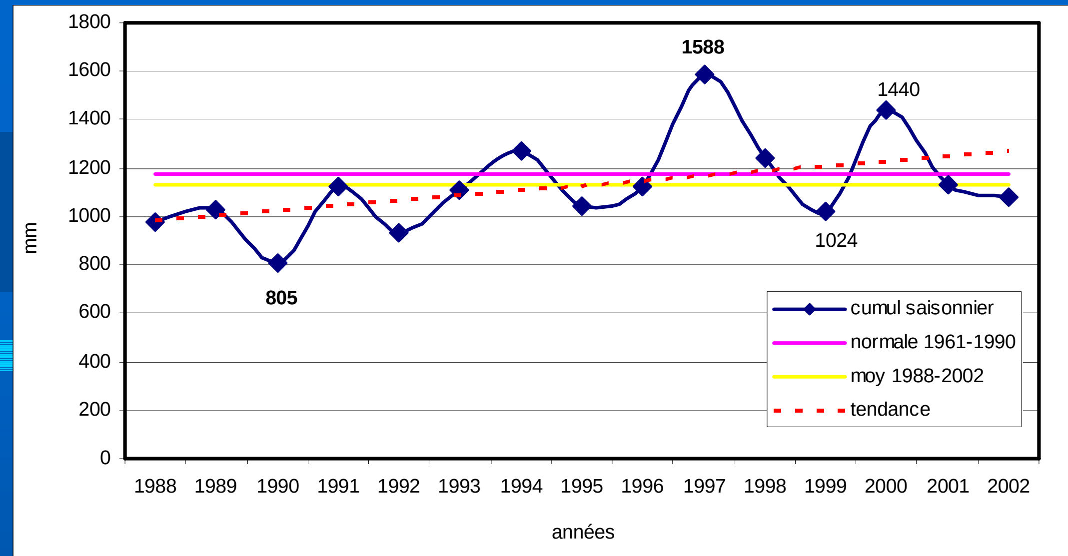


Results

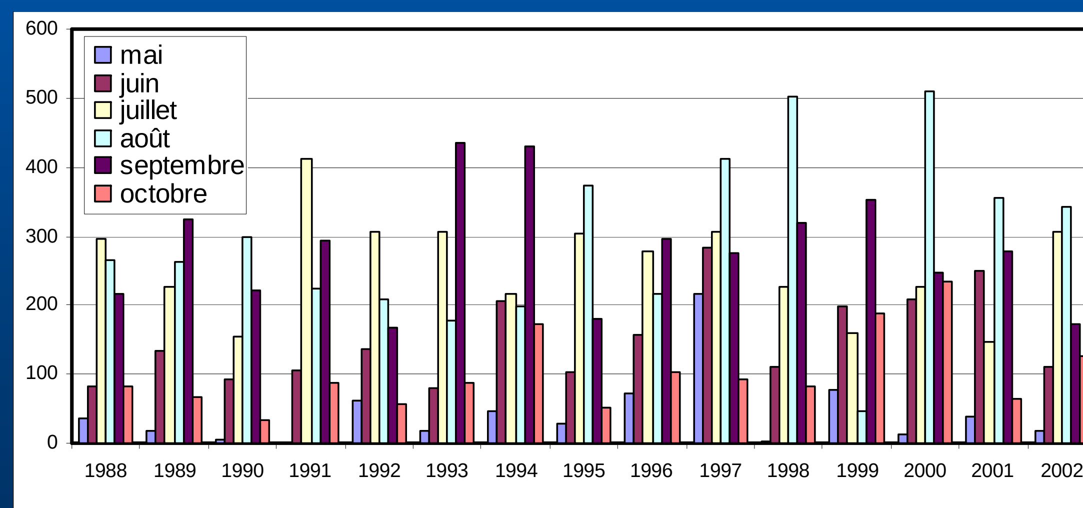
✓Rainfall estimates



Evolution of seasonal rainfall (1988-2002) vs. average seasonal reference (1961-1990)



Evolution of seasonal rainfall (1988-2002)



Total amount of monthly seasonal rainfall (1988-2002)

Results

✓Rainfall estimates
Despite a strong rainfall variability, there is no evident relationship between seasonal rainfall and Dengue-2 virus outbreak

Years	Dengue-2 outbreak	may	june	july	august	september	october
1988	No	–	–	+	N	–	–
1989	Yes	–	N	N	N	+	–
1990	Yes	–	–	–	N	–	–
1991	No	–	–	+	–	N	–
1992	No	+	N	+	–	–	–
1993	No	–	–	+	–	+	–
1994	No	N	+	N	–	+	+
1995	No	–	–	+	+	–	–
1996	No	+	N	N	–	N	N
1997	No	+	+	+	+	N	N
1998	No	–	–	N	+	+	–
1999	Yes	+	+	–	–	+	+
2000	Yes	–	+	N	+	N	+
2001	No	N	+	–	+	N	–
2002	No	–	–	+	+	–	+

(+) *: > 110% of the average seasonal rainfall (1961-1990)*
(-) *: < 80% of the average seasonal rainfall (1961-1990)*
(N) *: Between 80 and 110% of the average seasonal rainfall (1961-1990)*

Results

✓Moisture

Minimal relative moisture might be a limiting condition for adult mosquitoes to survive. Nevertheless there seem not to exist any relationship between this factor and the Dengue-2 virus outbreaks

Minimal relative moisture during the rain season

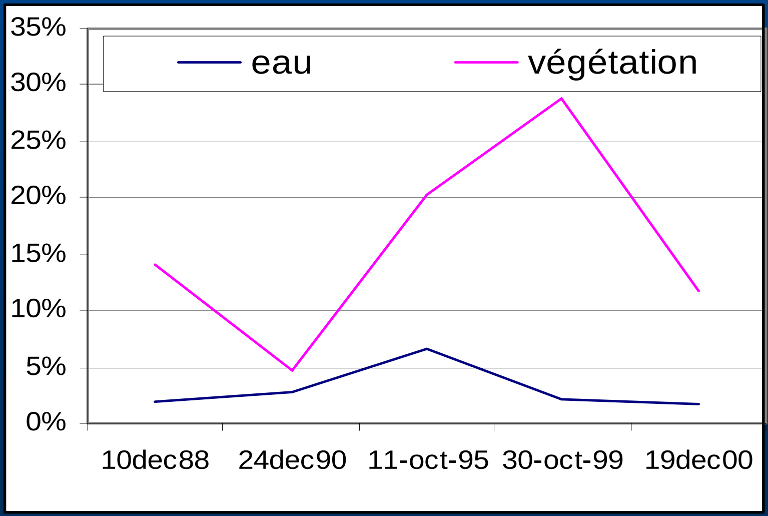
Years	May	June	July	August	September	October
1988	21,1	44,5	63,4	64,7	57,6	46,7
1989	22,3	44,7	58,3	65,1	61,7	48,5
1990	16,4	29,8	58,2	60,5	59,2	49,5
1991	14,1	41,6	62,5	62,9	55,3	43,2
1992	16,8	58,1	64,7	62,4	59,5	47,1
1993	23,9	37,4	62,1	64,5	62,7	50,4
1994	21,3	54,7	63,8	69,8	63,1	55,8
1995	19,5	36,0	57,8	68,4	65,1	53,5
1996	25,6	42,5	58,0	62,5	59,6	52,2
1997	34,1	57,0	62,9	65,9	62,4	51,6
1998	20,1	34,5	49,9	66,5	65,5	47,1
1999	20,5	49,3	59,6	67,6	62,6	57,8
2000	16,9	39,0	58,6	63,3	57,4	44,7
2001	13,8	42,4	59,3	61,9	58,9	40,5
2002	30,1	50,9	62,2	67,6	62,9	54,0
Mean rainfall (61-90)	27,6	47,7	61,6	64,1	60,9	50

Results

✓From satellite images

	10 dec 88	24 dec 90	11 oct 95	30 oct 99	19 dec 00	26 apr 01
Water	1,89%*	2,77%	6,59%	2,09%	1,77%	8,97%
Vegetation	14,01%	4,63%	20,30%	28,74%	11,72%	15,35%
Living areas	5,11%	5,60%	7,89%	1,92%	2,19%	7,76%
Bare soils	78,99%	86,99%	65,21%	67,25%	84,32%	67,93%

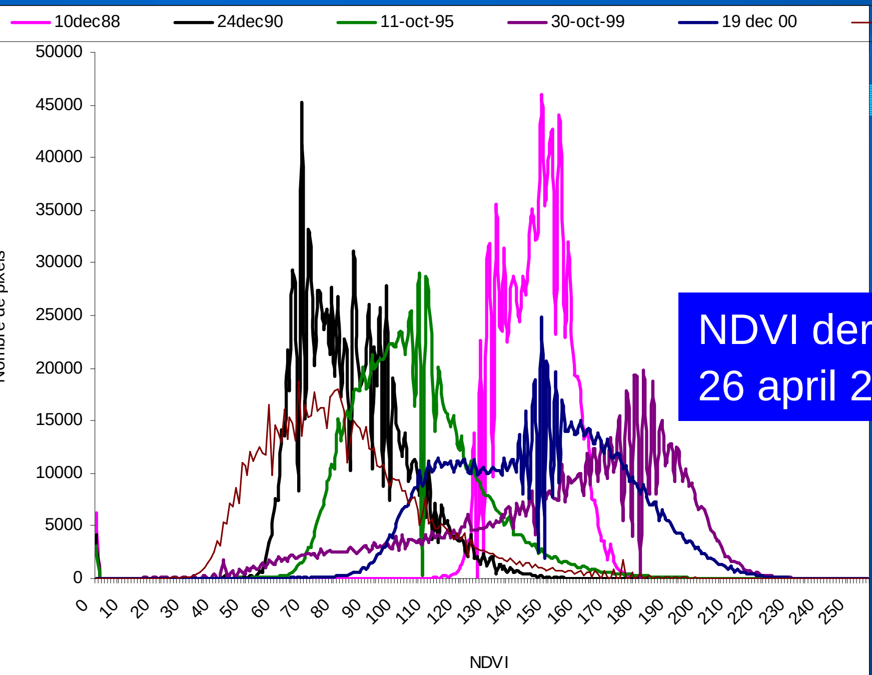
1,89%* - Percentage of various themes compared to the total surface of the area study (30 x 30 km)
There seems to be no correlation with the Dengue-2 virus outbreaks



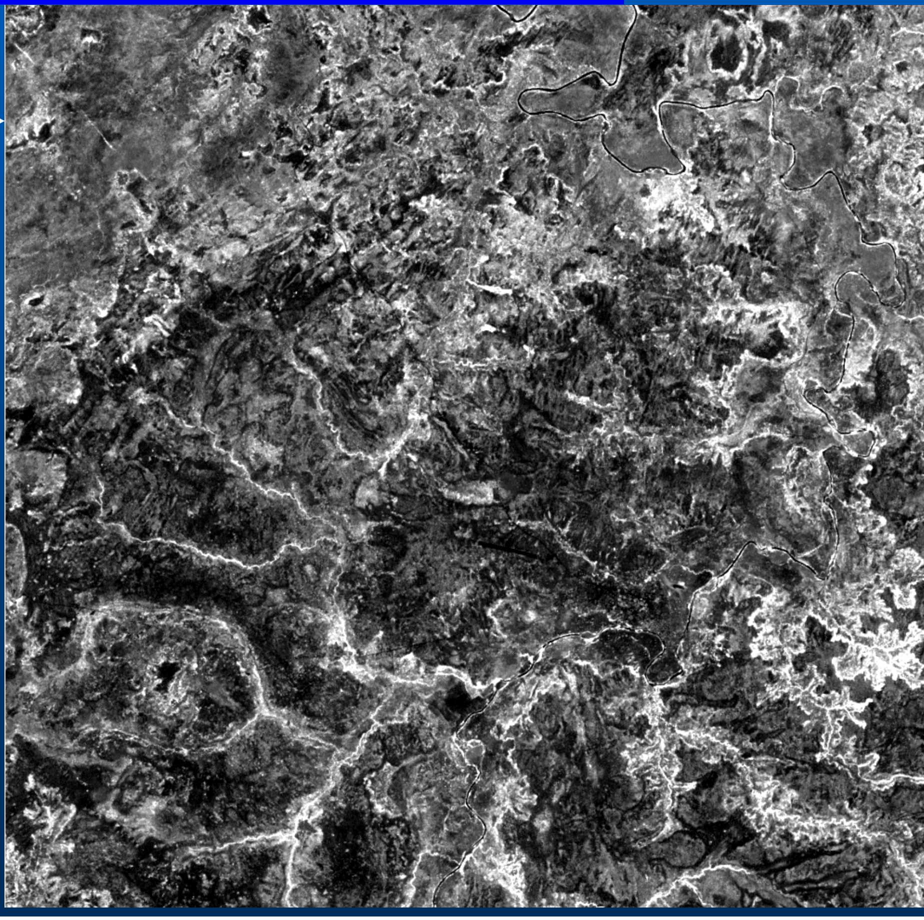
Results

✓NDVI (Spatial distribution of active vegetation throughout the study area

- Outbreak cycle 1990: reduced and slightly homogeneous biomass
- Outbreak cycle 1999-2000: important and heterogeneous biomass
- Years without outbreak: biomass important and homogeneous to intermediate and heterogeneous



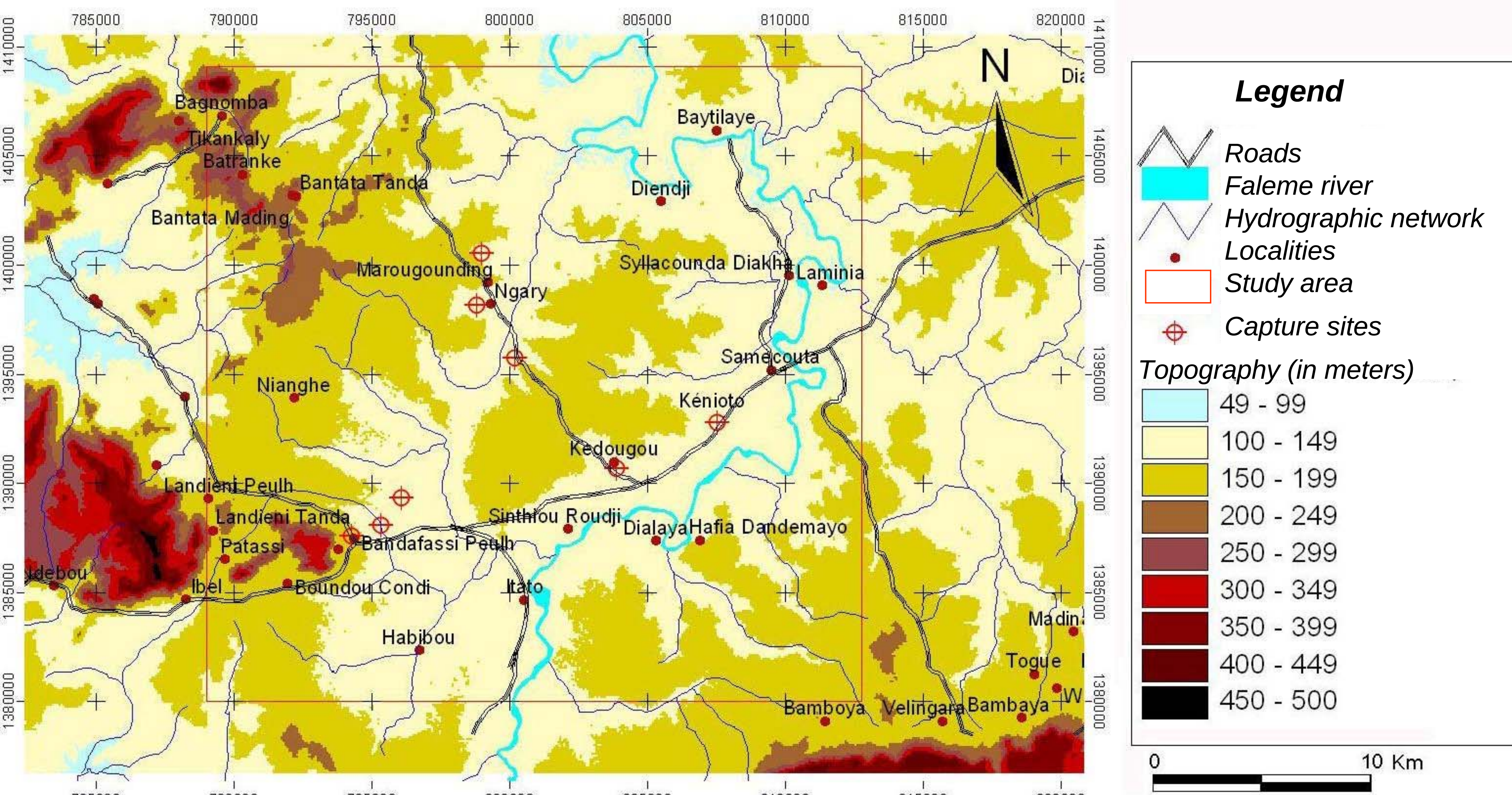
NDVI derived from 26 april 2001 image



	10dec88	24dec90	11-oct-95	30-oct-99	19dec00	26-apr-01
Médiane	145	81	102	161	146	77
Quartile25%	136	70	90	128	123	61
Quartile75%	152	95	115	181	166	94
Intervalle interquartile	16	25	25	53	43	33

✓Topography (Digital Elevation Model)

- Globally, the topography is low, except some highlands in the West and South-East. Capture sites are located in lowlands (<150m) close to river beds.



Discussions

- *Rainfall estimates and analysis at different scales did not allow to elucidate the climatic conditions favorable to the Dengue-2 virus outbreaks*

- *Furthemore, environmental parameters derived from satellite images show a random variability during the outbreak periods. These results did not allow to find clear relationships with Dengue-2 outbreaks in the study area.*

- *The reason of this might be that factors and parameters giving rise to Dengue-2 outbreak in the region play at a scale different from the scale of our analysis*

Conclusion and the way forward…

- *Analysis of the environmental parameters derived from the satellite imagery, supplemented by climatic, entomological and virological data, showed that the Dengue-2 virus outbreaks proceeded in very different environmental contexts.*
- *The reason for this might be that, either the studied variables are insuficient to explain the phenomenon, or they do not intervene directly in the outbreak cycles.*
- *The problematic of the identification of factors and parameters causing the virus outbreaks has to be deepened and the methodology refined*
- *There is a need to carry additional field studies with the use of a portable radiometer, for vegetation cover and canopy density estimation.*

Conclusion and the way forward…

- *The image database needs to be enriched with aerial photographs, very high resolution images (Ikonos, Quickbird, Spot-5 2.5m), and radar images, which could provide additional information.*

  For example, small ponds where mosquitoes can thrive and thus contribute to the diffusion and transmission of the disease, need to be mapped. Use of very high resolution imagery could allow detailed assessment of the spatio-temporal evolution of such ponds, through new indices: i.e., the Normalized Difference Pond Index (NDPI), and the Normalized Difference Turbidity Index (NDTI)

- *But this again raises the crucial problem of access to expensive imagery !*

- *Finally, a scientific collaboration with zoological programmes monitoring and capturing monkeys might allow a better understanding of how Dengue virus stays in the region and outbreaks cyclically.*

Thank you for your kind attention!…