

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

## 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 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

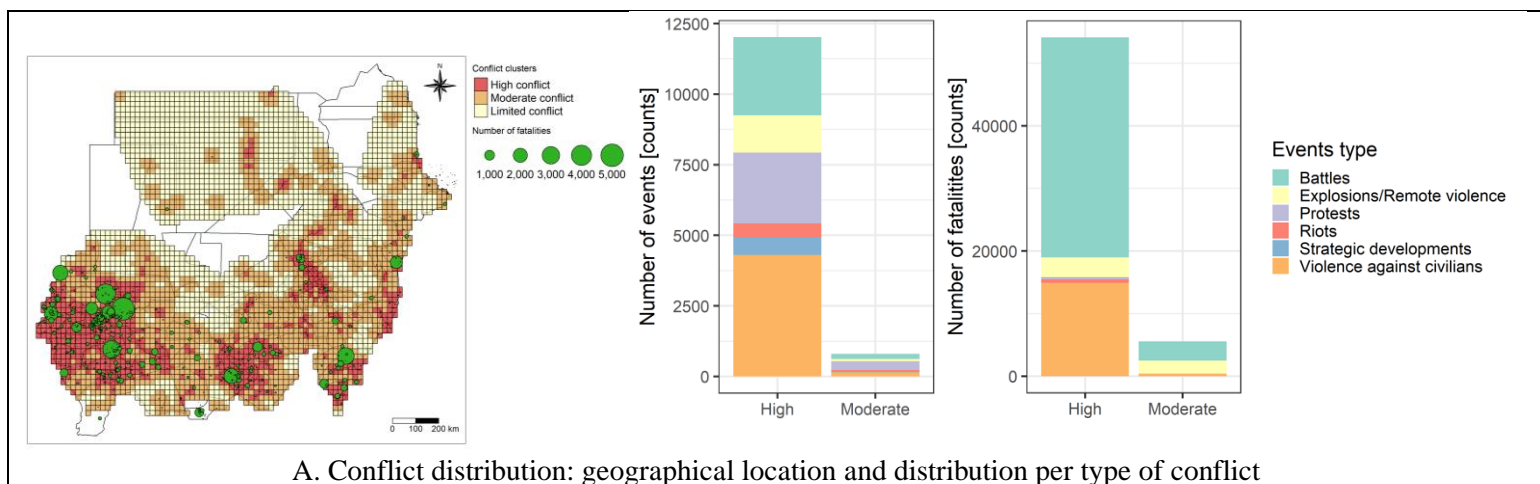
The hotspots analysis develops four steps: 1) determination of conflict clusters, 2) determination of climate clusters, 3) identification and mapping of conflict-climate interactions, and 4) identification of socio-economic vulnerabilities. The conflict and climate clusters are determined through pattern-based spatial cluster analysis using a regular grid of 30 km<sup>2</sup> 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% or 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.

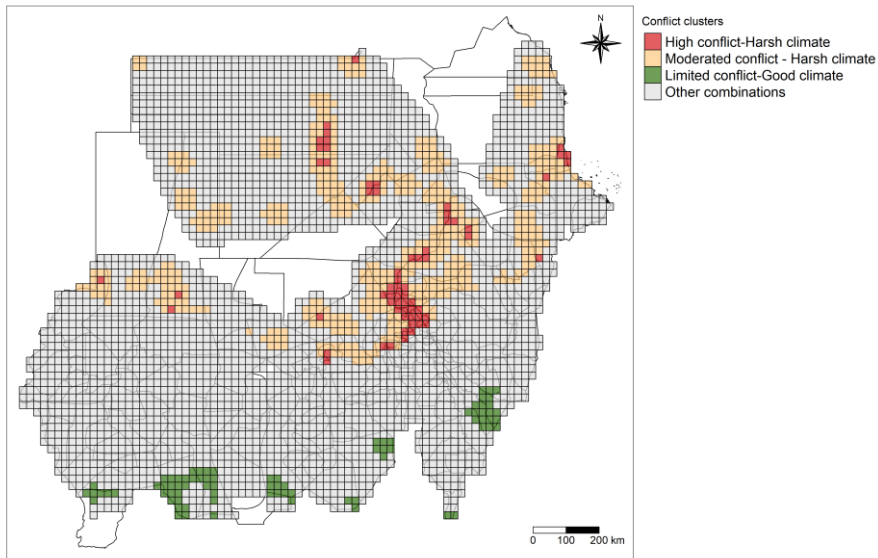
## 3. Results

- Conflict events across Sudan during 1997-2021 are highly concentrated over southern areas of the country (Figure 1.A). Three clusters were identified based on statistical analyses. High conflict areas are estimated in the North Darfur, East Darfur, South Darfur, Central Darfur, West Darfur, South Kurdufan, North Kurdufan, Blue Nile, Sennar, Khartoum, Al Jazirah, Al Qadarif, and Kassala states, but also with some localized areas close to Dongola city. The moderate conflict cluster covers most of the rest of the country surrounding the high conflict areas. Violence against civilians, protests, battles, and explosions are the main historical

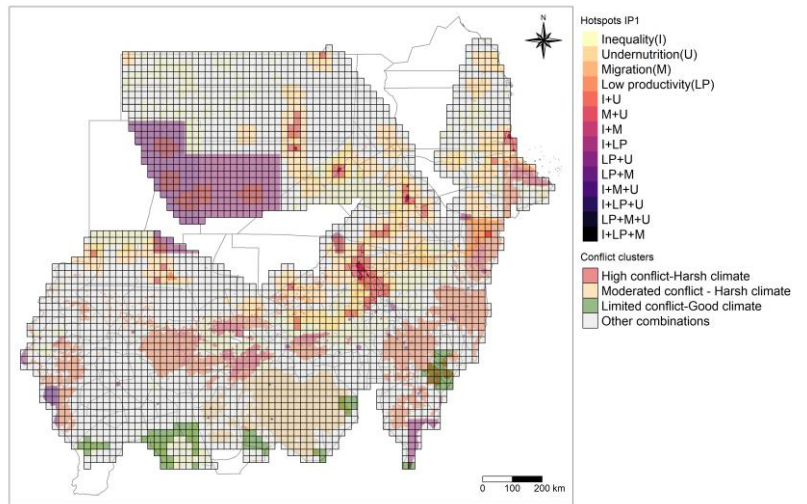
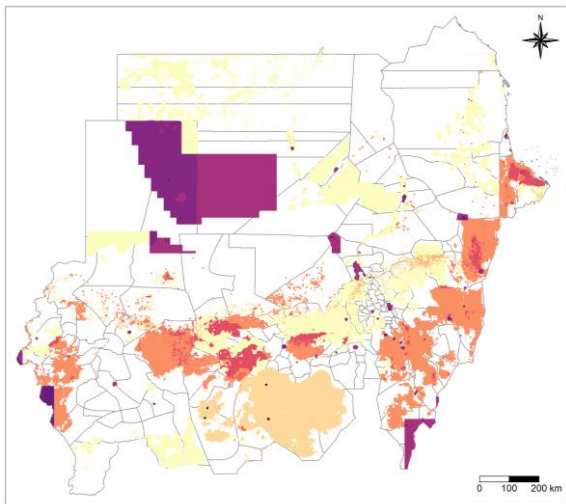
conflict events. Nevertheless, battles and violence against civilians have attributed the major number of fatalities in high conflict cluster.

- 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 moderate variability in rainfall, high levels of water deficit, and moderate increases in temperature over the last 30 years. Yellow color corresponds to the co-occurrence of **moderate conflict and harsh climate conditions.** The location of high/moderate conflict but also harsh climate covers the north and central part of Sudan covering the surrounding area of the capital **Khartoum, southeastern of Delgo, northeastern of Argo, border between Karima and Marawi, eastern of Port Sudan, and some spread locations in North Darfur state.** Limited conflict and good climate combinations are localized the in the southern areas of Sudan, mainly in Sennar, Blue Nile, South Kurdufan, West Kurdufan, East Kurdufan, and South Kurdufan states. 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), migration (M), low productivity (LP), and their co-occurrences. Despite the reduced number of **high conflict and harsh climate interactions, they co-occurred with hotspots where inequality vulnerabilities are present.** This occurs around the capital Khartoum. Port Sudan is characterized by migration and low productivity hotspots. In the Northern regions inequality issues are present, while in the western of the country (North Darfur), low productivity vulnerabilities are predominant. River Nile state has the interaction of all the different hotspots categories.
- Despite the southern areas of the country are characterized specially for limited conflict and good climate conditions, there are some socio-economic vulnerabilities. These are some of the socio-economic issues identified: migration in West Kurdufan and South Kurdufan, low productivity in South Darfur, East Darfur, and Sennar.





**B. Conflict-climate interactions**



**C. Hotspots**

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