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

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

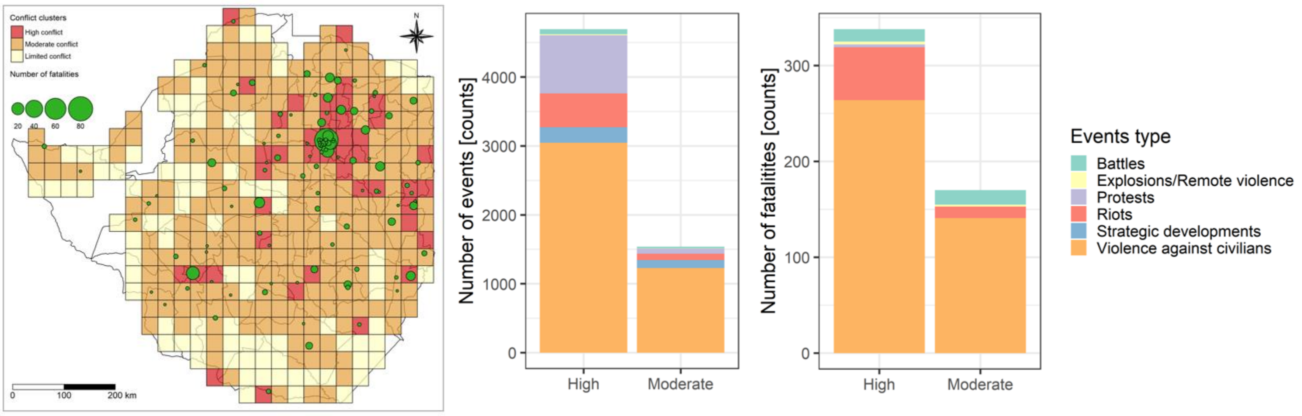
The hotspots analysis develops four steps: determination of conflict clusters, determination of climate clusters, identification and mapping of conflict-climate interactions, and identification of socio-economic vulnerabilities. The conflict and climate clusters are determined through pattern-based spatial cluster analysis using a regular grid of 30 km^2 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

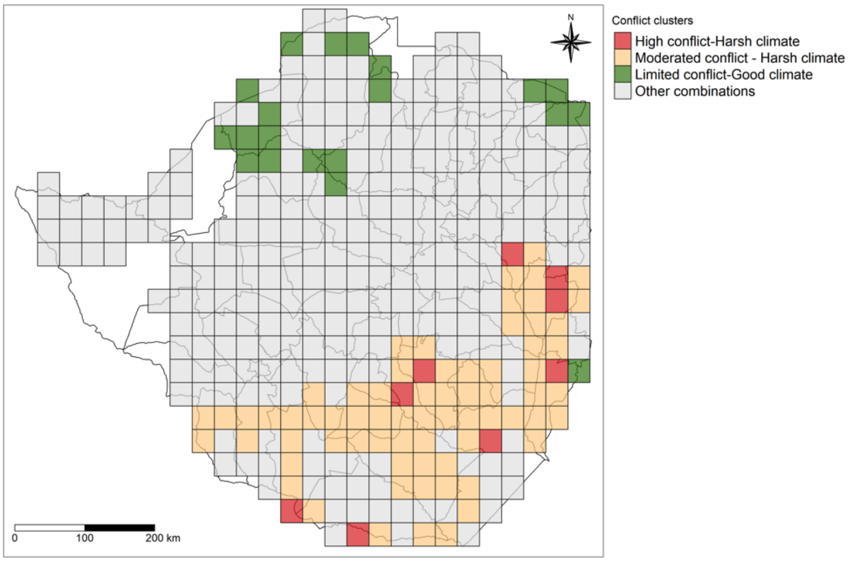
- Conflict events across Zimbabwe during 1997-2021 are scarcely distributed over the country (Figure 1.A). Three clusters were identified based on statistical analyses. High conflict conditions are estimated in the northern central part of Zimbabwe, primarily around major cities (Harare, Bulawayo). The moderate conflict cluster covers most of the rest of the country, including virtually all rural areas. The violence against civilians is the main conflict event and produces a greater 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 interannual rainfall variability, a high number of days with moisture stress, and 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 southern part of Zimbabwe covering most of the area of the provinces of **Matabeleland South, south of Midlands, Masvingo, and Manicaland**.

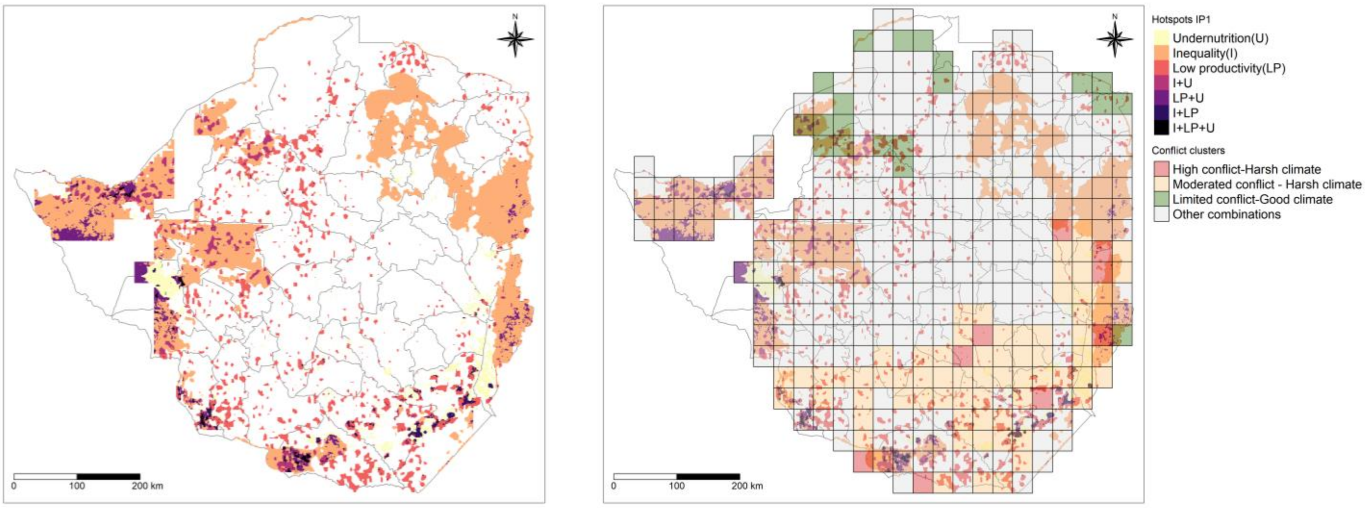
- The green color determines the intersection between limited conflict and good climate settings, as can be seen in the northern area in the following provinces: north of Midlands, Mashonaland West, and the northern boundaries between Mashonaland Central and Mashonaland East. All other combinations (which cover a substantial portion of the country) are colored in grey, for simplicity in the visualization.
- Figure 1.C shows the socio-economic vulnerability hotspots (left), and they are overlaid by the conflict-climate interactions (right). The social vulnerabilities are determined by the food insecurity and competition over access and use of natural resources impact pathway. In the map, the vulnerabilities are presented by the following categories: undernutrition (U), inequality (I), low productivity (LP), and their co-occurrences. **The high/moderate conflict and harsh climate interactions co-occurred principally with low productivity, inequality, and undernutrition hotspots**. This occurs in the following districts: Beitbridge, Chiredzi, Mwenezi, and Chipinge.
- Limited conflict and good climate conditions show hotspots in terms of inequality, and low productivity in **Kariba and Gokwe North districts**. Some of these areas also show low productivity, specifically in the north of Hurungwe, south and north of Makonde, Rushinga, and Mudzi.
- A high number of hotspots determined by different combinations of **undernutrition, low productivity, and inequality** are present in the western of Zimbabwe in the **Matabeleland region**.



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



B. Conflict-climate interactions



C. 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^2 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.

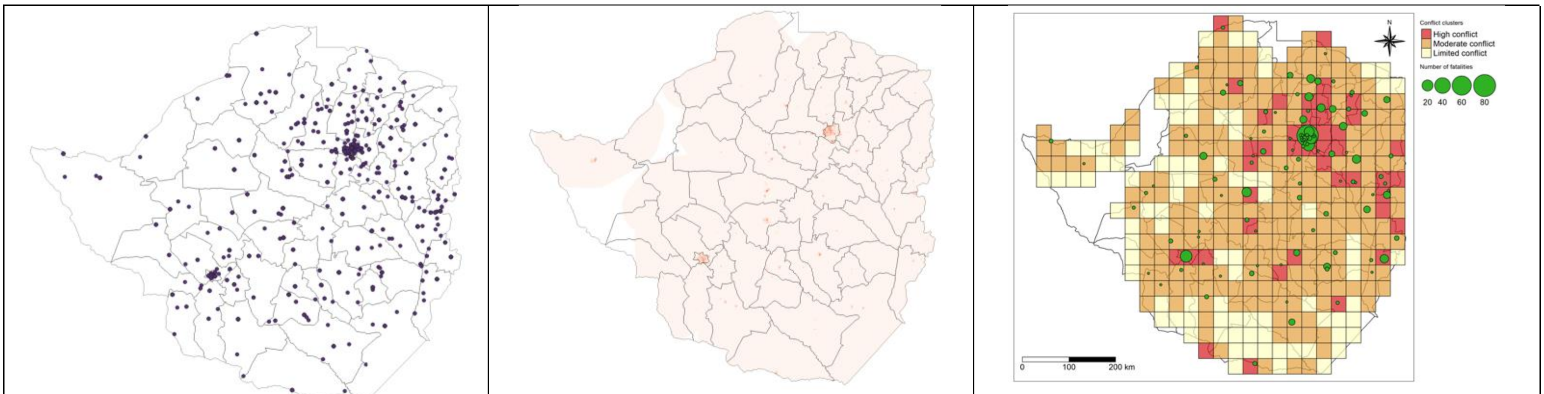
Step 1. Conflict clusters determination

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.



1. ACLED conflict coordinates | 2. Number of unique actors 1 involved in conflicts interpolated variable | 3. Conflict clusters

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.

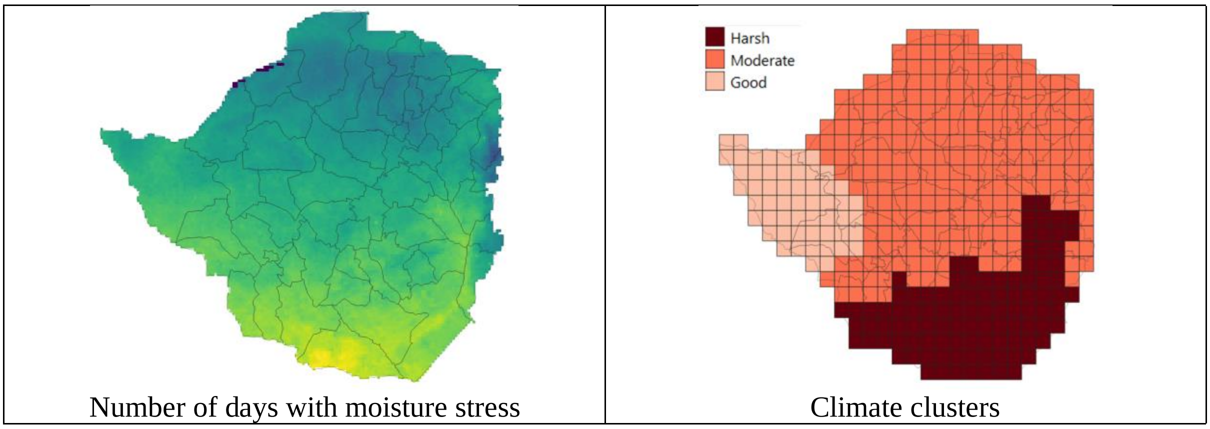


Figure 3. Process to obtain the climate clusters

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.

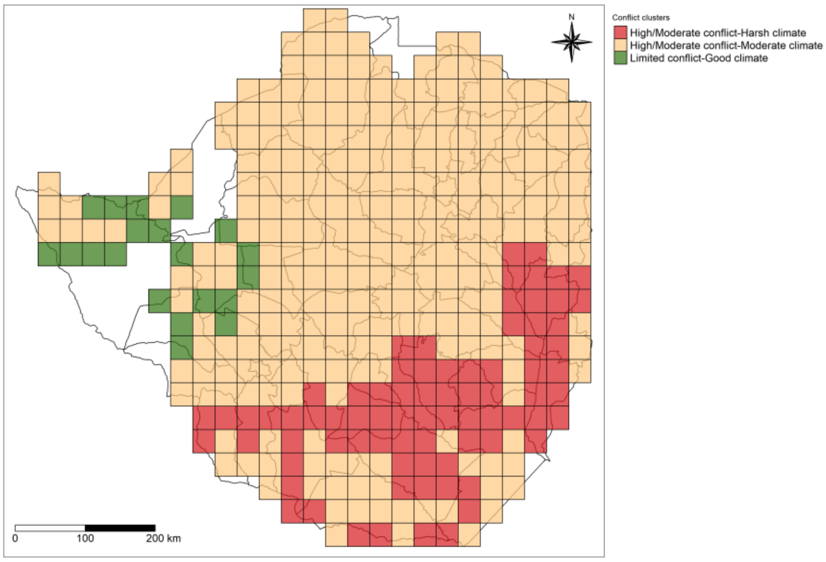


Figure 4. Conflict-climate groups intersection

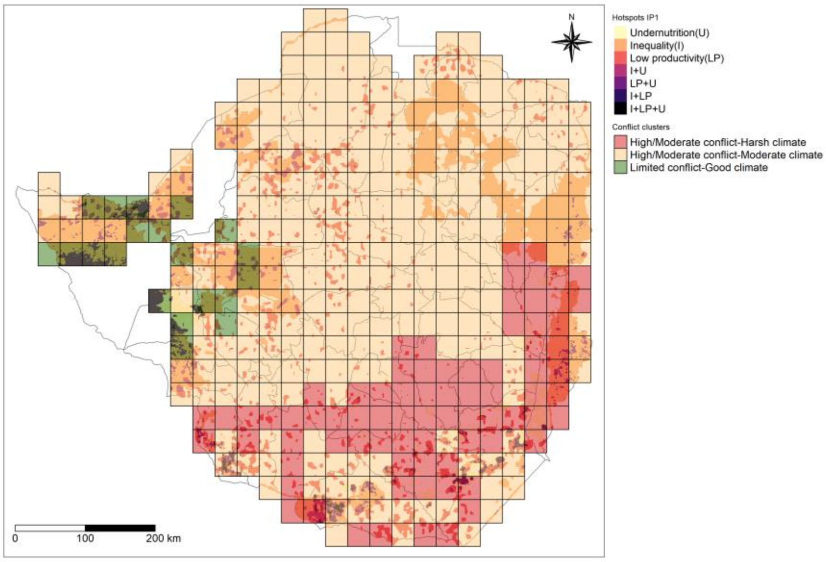
Step 4. Vulnerable social conditions identification

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.