

Where are the most vulnerable areas to climate induced insecurities and risks in Senegal?

1. Objectives and research questions

The main objective of the spatial hotspots analysis is to map the climate-conflict nexus, and identify the geographic co-occurrence of specific combinations of conflict, climate conditions, and socio-economic vulnerabilities. The process follows four steps: determination of conflict clusters, determination of climate clusters, identification and mapping of conflict-climate interactions, and identification and mapping of socio-economic vulnerabilities. The purpose of the spatial hotspots analysis is to provide answers to the following research question:

Where are the hotspots of climate hazards, conflict, and socio-economic vulnerability?

In response to this question, a traffic light code is created following three categories (green color: limited conflict - good climate, yellow color: moderate conflict - harsh climate, and red color: high conflict – harsh climate). All other co-occurrences are colored in gray, for simplicity. The hotspots of climate insecurities correspond to the socio-economic vulnerabilities overlapping with the yellow and red categories of the traffic light code.

2. Methods and data

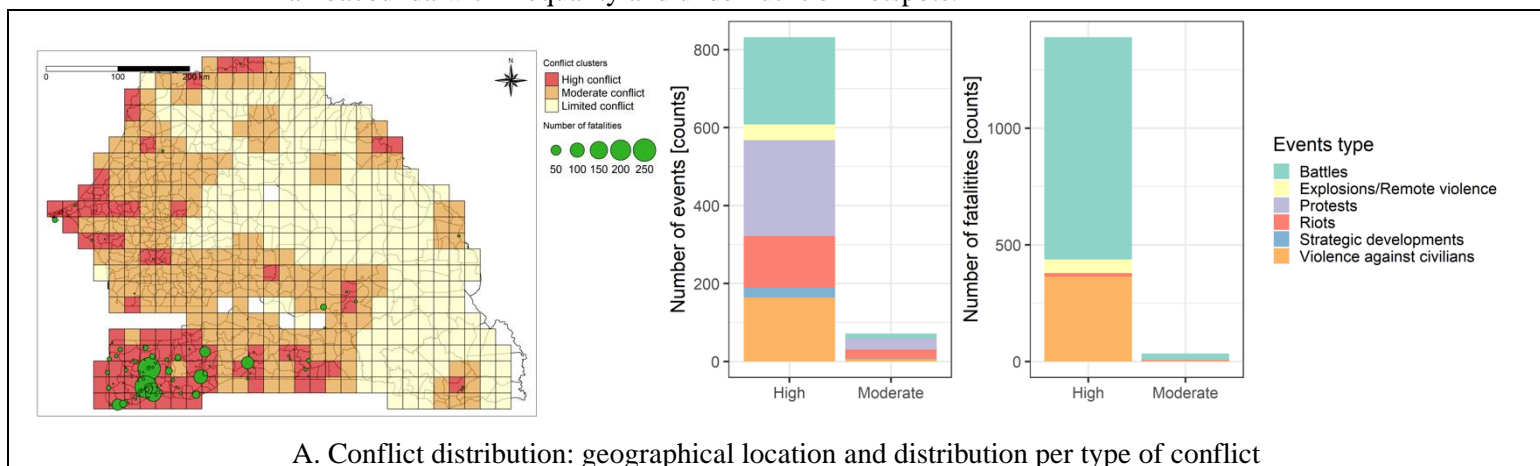
The hotspots analysis develops four steps: determination of conflict clusters, determination of climate clusters, identification and mapping of conflict-climate interactions, and identification of socio-economic vulnerabilities. The conflict and climate clusters are determined through pattern-based spatial cluster analysis using a regular grid of 30 km² of resolution. The labels for the resulting groups are defined by a conflict or climate gradient from descriptive statistics. The socio-economic vulnerability conditions are determined by extreme percentiles (10% and 90%, depending on the variable), based on the assumption that the most extreme conditions (in either tail of the probability distribution) are the most likely spots for urgent intervention. Finally, a simple traffic light code is used to identify the hotspots of climate-conflict and socio-economic vulnerability. Conflict data are from ACLED; climate data are from CHIRPS, TerraClimate, and AgERA5; and socio-economic variables are from the Institute for Health Metrics and Evaluation (IHME), Facebook's wealth maps, amongst others. Most of these data are directly available through Google Earth Engine.

3. Results

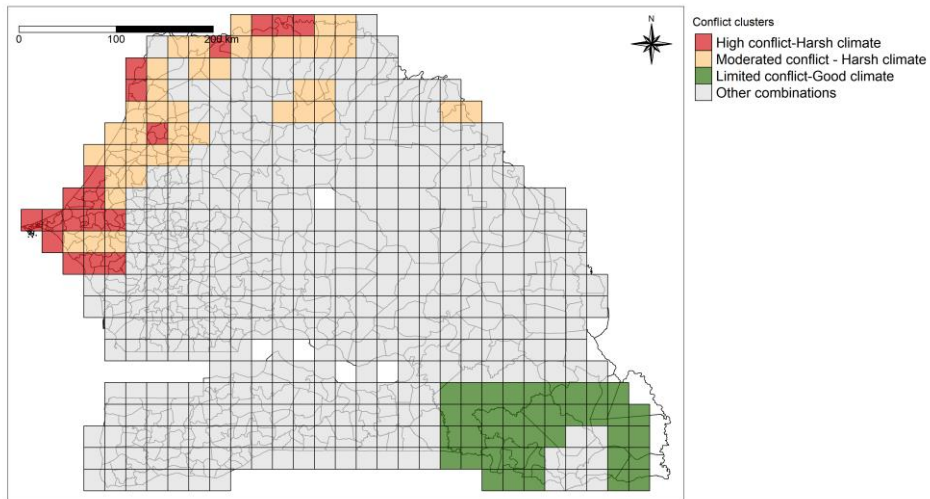
- Conflict events across Senegal during 1997-2021 are very limited over the south-western part of the country in the Ziguinchor and Sédhiou regions, but also sporadically in Dakar and the northern border with Mauritania. (Figure 1.A). Three clusters were identified based on statistical analyses. The high conflict cluster is estimated in Ziguinchor, Sédhiou, Dakar, Thiès, and northern of Saint-Louis regions. The moderate conflict cluster surround the high conflict areas, but are mainly distributed in the Kolda, western of Tambocounda, Kaffrine, Kaolack,

Factick, Diourbel, western of Louga, and Saint-Louis regions. The conflict events are diverse and representative between high and moderate conflict clusters. The protest, battles, violence against civilians, and riots are the main conflict events. Nevertheless, the major number of fatalities are attributed to battles, violence against civilians, and explosions.

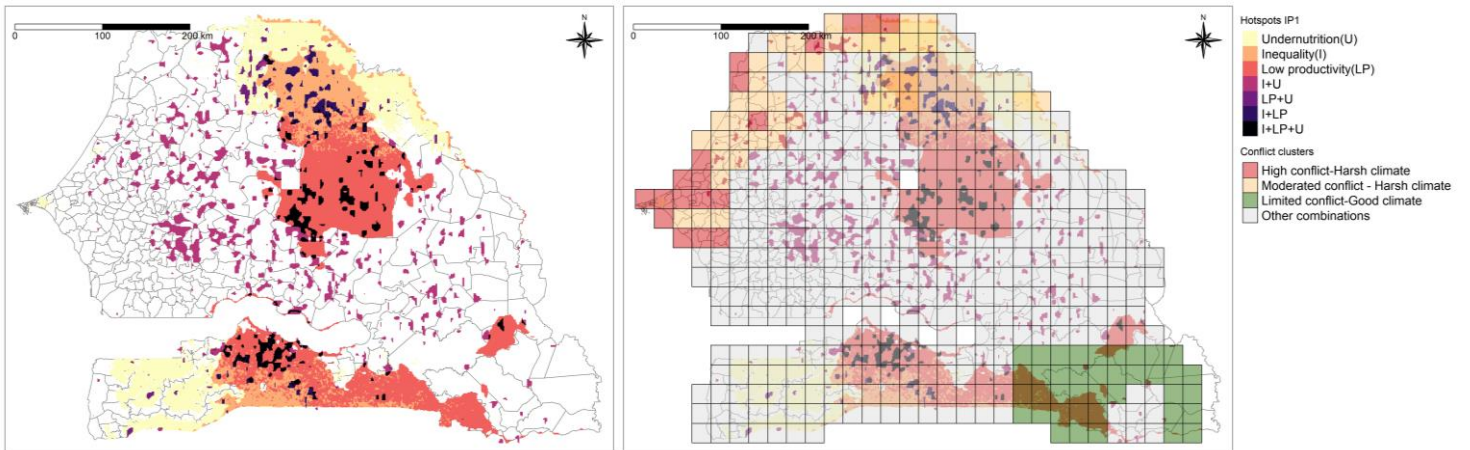
- The interaction between conflict and climate clusters is presented through a traffic light color code (Figure 1.B). **The red color indicates the co-occurrence of high conflict and harsh climate conditions.** Here specifically, the negative climate conditions are determined by high variability in rainfall, a high number of days with moisture stress, long dry spells, high levels of water deficit, and high temperatures. Yellow color corresponds to the co-occurrence of **moderate conflict and harsh climate conditions.** The location of high conflict but also harsh climate covers the north-western part of Senegal covering most of the area and surroundings of **Dakar region, Meouane, Keur Moussa, Bambilor, Sessene, Fissel, Fimela, Mbediene, Ndiaye Mberess, central north of Mbane, northern of Gamadji Sarre districts.** The moderate conflict and harsh climate are present in the Sagatta Gueth, Meur Momar Sarr, central part of Fissel, Coki, southern of Dodji, western of Ndiaye Mberess, and Ogo districts. Meanwhile, the green color determines the intersection between limited conflict and good climate settings, as can be seen in the **Kédougou region.** All other combinations (which cover a substantial portion of the country) are colored in grey, for simplicity in the visualization.
- Figure 1.C shows the socio-economic hotspots (left), and they are overlaid by the conflict-climate interactions (right). The social vulnerabilities are determined by the resource scarcity impact pathway. In the map, the vulnerabilities are presented by the following categories: undernutrition (U), inequality (I), low productivity (LP), and their co-occurrences. Despite of the reduced number of **high conflict and harsh climate interactions, they co-occurred with hotspots where undernutrition and inequality socio-economic vulnerabilities are present.** This occurs in the following communes: **Dakar, Thienaba, Kelle Gueye, northern of Mbane, western of Bokhol, northern of Ndiayene Pendaou, northern of Guede Village, and northern of Fanaye.**
- A high number of hotspots determined mainly by **low productivity issues occurred in the south-eastern of Senegal, Kédougou region, where limited conflict and good climate co-occur.** **Matam, southern of Saint-Louis, and Kolda regions are mainly represented by the co-occurrence of undernutrition, inequality, and low productivity hotspots.** Ziguinchor and Sédhiou regions with undernutrition issues, and Louga, Kaffrine, and Tambacounda with inequality and undernutrition hotspots.



A. Conflict distribution: geographical location and distribution per type of conflict



B. Conflict-climate interactions



C. Hotspots

Figure 1: Conflict distribution, conflict-climate interactions, and spatial hotspots