

# Contribution of remote sensing to the monitoring of infectious diseases and focus on environmental monitoring of *E. coli* in West Africa

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**Infectious diseases and climate change**

Tuesday 21 st of May 2024, Paris

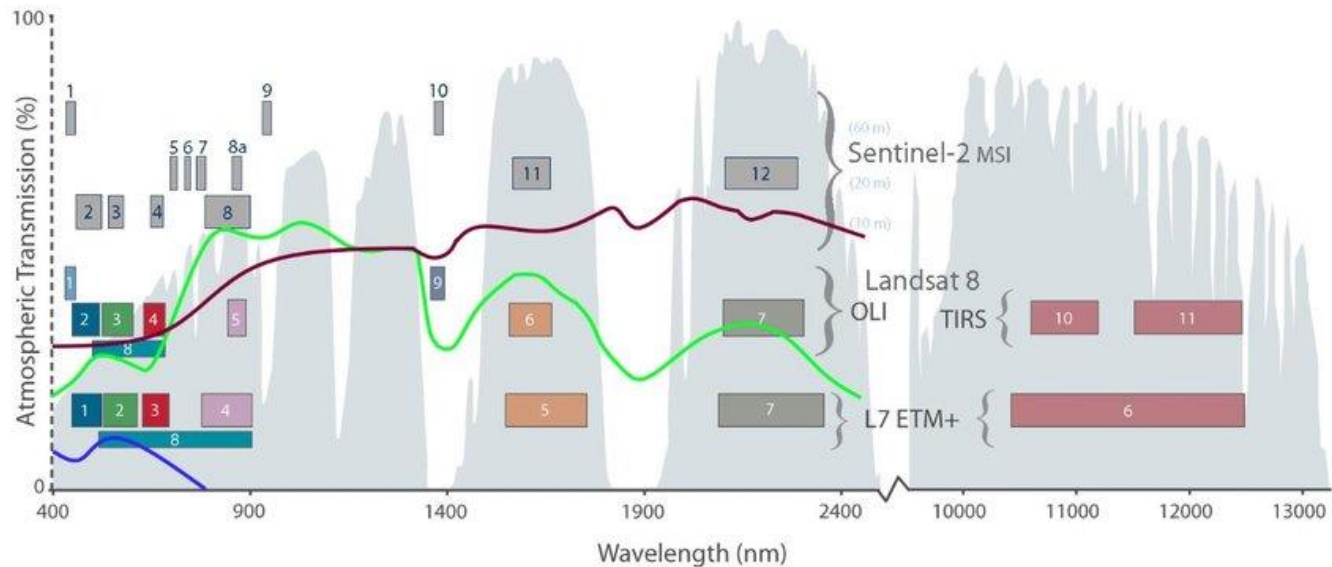


# Remote sensing

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- Spectral signature.



*Spectral bands of Sentinel-2 and Landsat 7 & 8. Spectral signatures of vegetation, soil, and water are depicted in green, brown and blue respectively, Muro Martin (2019).*





# Remote sensing

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- Spectral signature.
- Development between 1970's and 2020's: spatial and temporal resolutions, spectral bands, free.
- Remote areas, areas lacking in-situ measurements, observing temporal dynamics, inter-site comparison.
- Monitoring surface changes (deforestation, urbanization, land use/land cover, water surface, etc.), estimating hydrometeorological parameters (air and water T°C, rainfall, humidity, etc.).



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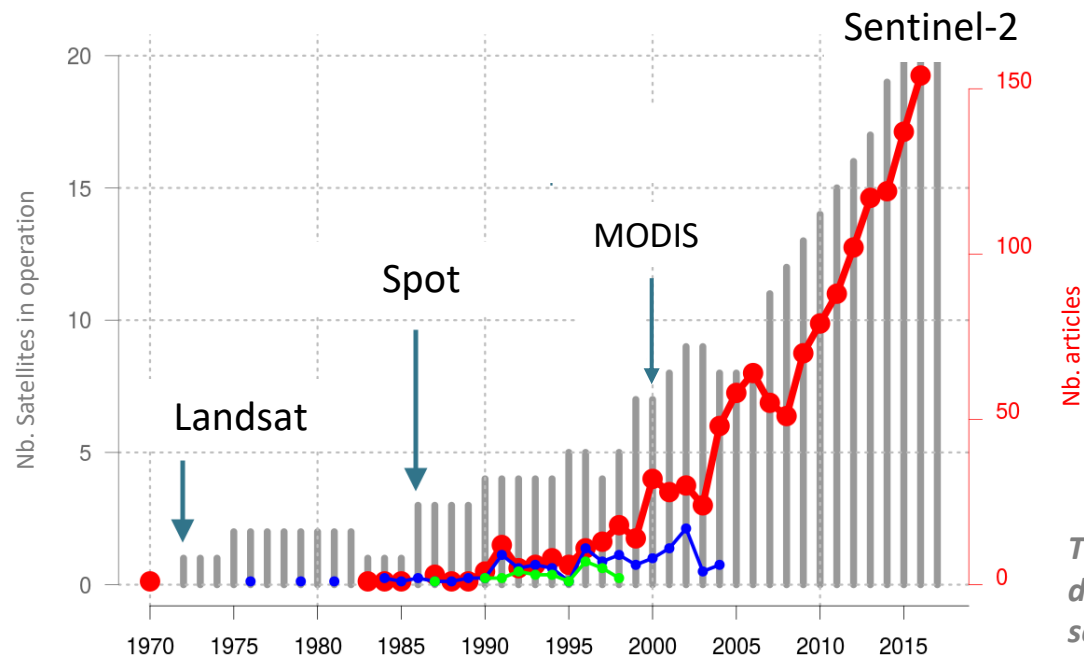
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- Mid-2010's : diversification of health applications linked to pollution and climate change.



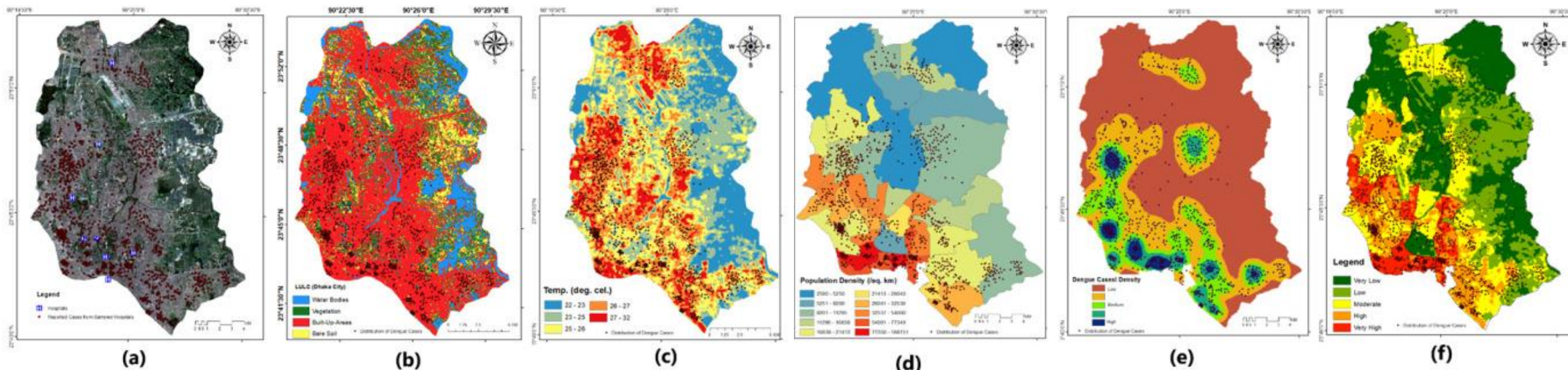
*The number of satellites and the number of articles found in the ISI Web of Science® database, whose abstract, title or keywords contain the regular expression “(remote sensing OR satellite data) AND (human health OR epidemiolog\* )” (Hebreteau et al. 2018)*

# Remote sensing and health

- Information on environmental indicators limiting distribution of pathogens (altitude threshold, T°C), on conditions favorable to their presence (type of vegetation, humidity), or their development and proliferation (cumulative rainfall, T°C, SPM, etc.).

# Remote sensing and health

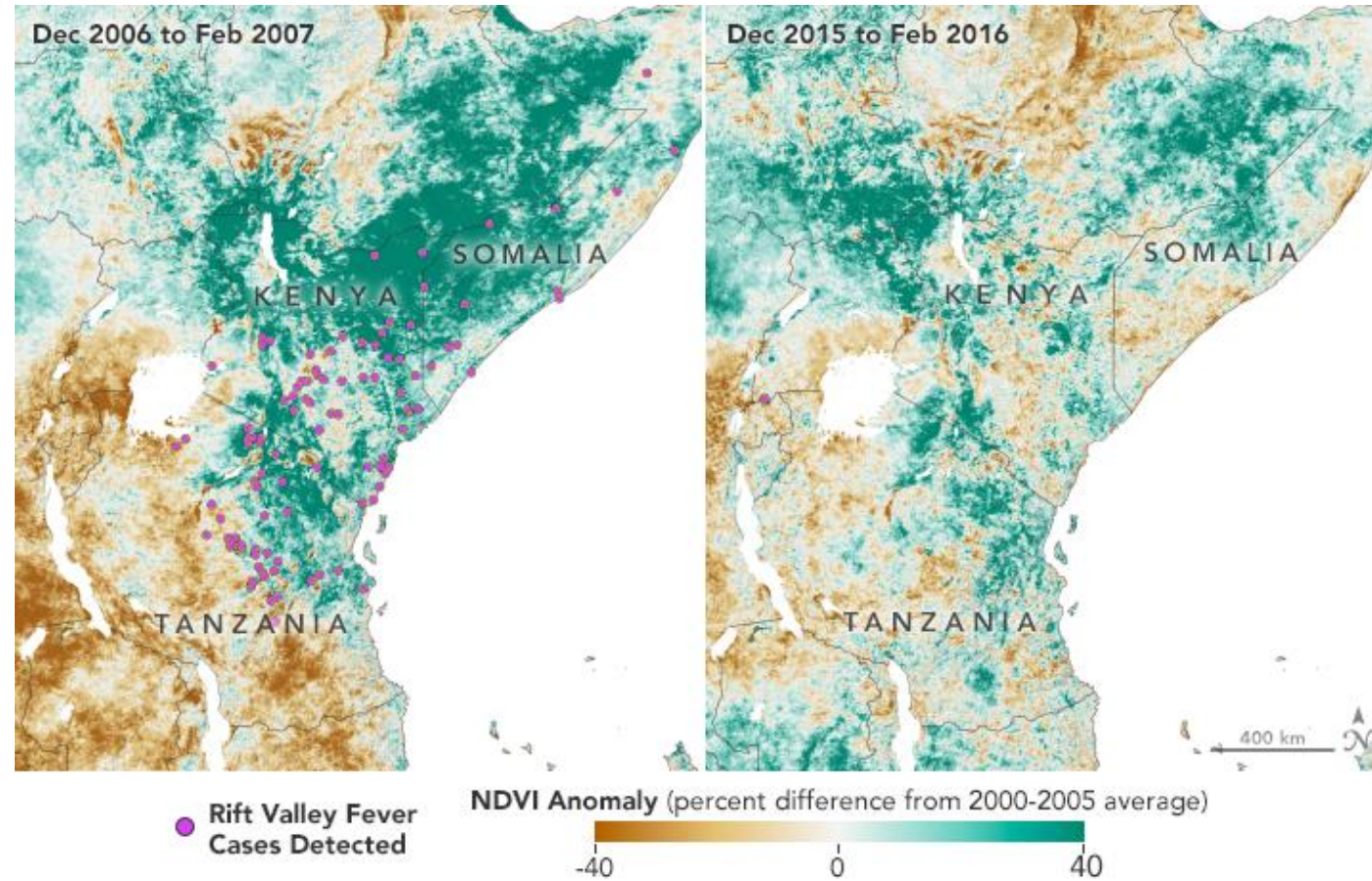
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(a) Dengue cases location on a true color image of Landsat 8 OLI; red dots show the reported dengue patients in hospitals, (b) distribution of Dengue incidence by LULC, and (c) influence of UHI in dengue distribution by the ranges of LST; higher-temperature region shows the higher density of reported dengue patients, (d) population density in Dhaka City with the number of reported dengue patients distribution, (e) dengue incidence density prepared by the interpolation methods, and (f) dengue risk map of Dhaka City prepared using the various environmental components (Kamal et al. 2023).

# Remote sensing and health

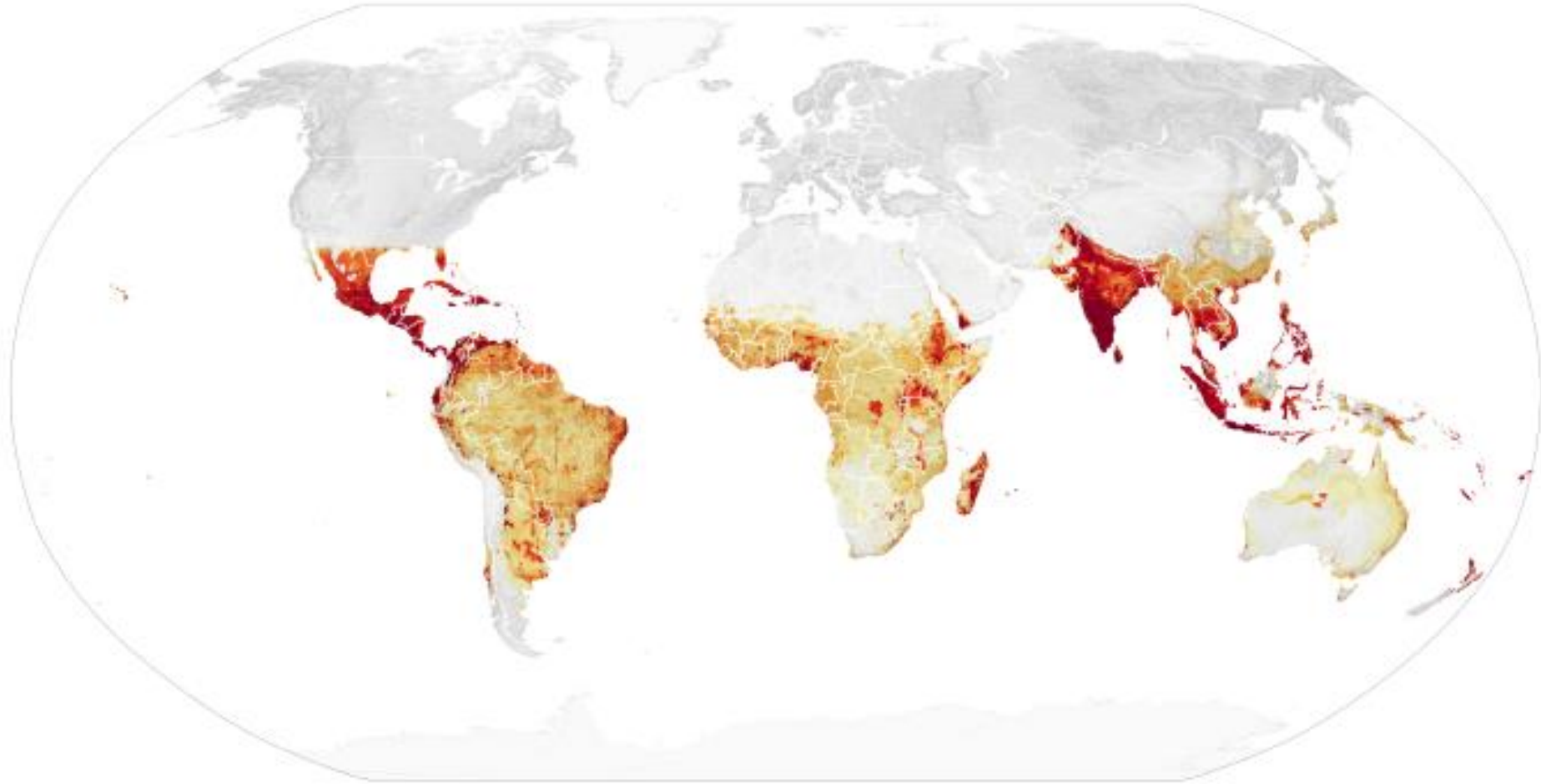
- At large scale: predict periods favorable to the transmission of diseases linked to the environment using hydrometeorological indicators, land cover.



*The Normalized Difference Vegetation Index (NDVI) is a satellite measurement of the “greenness” of vegetation; NDVI anomalies reveal how much healthier (greener) vegetation is than normal. Greener areas are usually wetter, suggesting better habitat for mosquitoes. Favorable conditions for mosquitoes in 2006 led to Rift Valley fever (RVF) outbreaks in eastern Africa. The region greened again in 2015, but early warnings helped officials prevent the spread of RVF. (NASA Earth Observatory maps by Lauren Dauphin, using NDVI anomaly data from Terra MODIS.) (Anyamba et al.)*



# Remote sensing and health



**July 2020 Chikungunya Forecast Risk**



Low

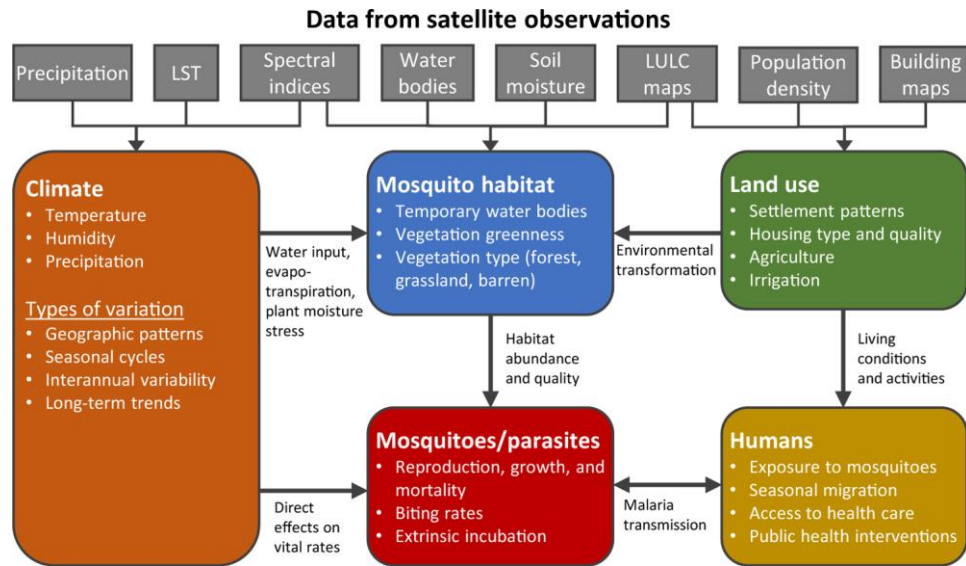
High

*Scientists use data from satellites and ground stations to predict the spread of chikungunya in a new project called CHIKRisk. The model forecasted an elevated risk of chikungunya for July 2020 in India, Mexico, Indonesia, Malaysia, and Philippines. (NASA Earth Observatory map by Lauren Dauphin using data from Assaf Anyamba, NASA GSFC.)*



# Satellite observation and malaria

- Connections between the environmental phenomena observed by satellite-borne sensors and different aspects of the malaria transmission cycle.

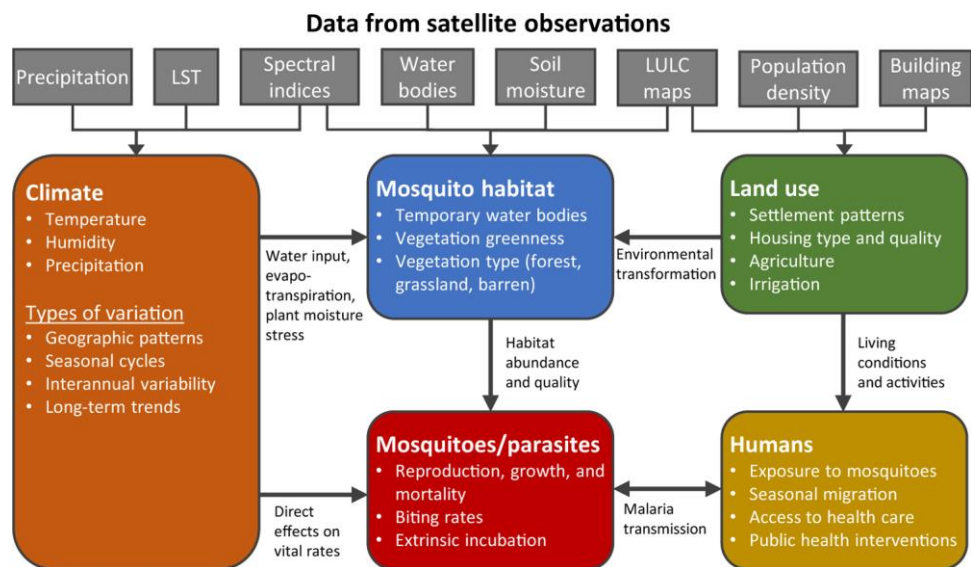


*Pathways through which satellite data provide information about malaria. Satellite data can be used to predict geographic patterns and changes over time in climate factors, mosquito habitats, and human land use. These environmental variables influence malaria transmission through their effects on mosquitoes, parasites, and humans.*

*Abbreviations: LST, land surface temperature; LULC, land use and land cover.*

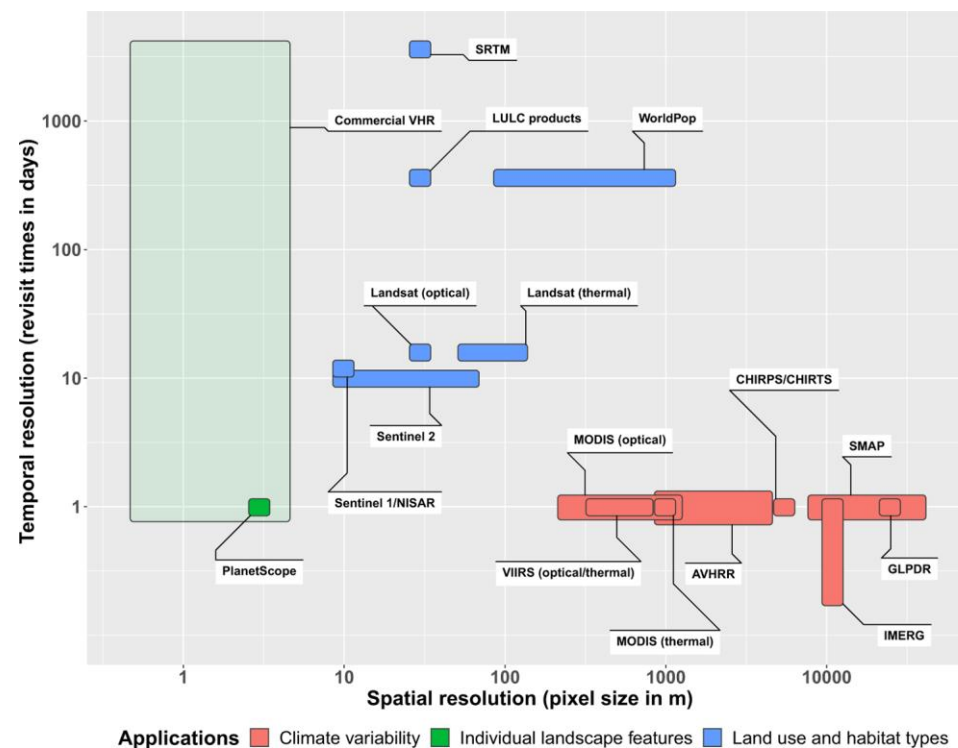
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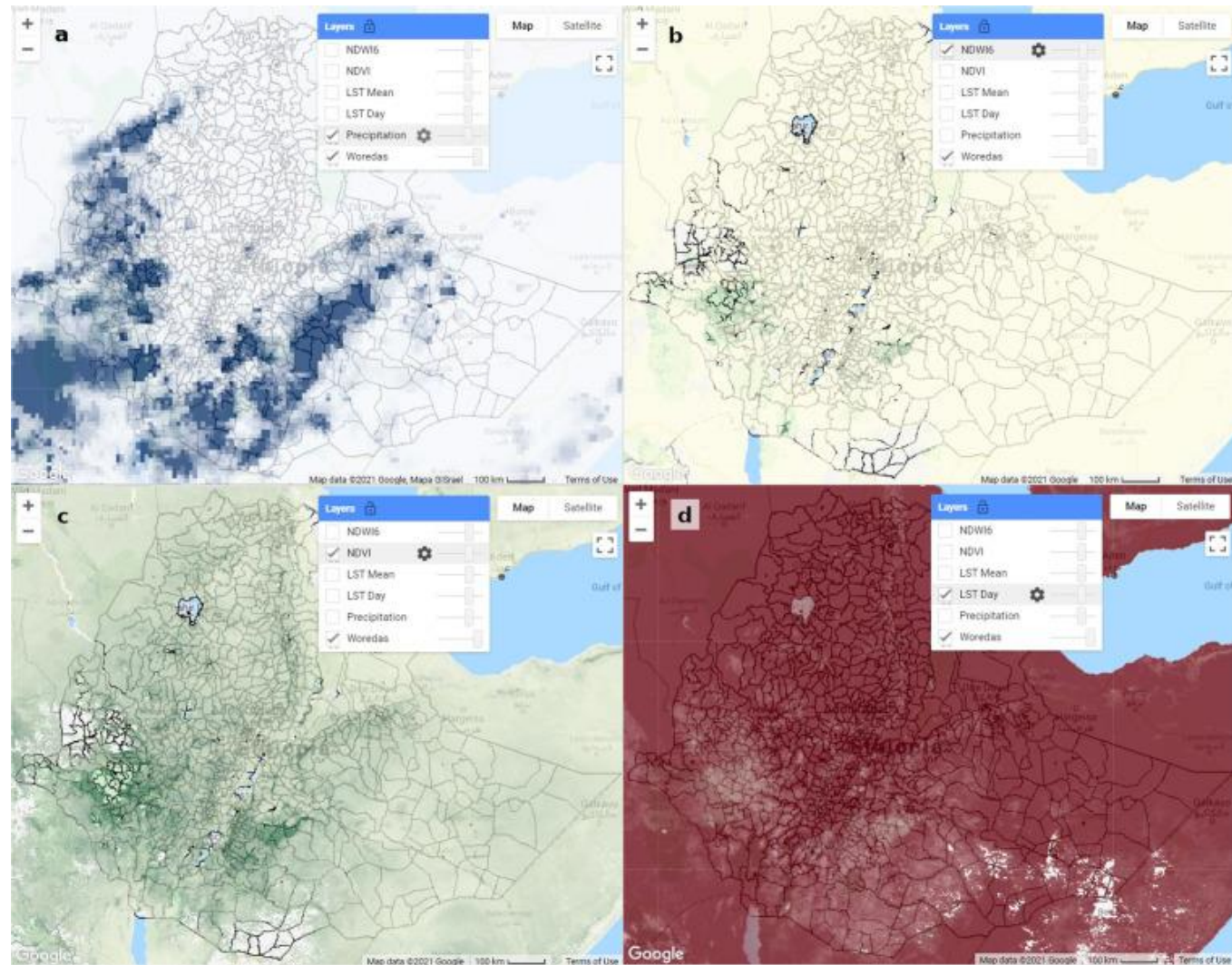
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*Spatial and temporal resolutions of satellite missions and data products with applications to malaria.*

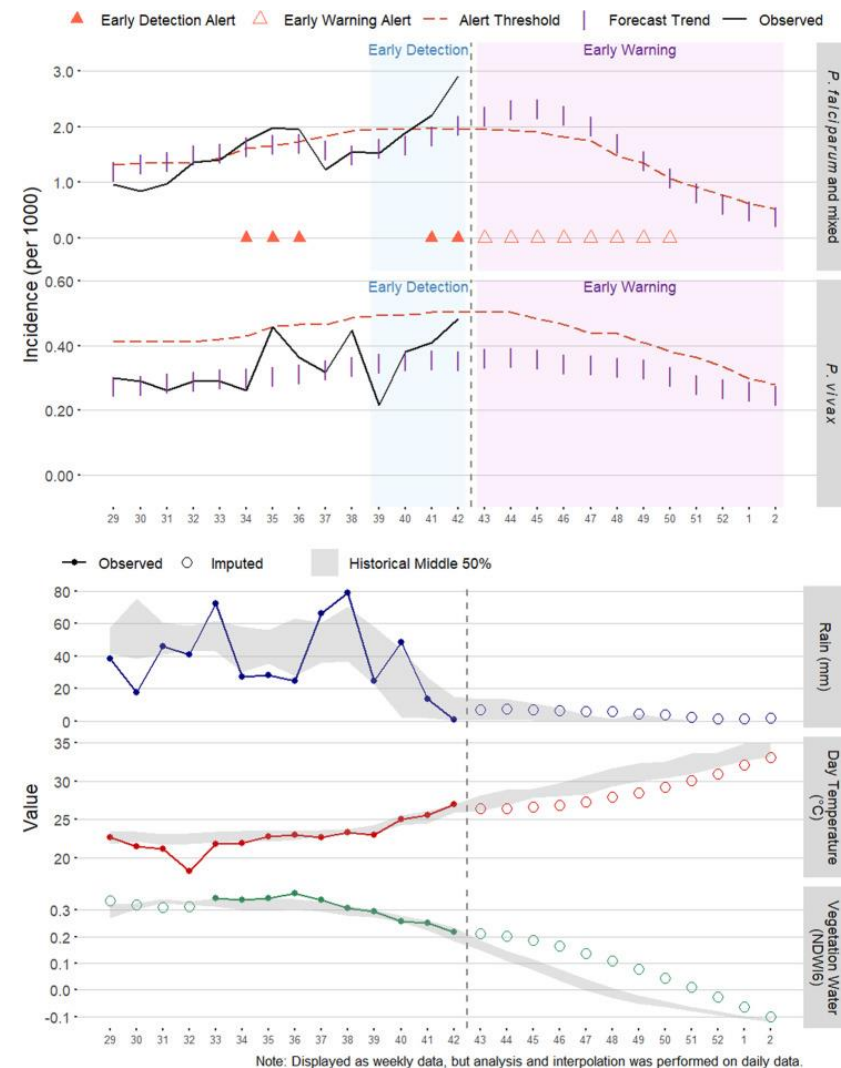
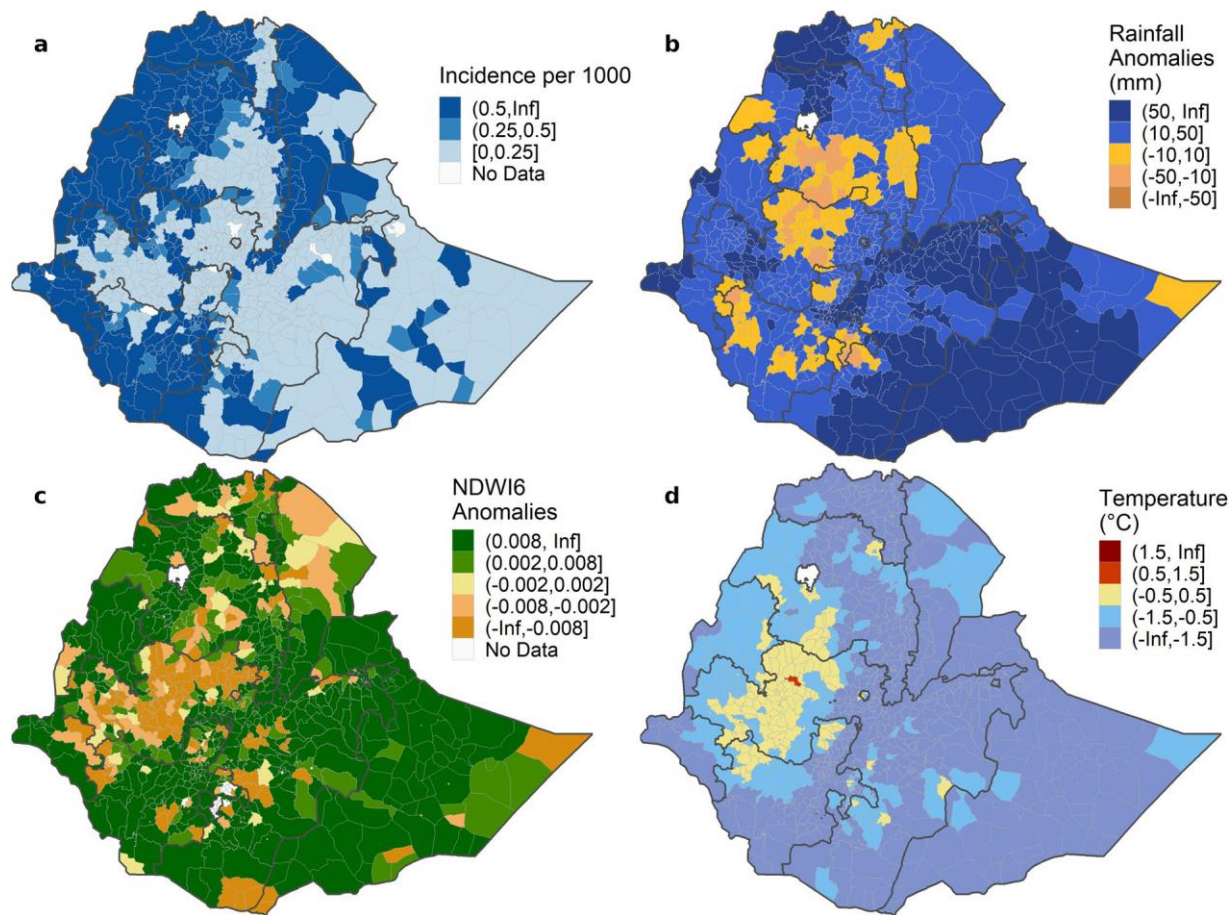
# Satellite observation and malaria



*Visualizations from the REACH map window showing examples of remote sensing data with woreda boundaries: (a) precipitation, (b) NDWI6, (c) NDVI, and (d) daytime LST (environmental data shown for 18 March 2021).*



# Satellite observation and malaria

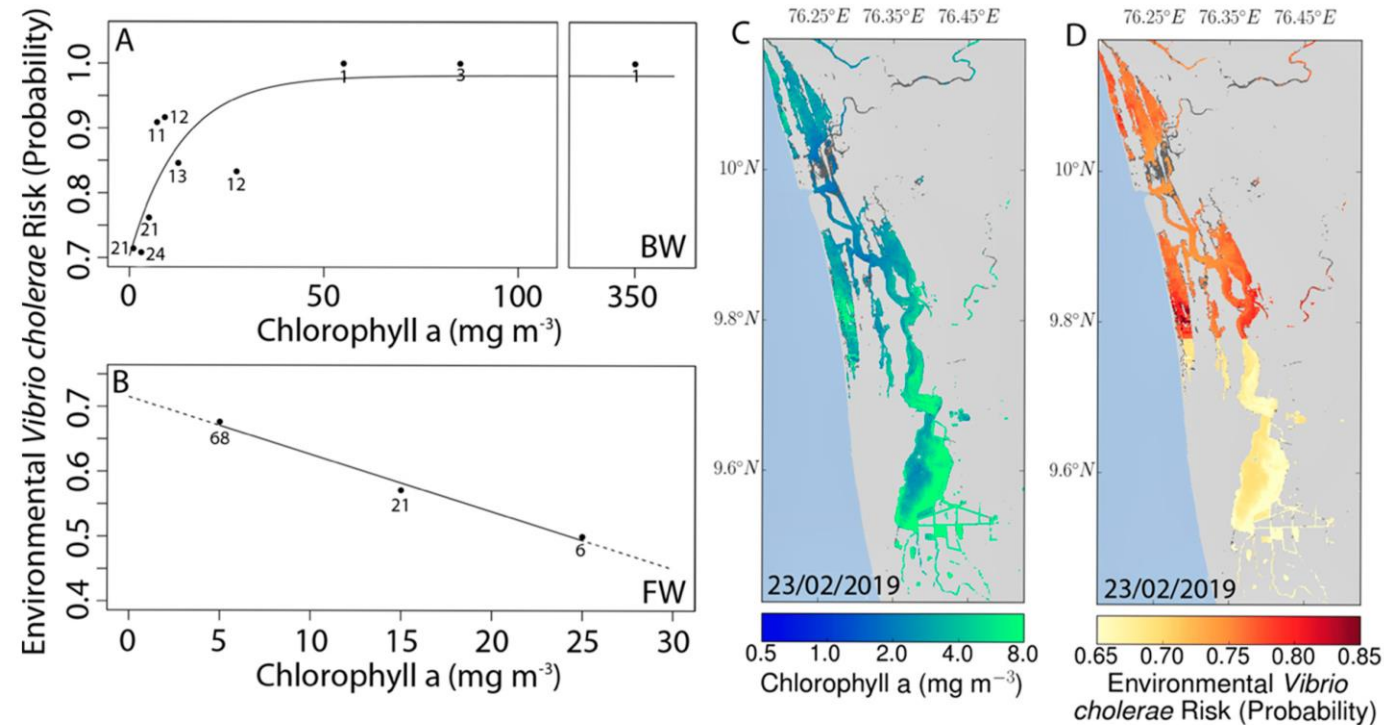


Example maps showing (a) *P. falciparum* malaria incidence, climate anomalies for (b) rainfall, (c) NDWI6, and (d) daytime LST for a four-week time period of week 39 through 42 2019. Incidence is reported per 1000 population, and anomalies are defined as the departure of the observed values from historical climate averages from 2002 to present.

Example timeseries charts from an EPIDEMIA forecast report for 2019 week 42. The top two series show the observed malaria incidence (solid lines) up to week 42 and forecasted incidence (vertical bars) through week 2 2020 (12 weeks ahead) along with expected malaria incidence (dashed lines) with alerts for early detection and early warning of outbreaks (triangles). The bottom three timeseries show the observed environmental variables from REACH (solid lines) with historical interquartile ranges (gray envelopes) and future extrapolations (circles).

# Satellite observation and cholera

- Colwell et al. (1996): propose remote sensing observations for mapping *V. cholerae* in relation to environmental conditions.
- Satellite-derived variables (T°C, salinity, sea surface height, chlorophyll concentration, and phytoplankton) to understand the ecology of bacterial pathogens and assess health risk (Anas et al. 2021, Racault et al. 2019).

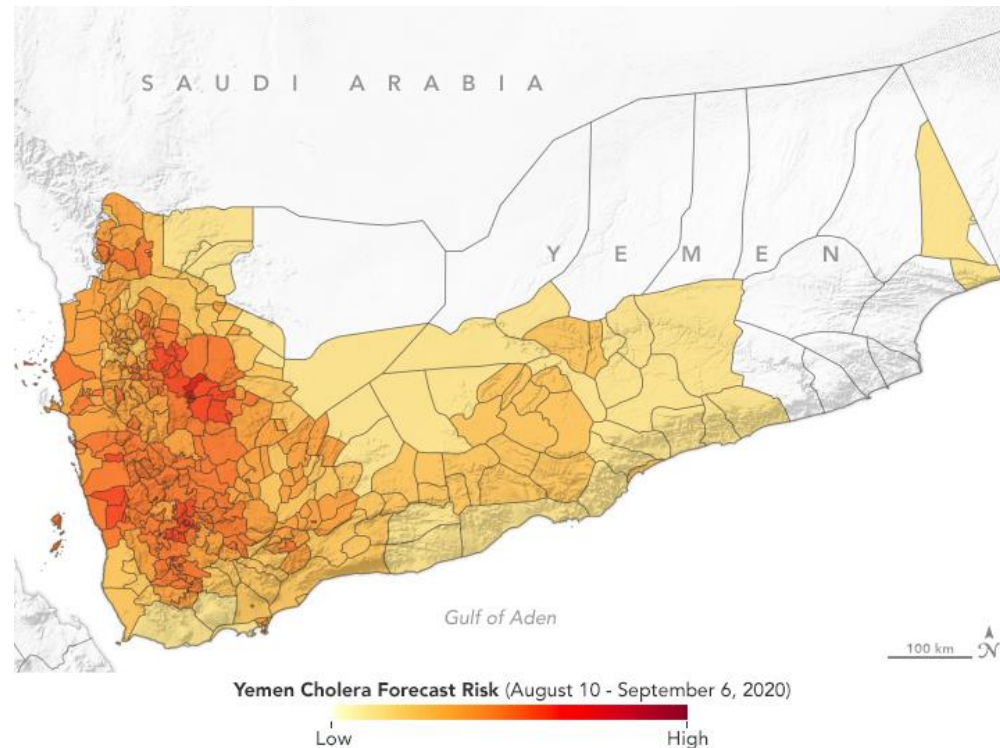


The relationship between satellite chlorophyll and probability of finding environmental *Vibrio cholerae* in the (A) brackish water (BW) and (B) fresh water (FW) regions in the Vembanad Lake (Kerala, India). (C) Representative satellite image (for 23 February 2019) of chlorophyll and (D) the corresponding risk map of environmental *V. cholerae* incidence in the lake, generated from the relationships shown in (A,B) for the two parts of the lake (Anas et al. 2021).



# Satellite observation and cholera

- Jutla et al. tested their cholera prediction modeling system, using satellite data (heavy rains and hot T°C).
- The team did not share its prediction because it had concerns about the accuracy of its model in the absence of reliable health data.
- Jutla et al. collaborated with UNICEF and the UK Depart. for International Development to share weekly reports on potential outbreaks in Yemen: to distribute hygiene and cholera treatment kits.



*NASA Earth Observatory map by Lauren Dauphin using data from A. Jutla and M. Usmani, University of Florida. The environmental data monitored include precipitation, air temperature (MERRA-2 reanalysis product), and population data.*

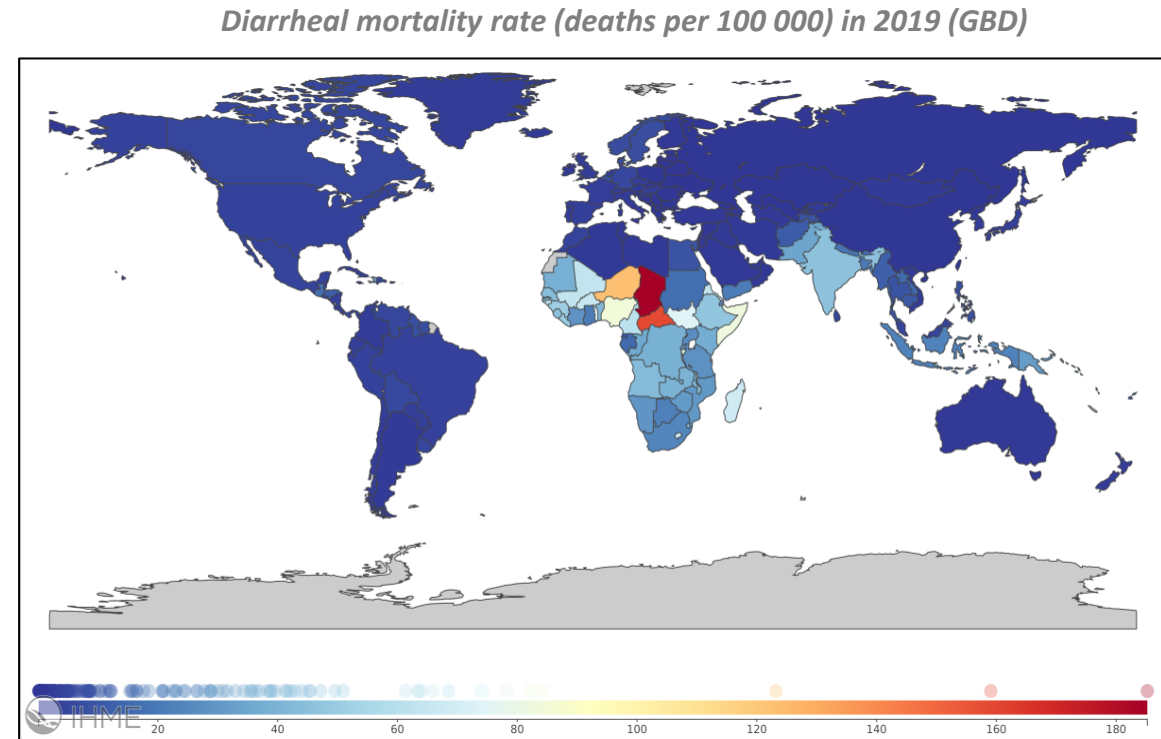
# Characterization of the *E. coli* environment in surface waters in West Africa

## Context, Challenges and objectives

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- 1.53 M deaths/year, 593 213 in Sub-Saharan Africa (GBD, 2019).

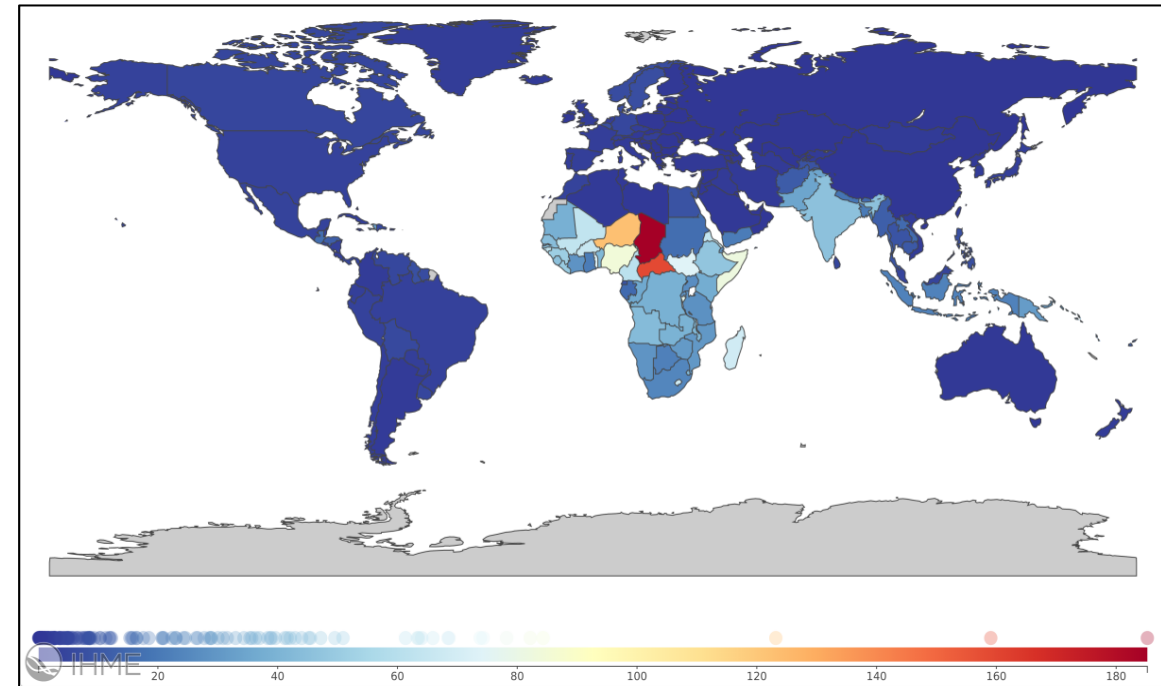


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- 1.53 M deaths/year, 593 213 in Sub-Saharan Africa (GBD, 2019).
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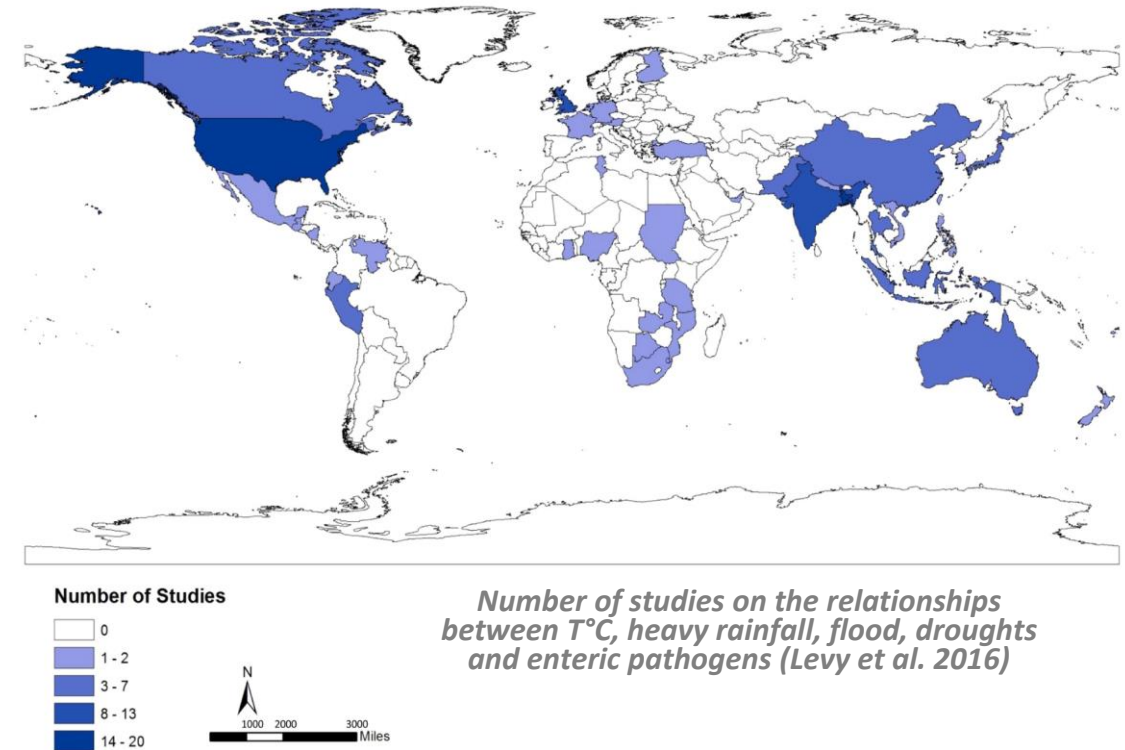
Diarrheal mortality rate (deaths per 100 000) in 2019 (GBD)



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  - *E. coli* is considered to be the best FIB in temperate areas => in muddy tropical surface water?

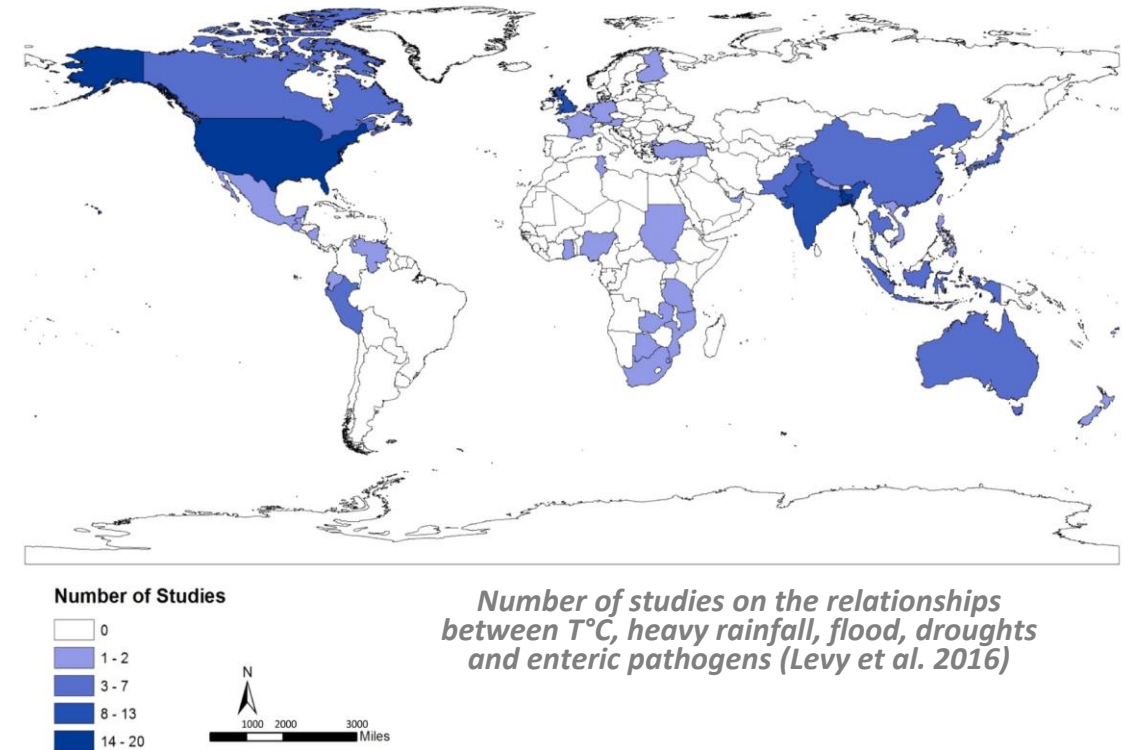




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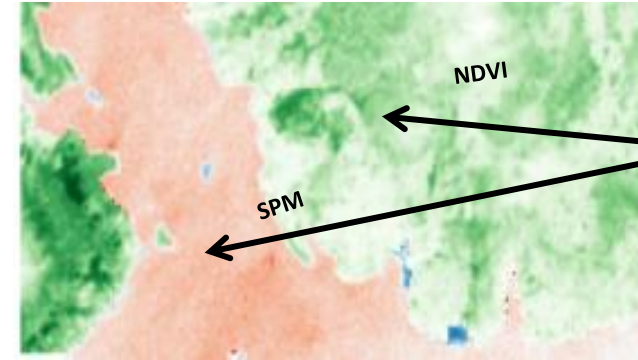
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- Few studies in tropical environments:
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  - Link between *E. coli*-FIB / environmental determinants / diarrheal diseases ? Study to what extent the environment plays a role in the transmission of diarrheal diseases?



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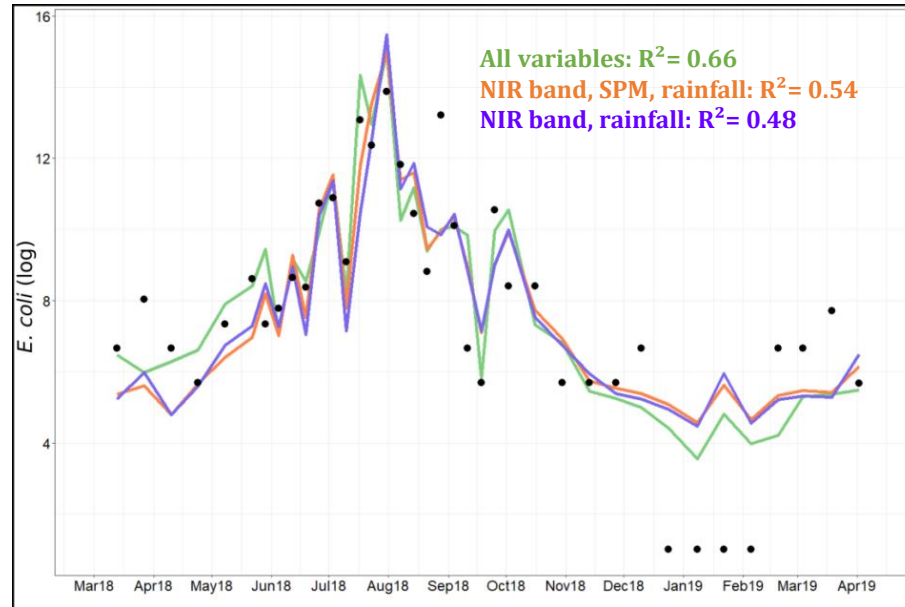
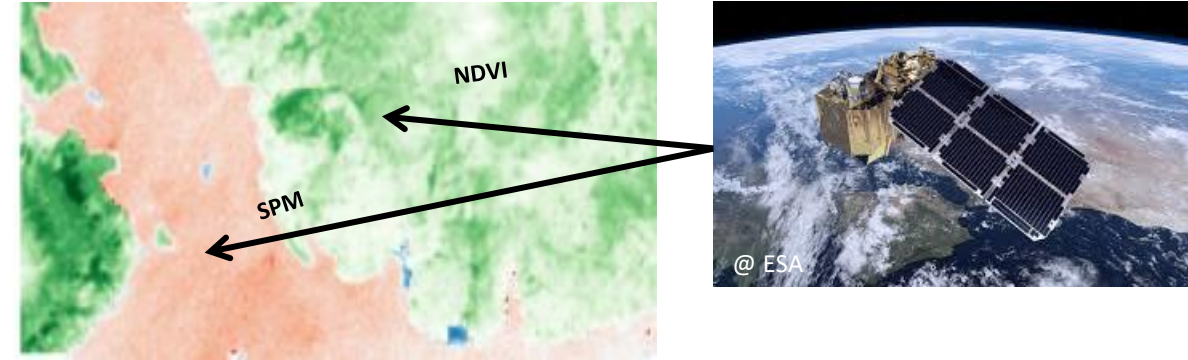
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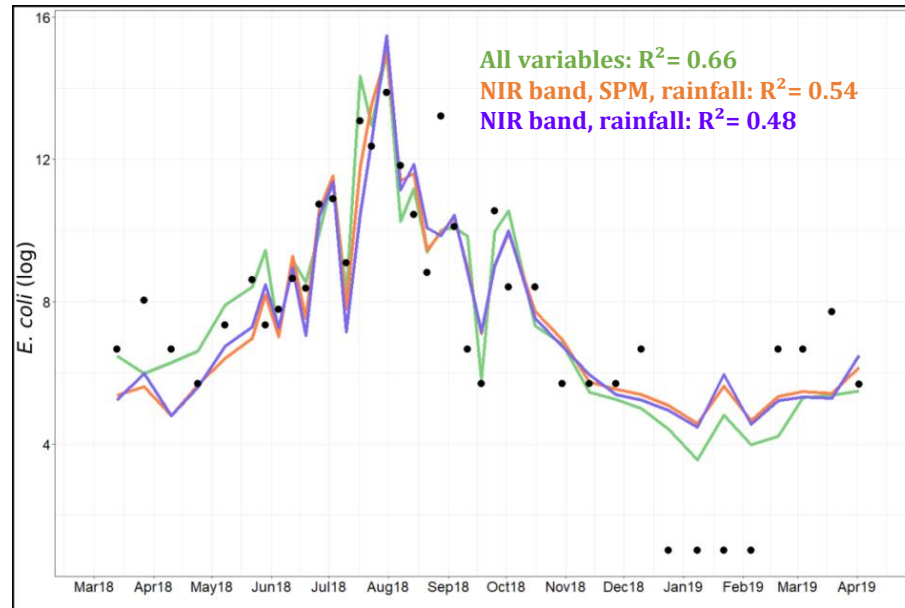
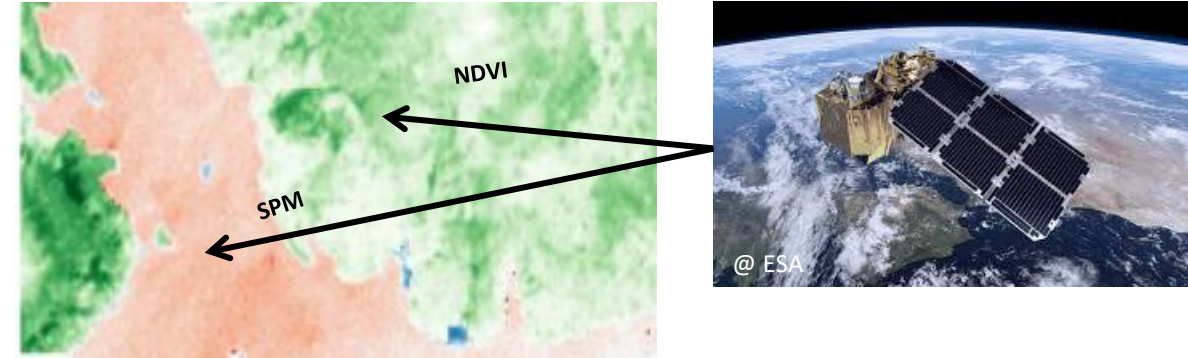
Observed *E. coli* (black point) and predicted *E. coli* (green line for all variables, orange line for NIR band, SPM and Rainfall variables, blue line for satellite variables)

Robert et al.  
2021

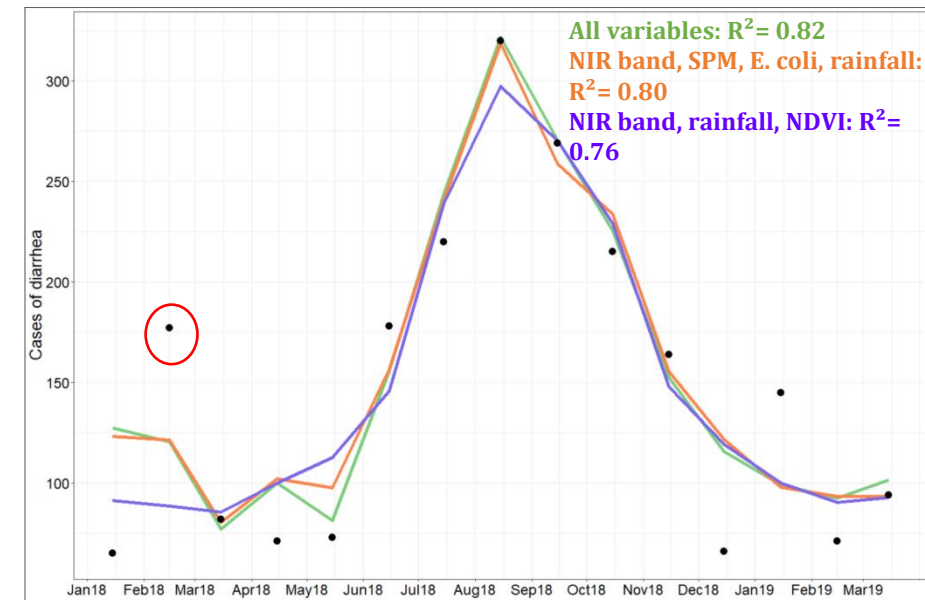
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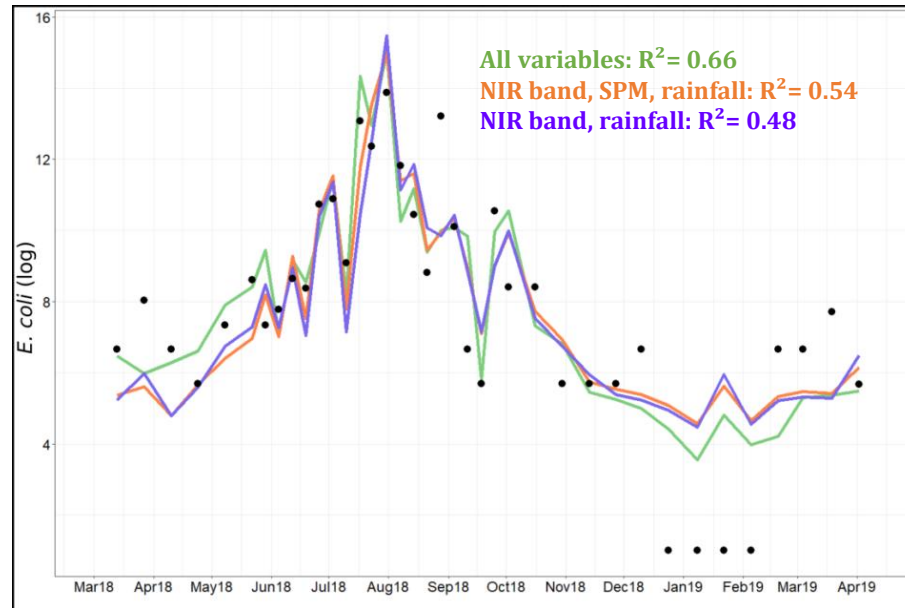
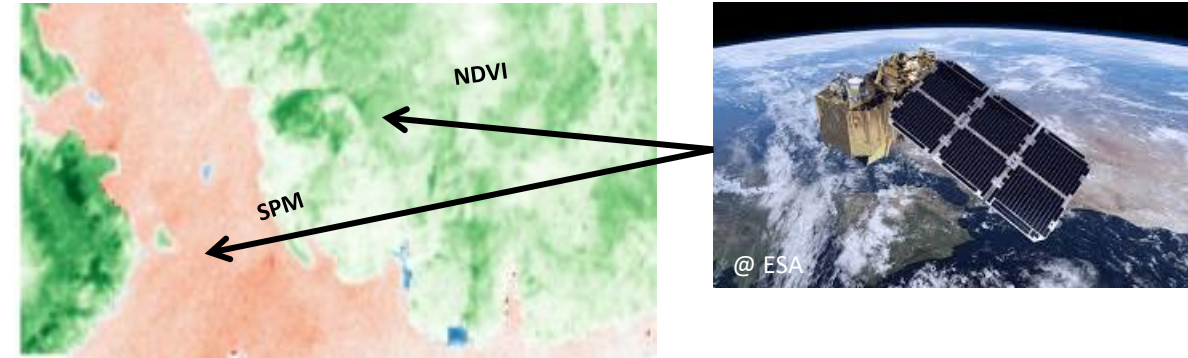
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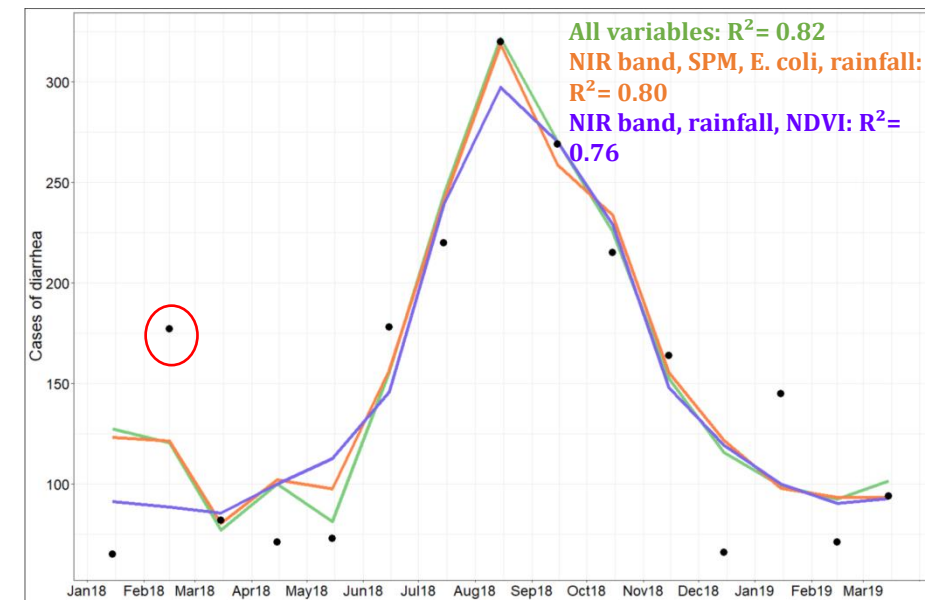
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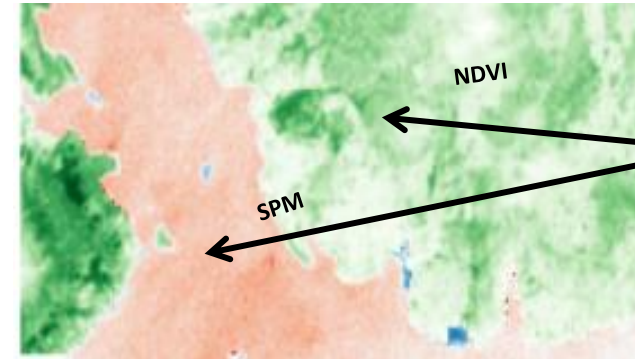
➔ **Tele-epidemiology of diarrheal Diseases in Muddy tropical surface Waters in West Africa: MAMIWATA project (2022-2026)**



# Characterization of the *E. coli* environment in surface waters in West Africa

## Context, Challenges and objectives

- Tele-epidemiology: powerful tool to study climate-environment-health relationship and to both understand and predict the spatio-temporal distribution of pathogens.
- Global changes: increasing of diarrheal diseases during the 21st century (*Kolstad and Johansson, 2011*)
  - Climate change is expected to impact water resources both in quantity and quality
  - Land uses changes and potential increase in SPM and pathogens (survival, dissemination and in soils and waters) (*Collins et al. 2013 Rochelle-Newall et al. 2017, Cecchi et al. 2020*)
  - Major changes in terms of demographic growths especially in rural areas (*Mecandalli & Losch, 2018*) and geopolitical insecurity.



➔ **Tele-epidemiology of diarrheal diseases in Muddy tropical surface Waters in West Africa: MAMIWATA project (2022-2026)**

# Characterization of the *E. coli* environment in surface waters in West Africa

## Study area

### *In-situ*

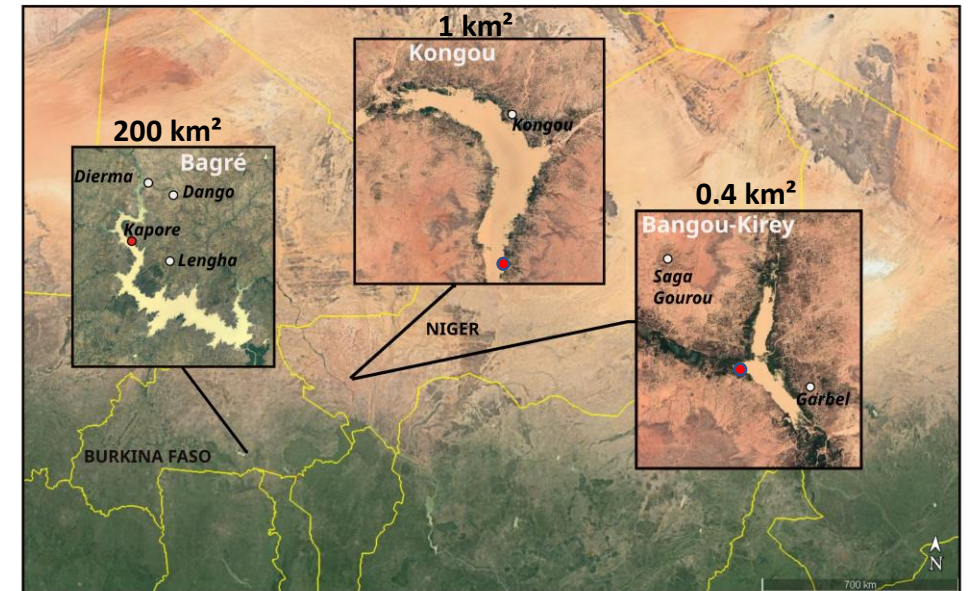
- **In-situ measurements** : Daily (since 2020) or weekly (2 months during rainy season), 5 days (beginning an end of the rainy season), 10 days (dry season)
  - *E. coli* (microplate) since 2018 (BF), since 2022 (Niger)
  - SPM (filtration method), since 2018 (BF), since 2022 (Niger)
  - POC, DOC since 2022
  - T°C, pH, conductivity, O2 dissolved since 2020 (BF), since 2022 (Niger)

### *Remote sensing*

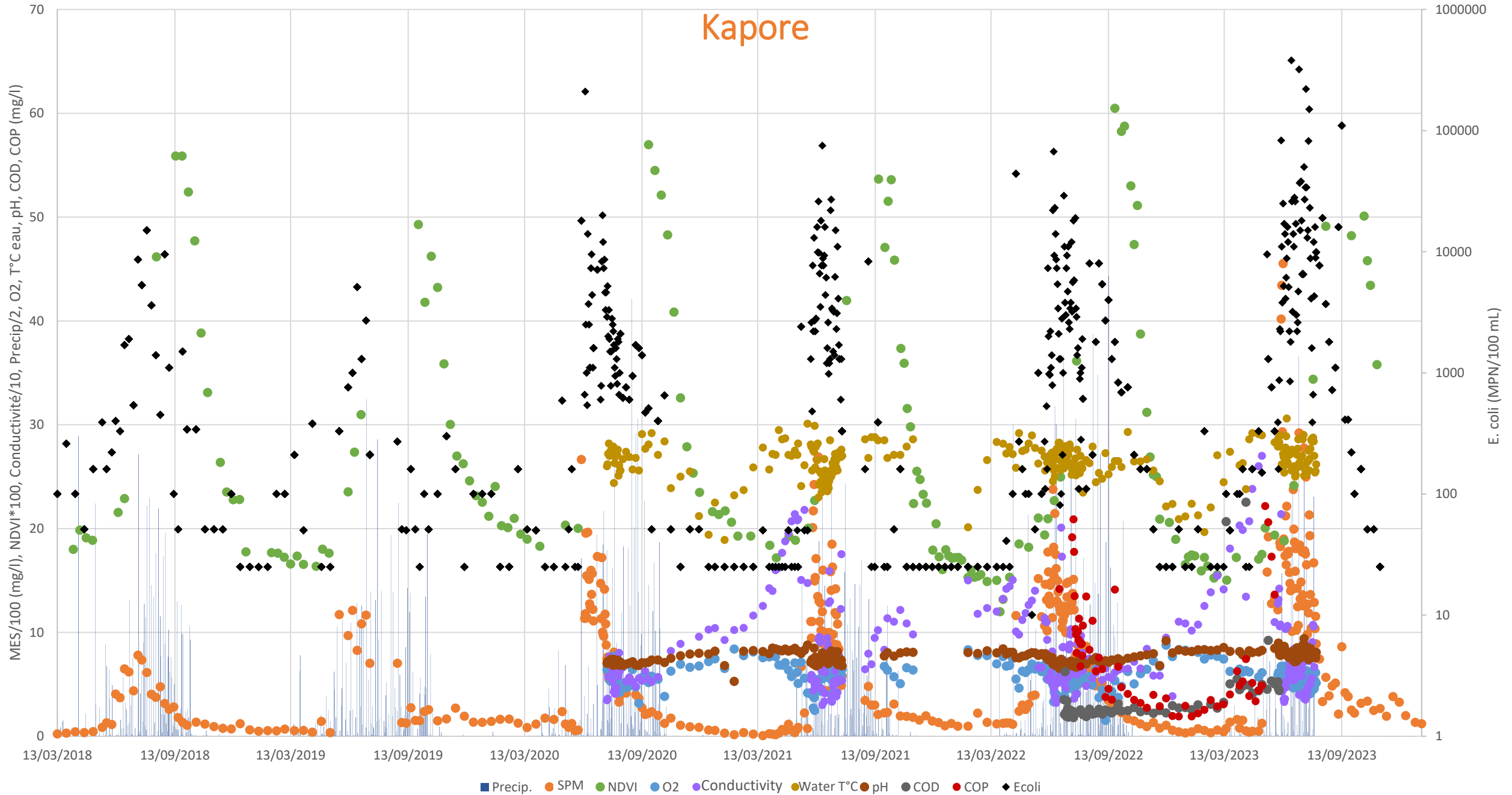
- **Rainfall**: GPM IMERGHHV06 (Giovanni)
- **NDVI**: Sentinel-2 (Theia)
- **Nb of water pixels/flooded surface**: Sentinel-2 (Theia)
- **Water level** Jason 3 (Dahiti)
- **Solar irradiance, relative humidity and soil moisture, wind, runoff, pressure, air temperature**: GLDAS
- **SPM retrieved**: Sentinel-2 (Theia)
- **POC retrieved**: Sentinel-2 (Theia)

### *Epidemiological data*

- **Daily diarrheal cases of Health Centers**



# Characterization of the *E. coli* environment in surface waters in West Africa



# Characterization of the *E. coli* environment in surface waters in West Africa

## Kapore (one-to-one regressions)

Environmental variables	Correlation (Spearman rank's)
SPM	<b>0,8***</b>
O2	-0,45***
Conductivity	-0,59***
pH	-0,22*
POC	<b>0,61***</b>
<i>NDVI</i>	<b>0,47**</b>
<i>NIR</i>	<b>0,61***</b>
<i>NIR/Red</i>	0,65***
<i>NIR/Blue</i>	0,72***
<i>Rainfall</i>	0,46***
<i>Rainfall aggregated over a 7-day moving time window</i>	<b>0,58***</b>
<i>Soil moisture db</i>	<b>0,52***</b>
<i>UV averaged over a 7-day moving time window</i>	-0,3***
<i>Runoff db</i>	<b>0,46***</b>
<i>Humidity db</i>	<b>0,50***</b>

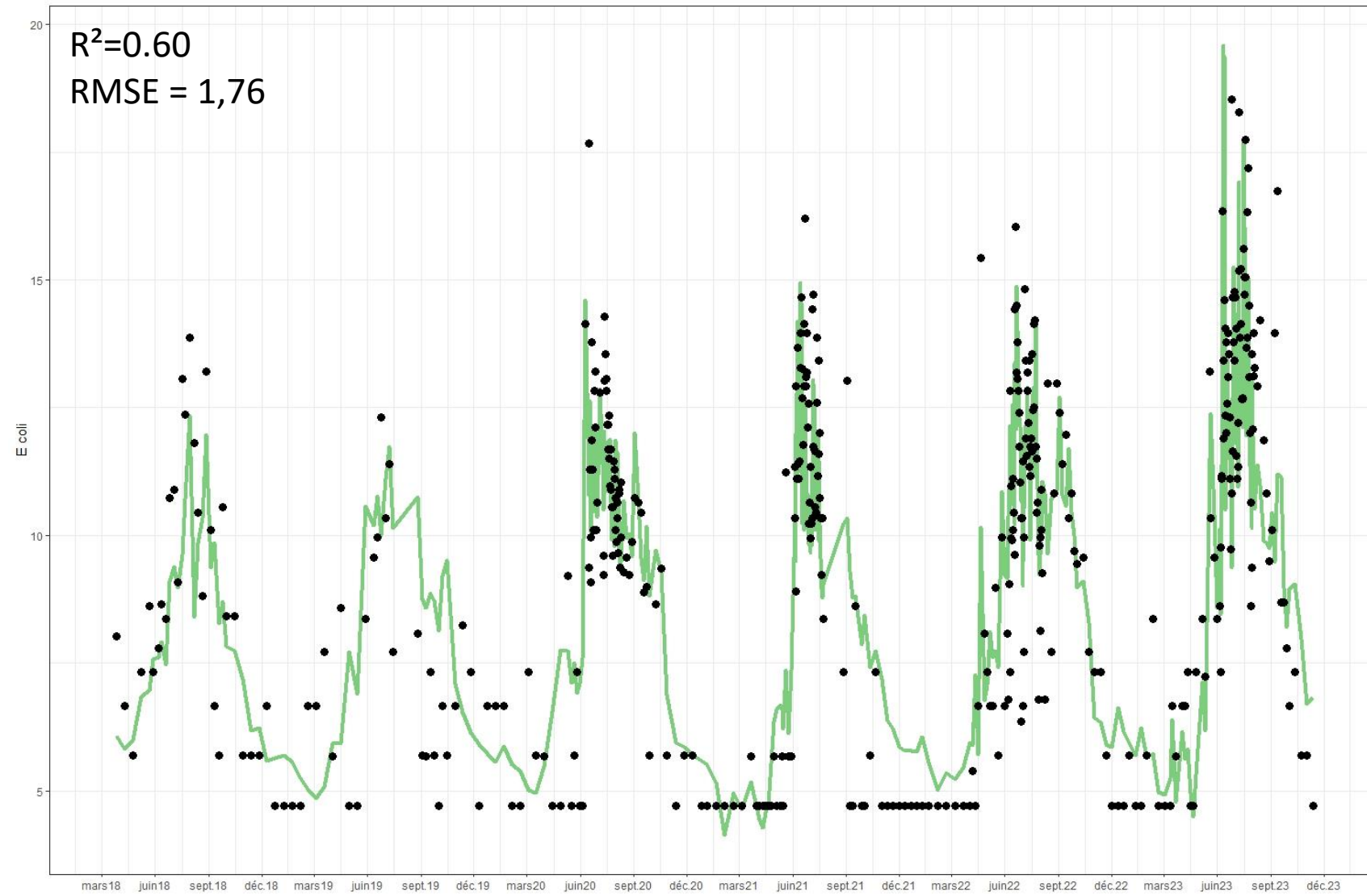
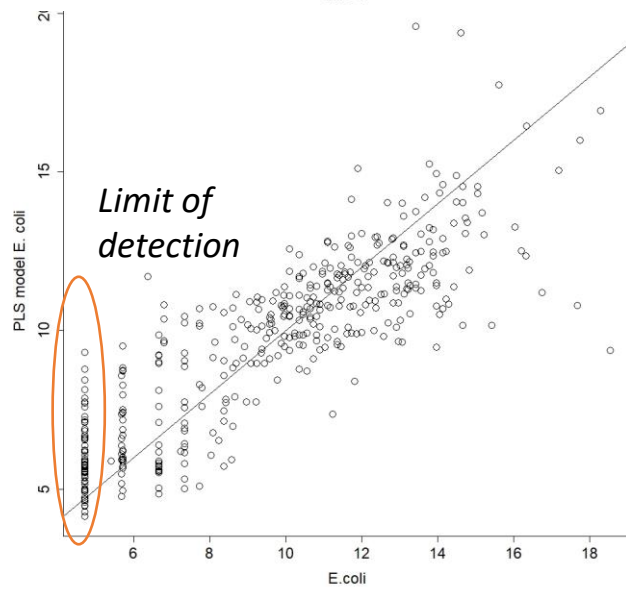
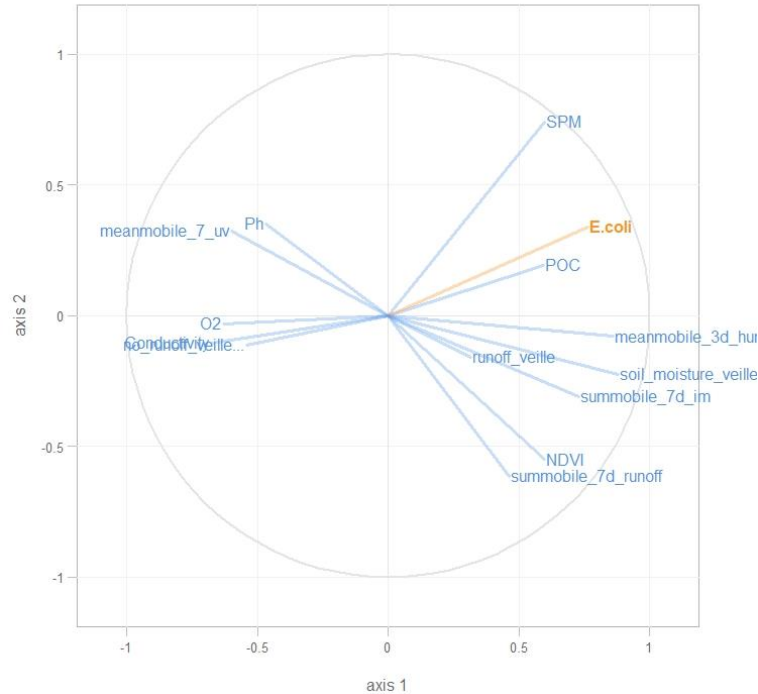
\*\*\* corresponds to p-value < 0.0001, \*\* corresponds to p-value < 0.001 and \* corresponds to p-value < 0.05



# Characterization of the *E. coli* environment in surface waters in West Africa

The two first components explains 70% of the variability

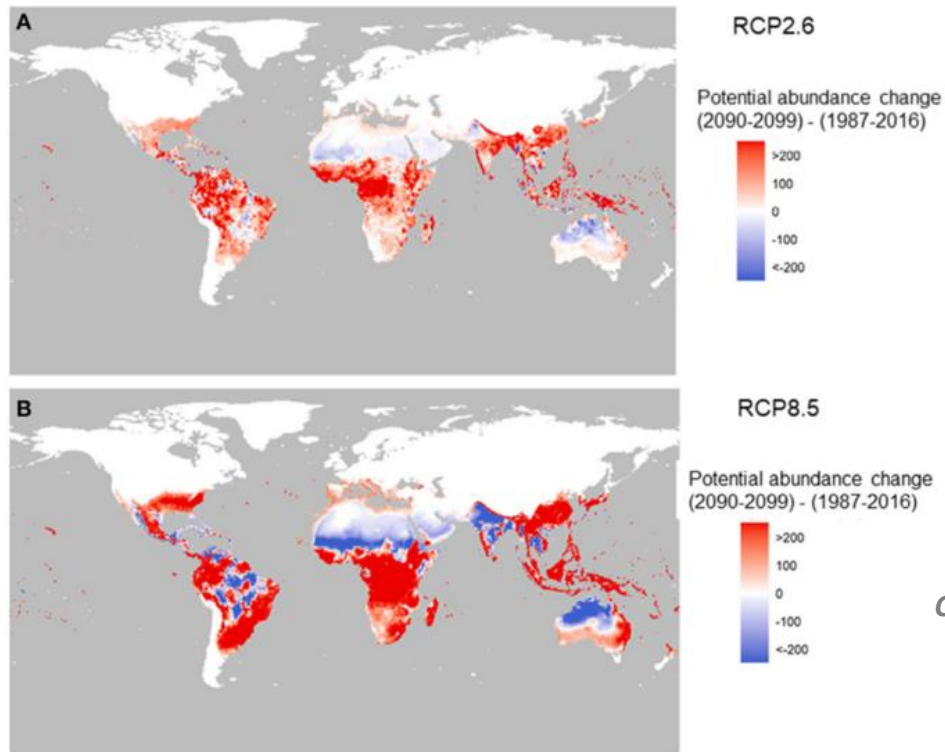
## Kapore (PLS)



MAMIWATA project (ANR JCJC 2022-2026)

# Conclusion

- Satellite data can provide an important input to monitoring the environment and reproduce the dynamics of pathogens and/or diseases, or even predict.
- Such a tele-epidemiological approach is particular interest in regions where in situ measurements are scarce and where the impacts of global and local changes are the most important.
- Importance of prediction for prevention and also anticipation in the context of climate change.
- Importance of in situ data: environmental, pathogen, epidemiological.



*Change in the potential abundance of dengue vector - A. aegypti (per larval site) over the 21st century (2090–2099 relative to 1987–2016). The two panels correspond to two carbon emission scenarios: RCP2.6 (a) and RCP8.5 (b). Semenza et al. 2022*



**Thank you for your attention**

