



Mapping the biophysical sensitivity of agrosystems in the central Sahel using machine learning models

I. Hanadé Houmma (1,2), S. Gadal (1), L. El Mansouri (2), M. Oukhattar (1),
A. Abdourhamane Toure (3), R. Hadria (4)



1. Aix-Marseille University, CNRS, ESPACE UMR 7300, Univ. Nice Sophia Antipolis, Avignon University, France, European Union
2. Department of Geodesy and Topography, Hassan II Institute of Agronomy and Veterinary, Rabat, Morocco
3. Abdou Moumouni University, Faculty of Science and Technology, Department of Geology, Niamey, Niger
4. National Institute of Agricultural Research, (INRA), Morocco

1. Background / Motivation

- **Biophysical sensitivity (BS) refers to responds of** natural or agricultural ecosystem to changes in climatic and/or environmental conditions such as variations in **rainfall, high temperatures, prolonged droughts, soil degradation**, etc.
- In this sense, biophysical sensitivity is therefore **a measure that provides information on drought resistance** that partly reflects their **seasonal climate resilience**.
- In several parts of the world, climate extremes and their trends **have exacerbated the biophysical susceptibility** of agrosystems in semiarid regions.

1. Background /Motivation

- In the Sahel region, BS is reflected in a gradual deterioration in the climatic resilience of agrosystems and their ecosystem productivity, with potential losses in cereal yields of up to **27% by 2050**.
- To meet current and projected challenges in terms of food security and the sustainability of agricultural systems, **a better understanding of** spatial variability of **the BS** of is crucial.
- In previous studies, vegetation anomalies, are the most commonly used variables for mapping biophysical sensitivity related to response of agrosystems to climatic water deficits.
- However, vegetation anomalies **can be influenced by other non-climatic factors**, for this reason in this study the **magnitudes of historical changes** in indicators were used for spatial modelling of biophysical sensitivity classes.

2. Objective of the study

The aim objective of this study is to develop an approach to mapping the biophysical sensitivity of agrosystems considering the history of Earth observation data over the last forty years (1981-2021).

Specifically, these are:

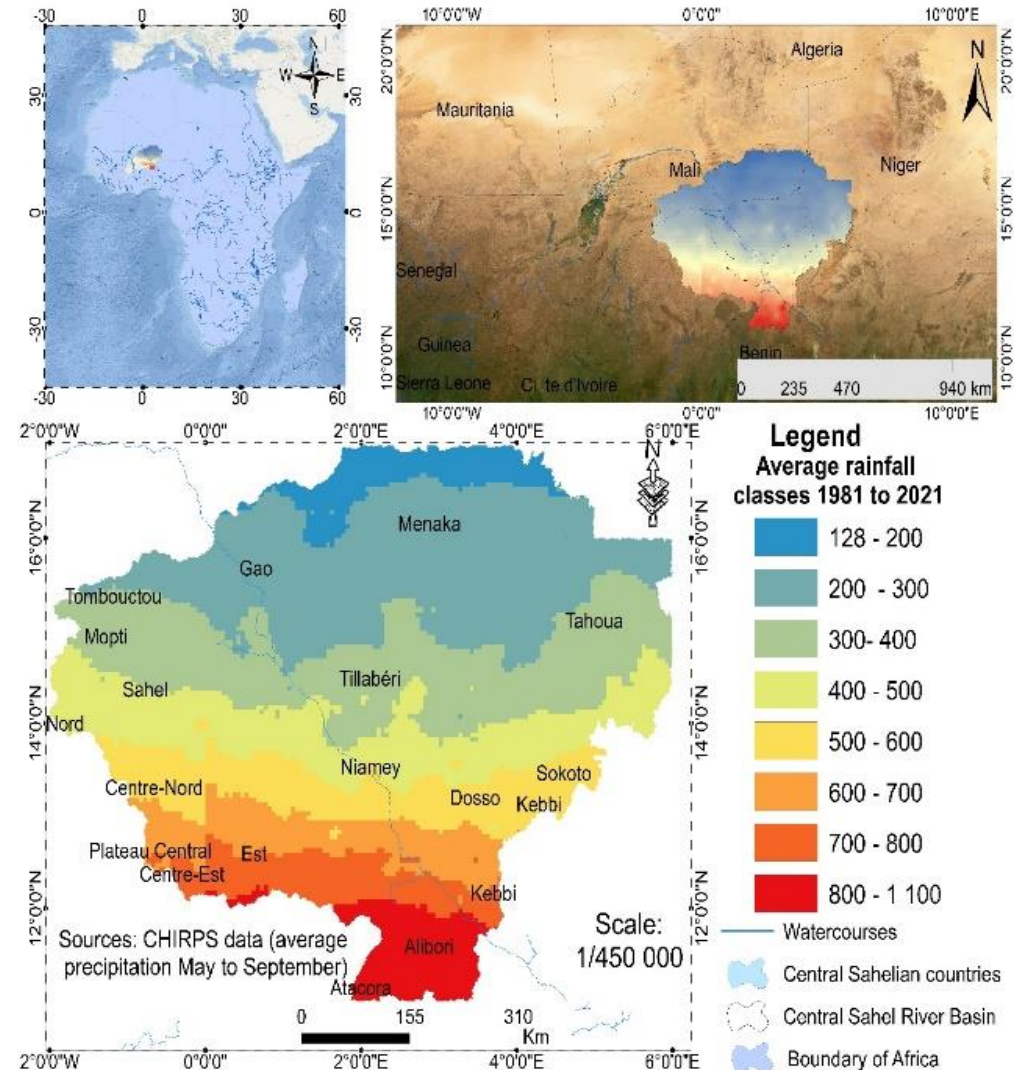
- Evaluate the predictive performance of four ML models in order to identify the appropriate model for spatial modeling of biophysical sensitivity.
- Analyze the spatial relationship between biophysical sensitivity and major land cover and land use units (LULCs).
- Identify the agrosystems most sensitive to climate variability based on magnitudes of changes in anomalies of bio-physical indicators and machine learning techniques.

3. Contents of today's presentation

1. Presentation of study area
2. Data used and methodology
3. Results and discussions
4. Conclusion and implications of the study

4. Presentation of study area

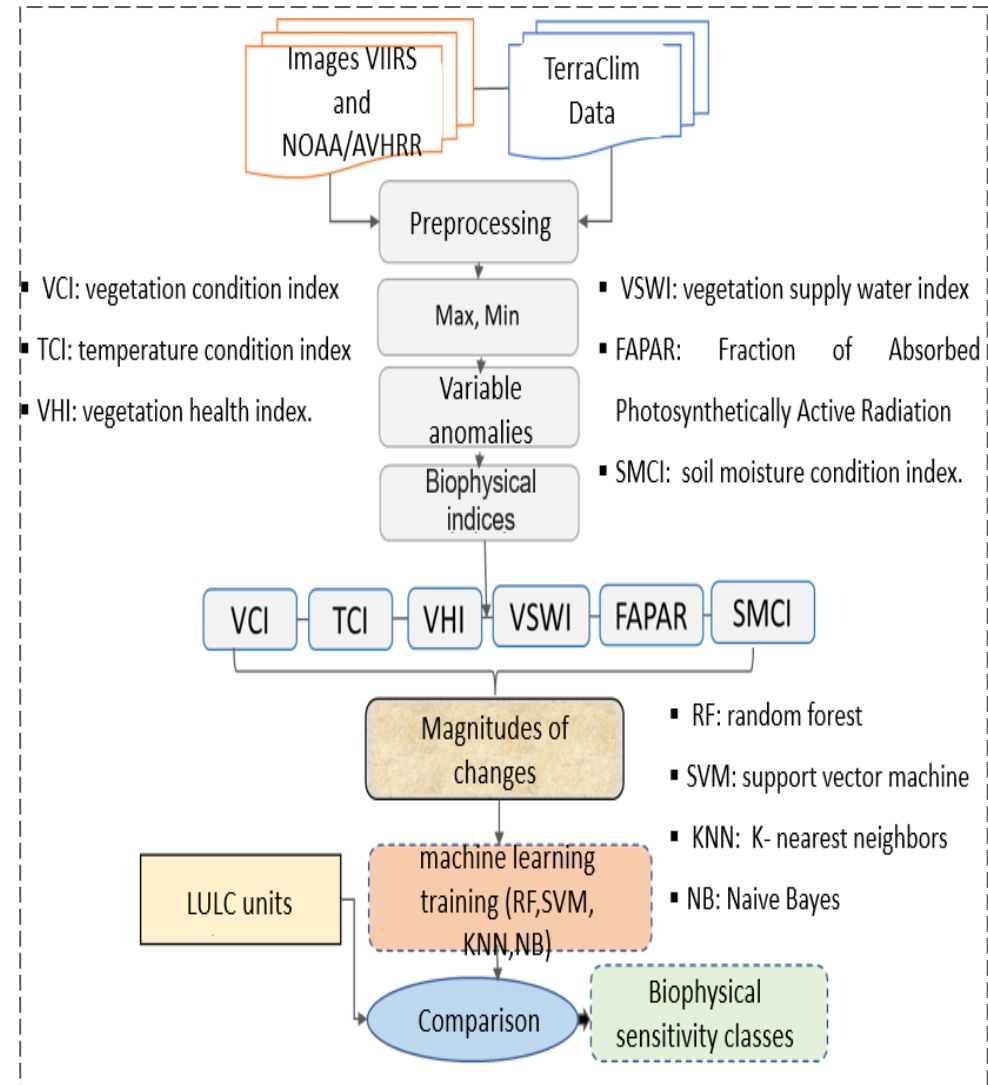
- Study area (340 km²) is the segment of the Niger River straddling three countries between.
- Topography is not very contrasted and climate is tropical with three distinct zones: Sahelo-Saharan (150-250mm), Sahelian (250-500mm) and Sudanian (500 -750 mm).
- Socio-economic characteristics are highly variable with a south-north gradient depending on physio-climatic conditions.
- In south, rain-fed agriculture is the main activity of the population (about 90%), in the north pastoralism replaces agricultural practices.



5. Data and methodology

Biophysical sensitivity mapping was performed by combining the magnitudes of trends from biophysical indicators over the period 1981-2021.

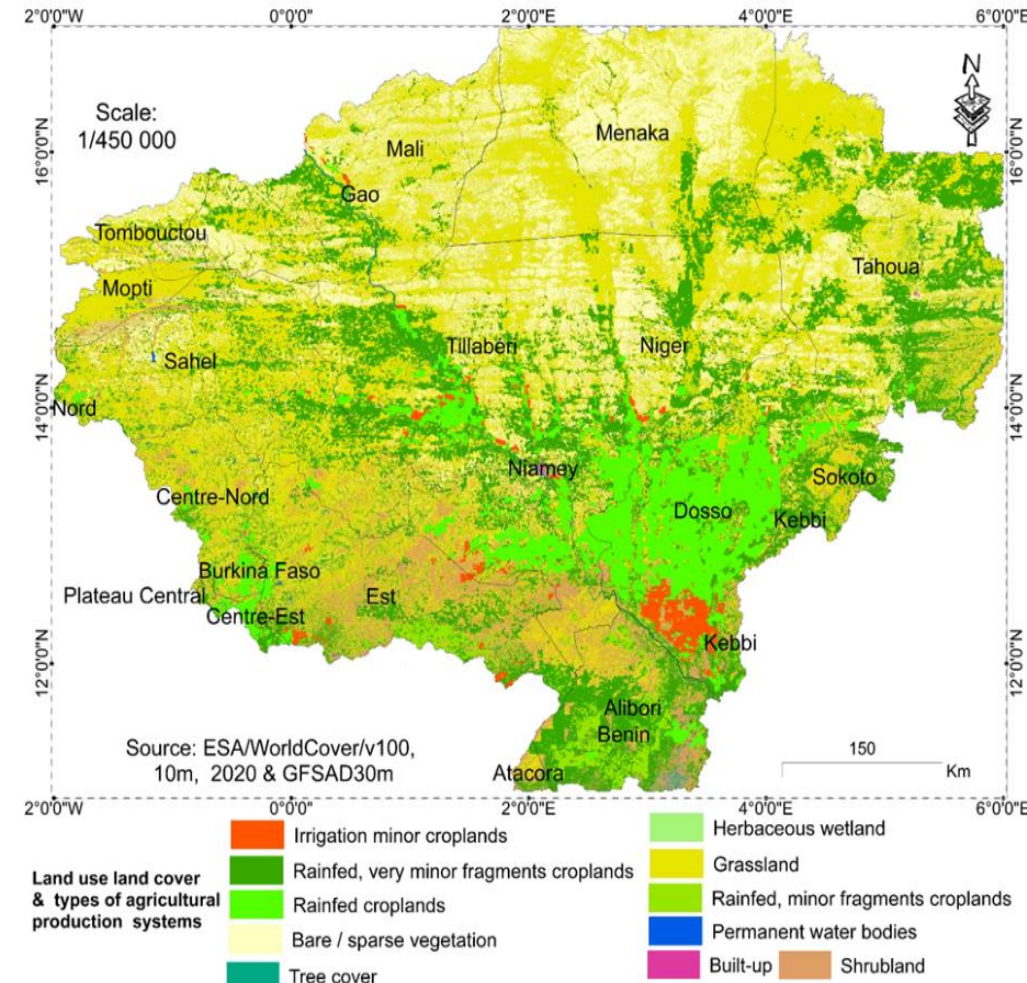
- Time series data of NDVI, temperature, vegetation productivity and soil moisture from NOAA/AVHRR and TerraClimate products were used.
- Methodological steps included analysis of significant trends obtained by linear regression of index using the `lm()` function in Rstudio.
- Next, models (RF, SVM, KNN and NB) were implemented using the caret package with a data partitioning of 70% of the model training and 30% of its testing.



6. Results and discussions

Mapping of spatial distribution of the main natural and anthropogenic agrosystems in study area:

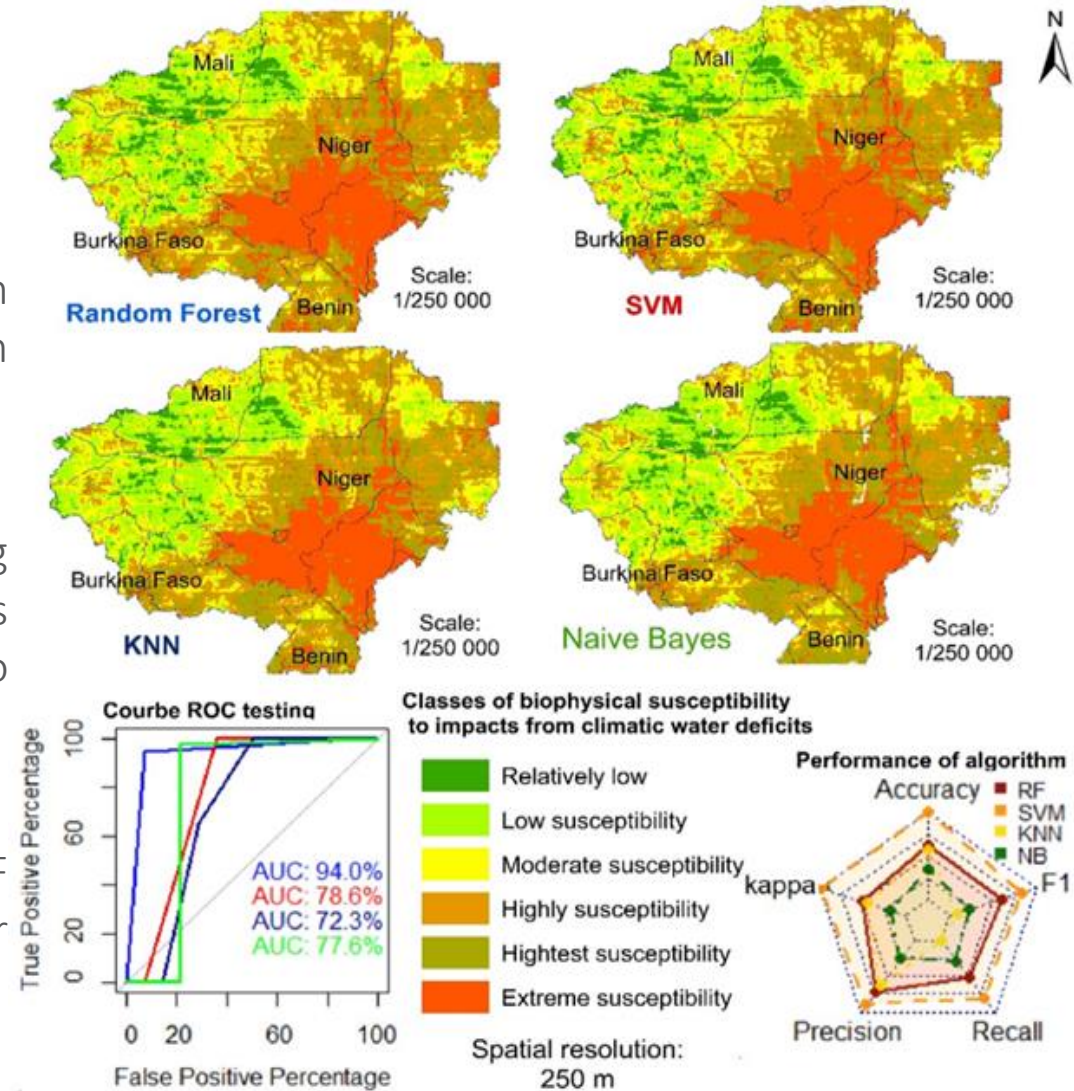
- Agricultural production systems are mainly located in the extreme south of the watershed.
- Different degrees of green correspond to rainfed production systems, which dominate compared to semi-irrigated systems.
- Red color corresponds to production systems with complementary irrigation.
- LULC namely grassland and bare soil, are the most dominant land cover units in the basin.



7. Results and discussions

Spatial modelling of biophysical sensitivity:

- Highest biophysical sensitivity is observed in rainfed crop areas mainly in the southwestern part of watershed.
- Northern pastoral zone constituting rangelands and perennial vegetation of thorns is relatively less sensitive compared to cultivated agrosystems.
- Comparing ML models predictive skills, RF model performs significantly better than other algorithms such as SVM, KNN and NB.



8. Conclusions

- This study aimed to develop an approach to **mapping the BS of agrosystems** in the central Sahel based on the **magnitudes of changes** in six biophysical indices.
- Obtained results shows a **spatial correspondence** between the **biophysical sensitivity** classes and the **LULC units**.
- By comparing the performance of four ML models, **RF model** was found to be better suited to spatial modelling of **BS of agrosystems** than **SVM, KNN and NB**.
- This suggests a spatial variability in biophysical sensitivity strongly **related to land cover type**. **Highest BS is obtained** in cropland and **is relatively low** in other types of land use.
- In this way, the results of this approach can be used as **cartographic decision-support indicators** for targeting territorial priorities in **agro-climatic risk management**.



Thank you!



Ismaguil Hanadé Houmma
hisaguil12@gmail.com

Sponsors / Partners: research was supported by the Islamic Development Bank under a three-year thesis grant. The first author is very grateful for this financial support, and also gratefully the following partners: UMR CNRS ESPACE 7300 (AMU France), laboratory (UR 18) of the Department of Geodesy and Topography (IAV Hassan II- Morocco), and the Regional Center for Agronomic Research of Marrakech (INRA, Morocco).