

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

## 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

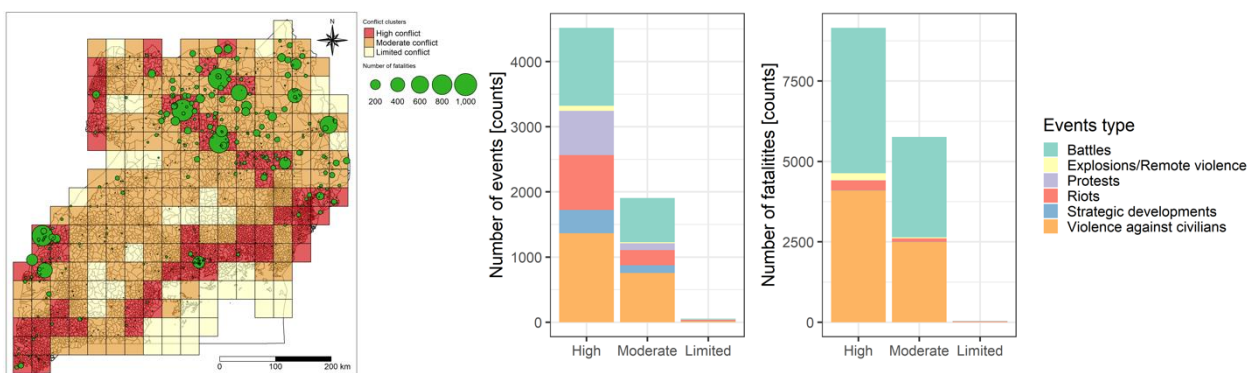
The hotspots analysis develops four steps: determination of conflict clusters, determination of climate clusters, identification and mapping of conflict-climate interactions, and identification of socio-economic vulnerabilities. The conflict and climate clusters are determined through pattern-based spatial cluster analysis using a regular grid of 30 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% 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

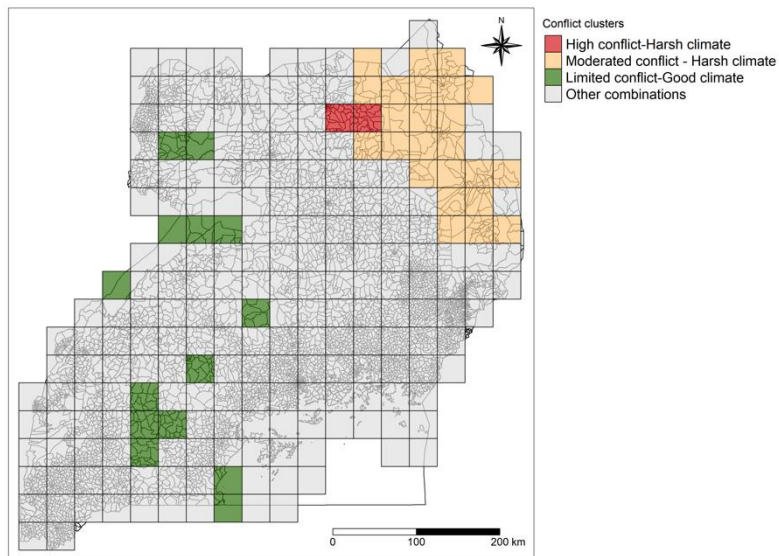
- Conflict events across Uganda during 1997-2021 are widely distributed over the country (Figure 1.A). Three clusters were identified based on statistical analyses. Conflict events highly concentrated in specific areas around the cities are: Gulu, Lira, Kitgum, Kalongo, Moroto, Kampala, Fort Portland, and Rukoki. The high conflict cluster is estimated around Kampala and the districts around the border of Victoria Lake, Fort Portland, Gulu, Lira, and north-western of Uganda. The moderate conflict cluster covers most of the rest of the country.

Violence against civilians, battles, and riots are the main conflict events and they have attributed the major number of fatalities in both high and moderate conflict clusters.

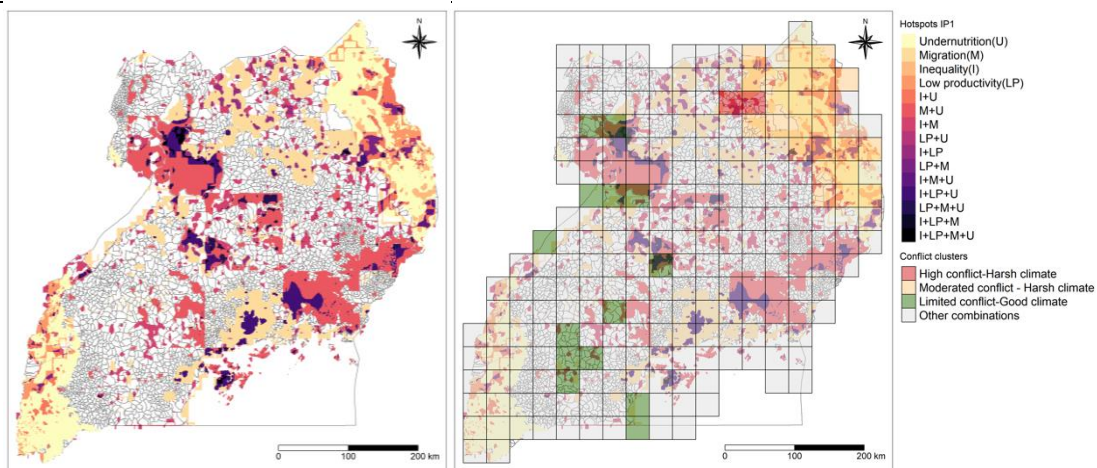
- The interaction between conflict and climate clusters is presented through a traffic light color code (Figure 1.B). **The red color indicates the co-occurrence of high conflict and harsh climate conditions.** Here specifically, the negative climate conditions are determined by high variability in rainfall, a high number of days with moisture stress, long dry spells, and high levels of water deficit. 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-eastern part of Uganda covering most of the area of the following counties: **Dodoch, Chua, Agago, northern of Aruu, Labwor, Bokora, and Chekwii.** Meanwhile, the green color determines the intersection between limited conflict and good climate settings, as can be seen in the **counties: Nyabushozi, Kazo, southern of Kyaka, Kabula, Buwekula, central part of Nakaseke, Bujenje, Buruli, Madi-Okollo, and East Moyo.** 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 pre-existing conflict, land, and livelihood insecurity 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 of the reduced number of **high conflict and harsh climate interactions, they co-occurred with hotspots where migration, inequality, and low productivity socio-economic vulnerabilities are present.** This occurs in the following parishes: **Lakwor, Oryang Lalano, Palwo, and Parumu.**
- A high number of hotspots determined by different combinations of **migration, inequality, undernutrition, and low productivity issues in the north-eastern of Uganda where moderate conflict and harsh climate conditions co-occur.** South-western areas of Uganda are characterized by inequality, undernutrition, and migration hotspots. Central and border areas of Victoria Lake exhibit hotspots interactions and there is where high conflict areas are present, despite they are not covered by harsh climate conditions.



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**

## Annex

### Methodology

The hotspots analysis develops four steps: conflict clusters determination, climate clusters determination, conflict-climate interactions, and vulnerable social conditions identification.

#### *Clusters construction*

The clusters construction (for both, conflict, and climate) is developed through pattern-based spatial cluster analysis using a regular grid of 30 km<sup>2</sup> of resolution (Nowosad, 2021). This method uses as input data a set of spatial variables in raster format, and with them computes an integrated co-occurrence signature to determine the spatial distances and to determine the groups uses a hierarchical cluster analysis.

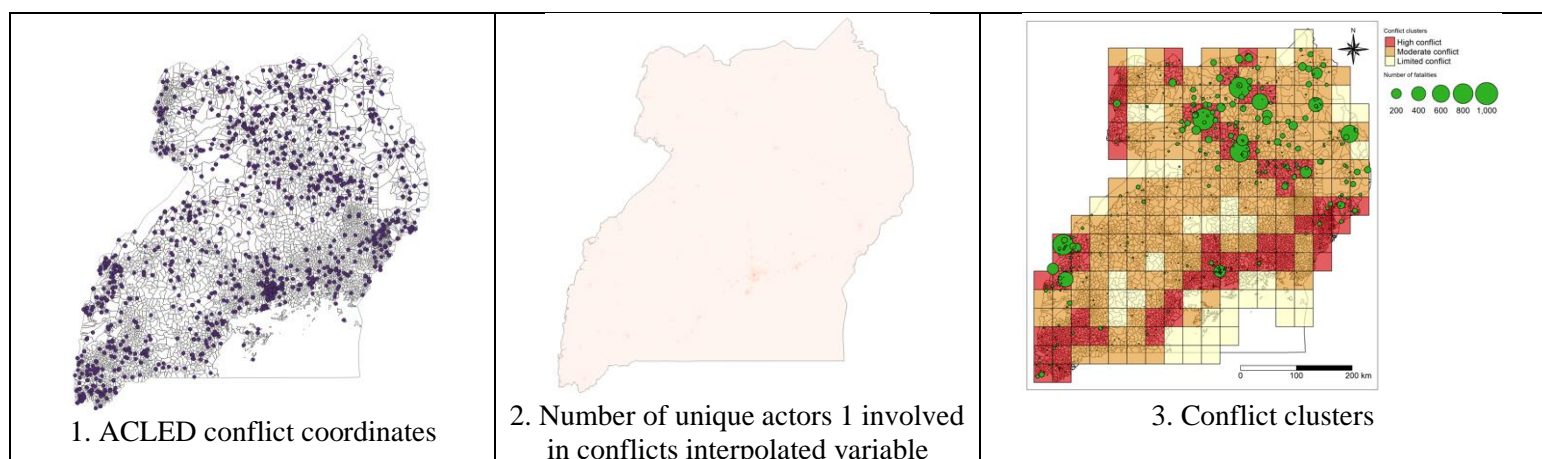
#### *Step 1. Conflict clusters determination*

To produce the input data for the pattern-based spatial cluster analysis for the conflict clusters, it is necessary to create 6-spatial interpolated variables derived from ACLED data during the whole period reported for the specific country:

- Total number of conflict events
- Total number of unique conflict type events
- Total number of unique conflict sub-type events
- Total number of unique actors 1 involved in conflicts
- Total number of unique actors 2 involved in conflicts
- Total number of conflict fatalities

The interpolation of the spatial conflict variables is based on the random forest spatial interpolation (Sekulić et al., 2020) and restricted to the conflict influence area which is determined by an iterative convex hull process around the conflict coordinates reported by ACLED.

Finally, the pattern-based spatial cluster analysis is applied over the 6 interpolated conflict variables and three groups are obtained. The labels for the three groups are defined by the descriptive statistics obtaining a conflict gradient.



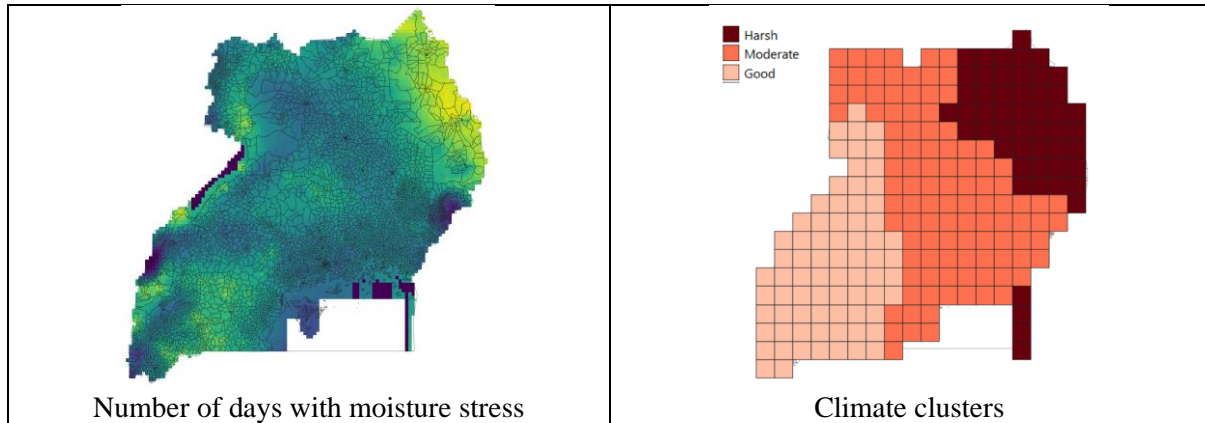
**Figure 2. Process to obtain the conflict clusters**

#### *Step 2. Climate clusters determination*

The climate variables are determined by the climate conditions mentioned in the country impact pathways. To remark, for each country different number of impact pathways can be determined, therefore all the climate conditions mentioned in their different impact pathways are considering for

producing the climate clusters. The main data sources are: TerraClimate (downloaded using Google Earth Engine platform), and some climate indicators are created based on an own methodology (they usually measure flooding, drought, and heat stresses conditions).

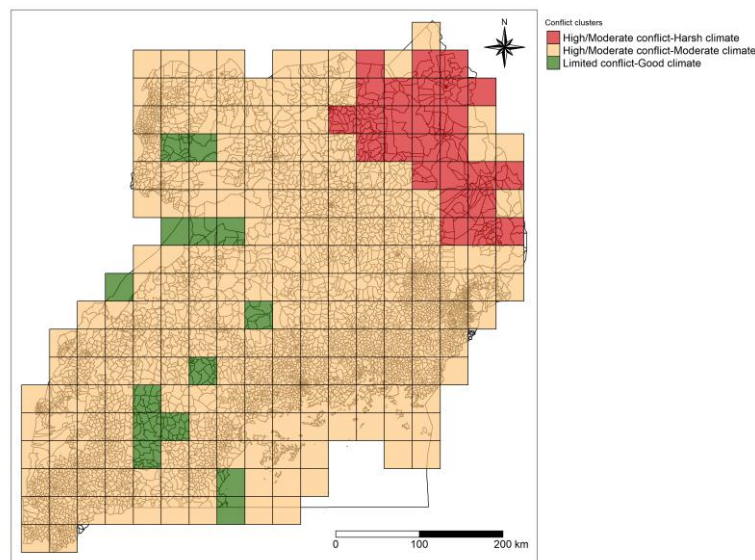
The pattern-based spatial cluster analysis is applied over the identified climate variables from the impact pathways producing an optimal number of groups estimation, and the labeling is produced identifying the most influential variables which defined a gradient of climate conditions.



**Figure 3. Process to obtain the climate clusters**

### *Step 3. Conflict-climate interactions*

The conflict-clusters interactions are determined by the concatenation of the labels from conflict clusters and climate clusters. These new categories are codified in a traffic light color code. Where red color indicates the most difficult combination of conflict and climate conditions, orange color intermediate conflict-climate conditions, and green color limited conflict and good climate settings.



**Figure 4. Conflict-climate groups intersection**

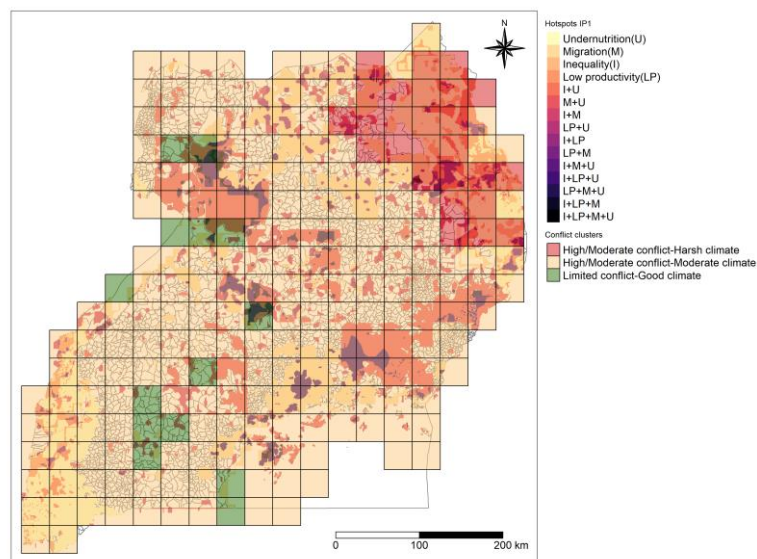
### *Step 4. Vulnerable social conditions identification*

This step is based on the definition of the impact on agriculture and livestock, resources, mobility, socio-economic, and socio-ecological variables identified in the country impact pathways. The determination of the vulnerability for each variable is based on the percentiles 10% and 90% (i.e., poverty variable is assigned to the percentile 10% or lower values, while crop failure is assigned to the percentile 90% or greater).

The set of variables are grouped by categories depending on the available variables determined by the impact pathways. The categories are inequality, low productivity, migration, resources scarcity, and undernutrition.

To obtain the hotspots per category, the original variables are thresholded by the percentiles 10% or 90% accordingly. Then the thresholded variables are summed up to identify the co-occurrence of at least one indicator under vulnerable conditions.

Finally, to achieve the general hotspots the hotspots per category are summed up and their co-occurrence is displayed in the final map. The general hotspots map is cropped just to conflict areas determined by the conflict clusters, and it is overlaid with the conflict-climate clusters intersection to identify the co-occurrence of vulnerable conditions under difficult conflict-climate conditions.



## References

Sekulić, A., Kilibarda, M., Heuvelink, G., Nikolić, M., & Bajat, B. (2020). Random forest spatial interpolation. *Remote Sensing*, 12(10), 1687.

Nowosad, J. (2021). Motif: an open-source R tool for pattern-based spatial analysis. *Landscape Ecology*, 36(1), 29-43.