Contribution of MODIS satellite imagery in modelling the flooding patterns of the coastal wetlands of the Tana River, Kenya.

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Introduction

- In Sub-Saharan Africa, **wetlands** render **numerous services**: groundwater recharge, water quality improvement, grazing zones.
- In the context of increased water abstraction and **hydroelectric infrastructure development**, it is important to understand the **flooding dynamics** for a better water resource management at the catchment scale.
- This is challenging because 1/ of scarce or poor quality data, 2/ difficult access to the zone, 3/ frequent cloud cover limits the use of remote sensing data.

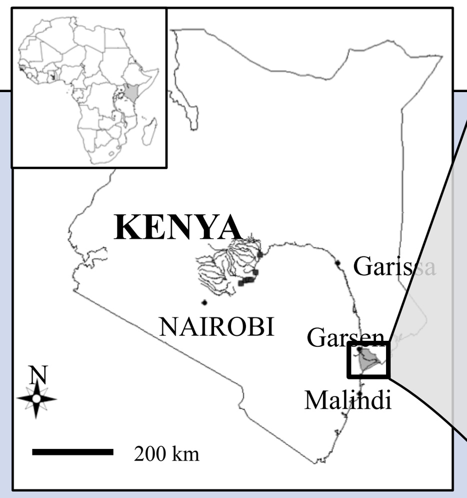
The **MODIS instruments** could offer a solution: high temporal resolution images at a moderate spatial resolution in the visible and infrared spectrum.

Objectives

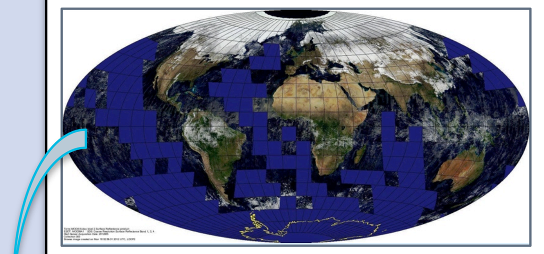
- Assess the use of MODIS satellite imagery (**MYD09A1** products) to measure flood extent in the Tana River Delta.
- Construct a hydrological inundation model in the context of extremely scarce data, using the MODIS satellite imagery.

Field site

Tana River Delta, Kenya (Fig. 1)



Methodology



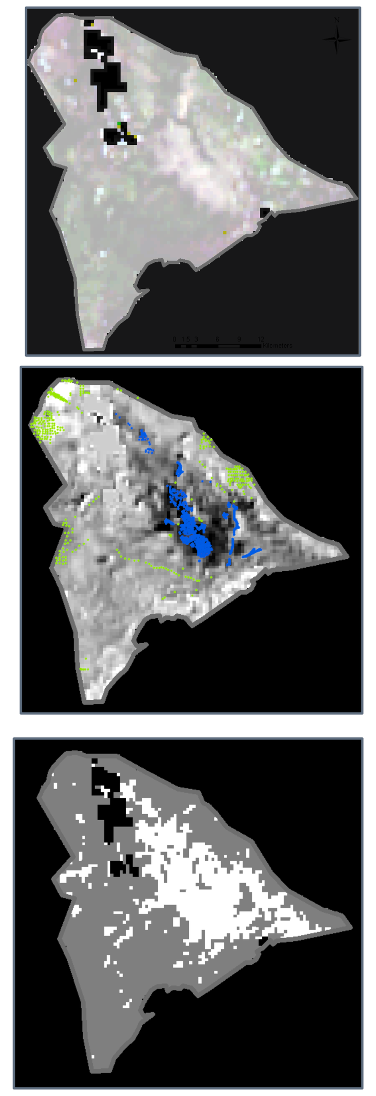


Figure 2: MYD09A1 image treatment steps

Remote sensing data

- Raw **MYD09A1** products: 8-day synthesis products, 500 m resolution

1/ Pre-treatment
- Reprojection
- Area selection
- Transformation

2/ Determine **threshold for NDMI indice** (Xu, 2006)
- 3 images where ground flood surface was known
- Determine best classification into flooded and non flooded pixels for the range of NDMI values
- Choose the best values as the threshold

$$\frac{MIR - IR}{MIR + IR}$$

3/ Flood extent

- Use all 434 available images
- Calculate frequency (f) for each pixel to be flooded weighed by their non-cloud cover frequency
- Maximal flood extent (2002-2011): all pixels f > 1 %

4/ Flood extent time series

Select images with < 10% cloud cover (70 of them)

Calculate total flooded surface

Other data

- **Daily discharge rates** (WRMA)
- **Daily rainfall**
- **Mean daily potential evapotranspiration** (Woodhead, 1969)

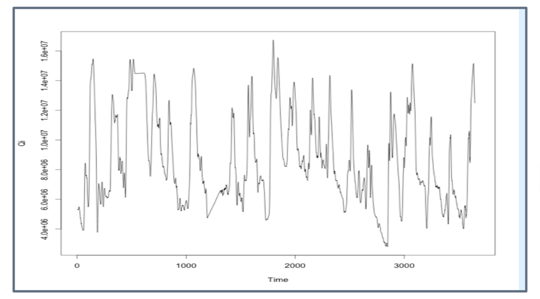


Figure 3: Daily discharge at inlet

Resolution method

- **Generalized Likelihood Uncertainty Estimation** (GLUE) (Beven, 1992, Beven 2001)
- 100 000 simulations each for 2002-2006 and 2006-2011 calibration/validation periods
- Select parameters sets with Nash-Sutcliffe coefficient > 0.6 (Nash & Sutcliffe, 1970)

Figure 4: Model equations

Water balance model

$$\frac{dV}{dt} = S \cdot \frac{dZ}{dt} = Q_i + R + L - Q_s - E - I$$

$$S = \frac{K}{1 + a \cdot \exp^{-r \cdot Z}}$$

$$L = C_R \cdot R_{Gssa}$$

$$I = infil \cdot S$$

$$Q_s = \alpha \cdot (Z - Z_m)^{\beta}$$

$$E = etp \cdot S$$

V: daily flood volume
Z: mean flood height
S: daily flooded surface
Qi, Qs: input and output discharges
L: daily surface inflow
E: evapotranspiration
Etp: potential evapotranspiration
I: infiltration
K, a, r, Cr, infil, α, β, Zm: model parameters

Inundation time series · **Water balance**

Results

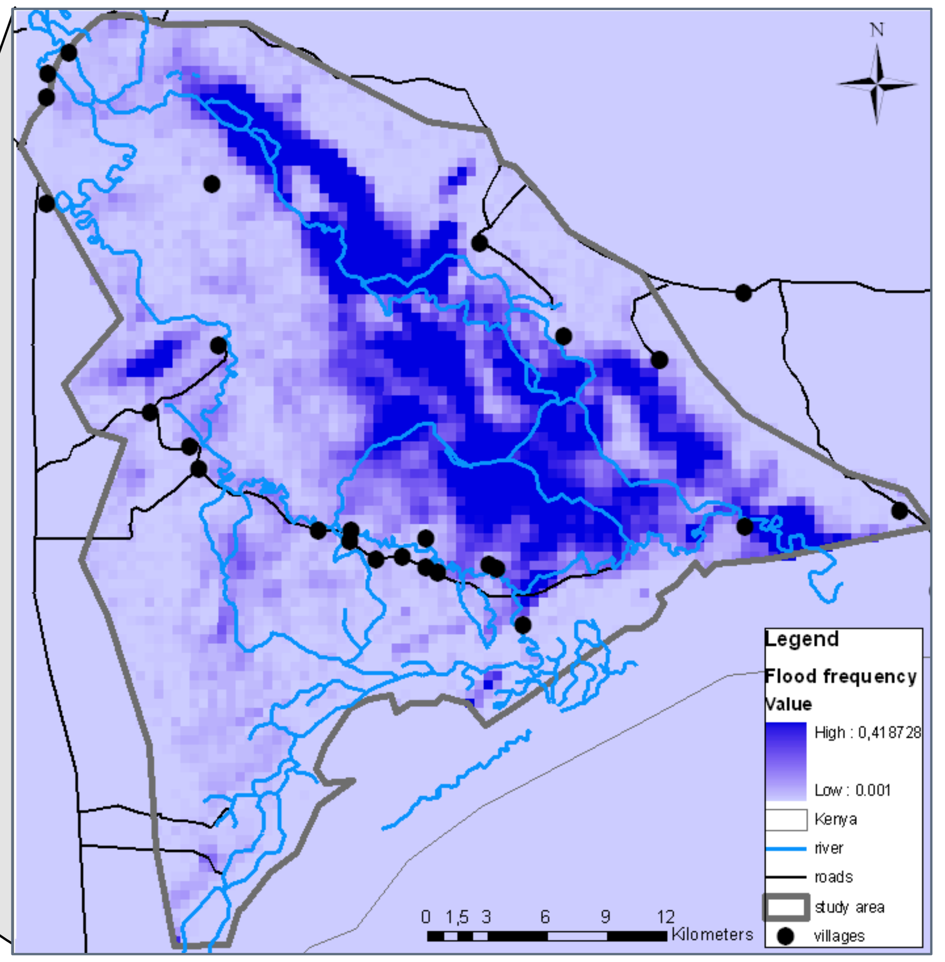


Figure 1: Flood frequency

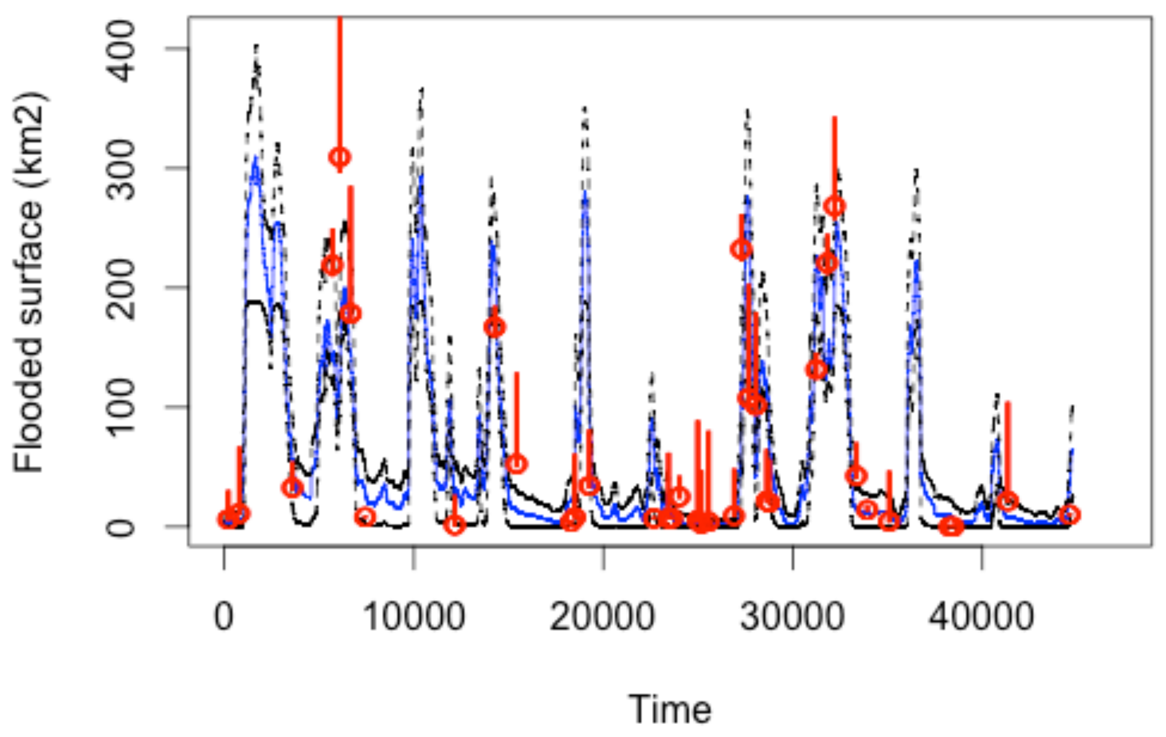
I. Flood extent:

- Gives a **spatial** representation of the floods
- **NDMI threshold** value: 0.9
- Flooded surface with f > 1%: 455 km²
- Flooded area around the current major river bed
- As expected, villages are not within the frequently flooded zones

II. Hydrological model:

1/ Inundation time-series

- Gives a **temporal** representation of the floods
- Global **Nash** values:
  - Calibration period: 0.86
  - Validation period: 0.81
- Reproduces major trends



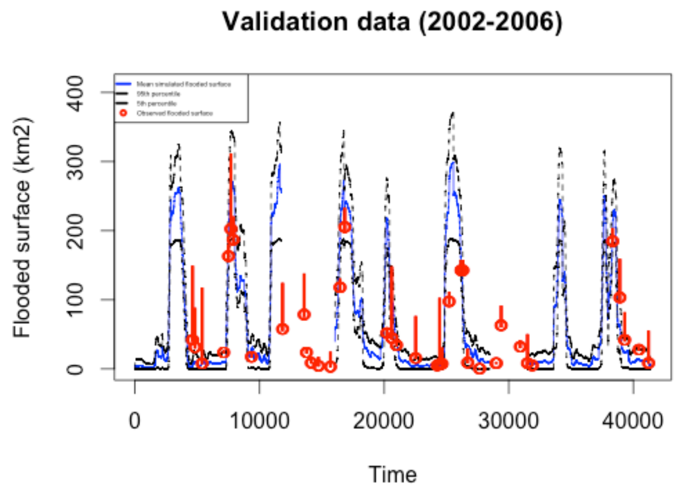


Figure 5: Simulated and observed flood extent in the Tana River Delta from 2002 to 2011 (calibration and validation data)

Inflow	16.07	Outflow	15.91-16.96
Rain	1.18	Evaporation	0.08-0.19
Surface inflow	0.01-0.76	Infiltration	0.01-3

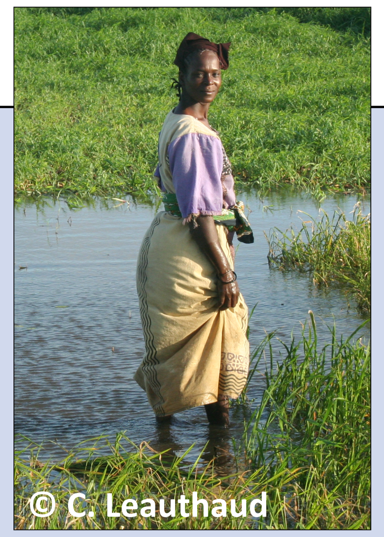
Figure 6: Water balance from 09/2006 to 12/2011 (unit: 10^9 m^3)

2/ Preliminary water balance

- **River inflow** and **outflow** are the major processes of this system

Conclusion and perspectives

- **MODIS products** have proven useful to **reconstruct the hydrologic dynamics of an ungauged floodplain**.
- These high temporal and medium-range spatial resolution satellite imagery provide a **free-of-cost** and **rapid solution** in monitoring water distribution and environmental changes in tropical, coastal or semi-arid areas.



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Acknowledgements

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