MAPPING CLIMATE INSECURITY HOTSPOTS: ENHANCING CLIMATE PEACE AND SECURITY DECISION MAKING IN EAST AFRICA AND GREATER HORN OF AFRICA

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Abstract

Climate change poses significant threats to East Africa and Greater Horn of Africa (EAGHA), impacting critical sectors such as agriculture, nutrition, resource availability, and overall human security. Projections indicate a temperature increase of 0.6°C to 1.6°C by 2050 in EAGHA countries with precipitation levels expected to either increase or remain stable on average. Despite acknowledging the existence of a complex nexus linking climate and conflict, there is still a pressing need to identify specific areas where climate impacts may have a more significant effect on conflict risks and security outcomes. This study aims at mapping the climate-security nexus by identifying locations where different conditions of climate, conflict and socio-economic vulnerabilities co-occur. We use conflict data from Armed Conflict Location and Event Data Project (ACLED), climate data from CHIRPS, TerraClimate, and AgERA5, and socio-economic data from Institute for Health Metrics and Evaluation (IHME). The mapping approach is designed on regular grids (megapixels) of approximately 20 km^2 which identifies three categories of conflict (high, moderate, limited), climate conditions, and vulnerability risks. Results from this approach provides an overview of the current hotspots of climate insecurity in EAGHA. We anticipate that the context-specific information on where climate-related security risks have intensified including vulnerable communities will support governments, as well as development, climate, peace, and security stakeholders in improving their targeted interventions to regions highly exposed to climate-related security risks.

Keywords

Climate Security; Climate-conflict hotspots; Climate change; Climate, Peace, and Security

1 Introduction

Climate change and variability pose a significant threat to the human security of millions of people worldwide, amplifying existing inequalities and compounding challenges for the most vulnerable members of society. The consequences of climate change, such as soaring temperatures, unpredictable rainfall patterns, surging sea levels, and intensified extreme weather events, exert immense pressure on natural resources. These environmental changes adversely affect agricultural productivity, inflict damage on critical infrastructure, disrupt the stability of food supply chains, and contribute to various conflict risks within and across countries (International Food Policy Research Institute (IFPRI), 2022; Mobjörk, 2017) contributing to climate security. Climate security refers to human security and community conflict risks induced or affected, directly or indirectly, by changes in climate patterns and their interactions with environmental impacts, socio-economic fragility and other macro contextual trends (UNDP & LPI, 2023). There exists a bidirectional relationship between climate impacts and conflict risks. This means that climate change may influence the emergence and nature of conflict and violence, but the presence of conflict and fragility is likely to further exacerbate climate vulnerabilities and erode the capacities of communities and households to cope with climate impacts in a cooperative and peaceful manner.

Eastern Africa stands as one of the world's most vulnerable regions to the impacts of climate change (Intergovernmental Panel on Climate Change (IPCC), 2022). Over the past four decades, mean temperatures have risen by 0.7°C to 1°C, with projections indicating a potential increase of 1.8°C to 4.3°C by 2100 (Trisos et al., 2022). Figure 1 illustrates that temperatures could rise between 0.6°C to 1.6°C by 2040 in the region assuming a fossil-fueled development with low to no climate change mitigation measures/policies undertaken. According to Trisos et al., (2022) drought frequency has doubled since 2005, occurring once every three years and intensifying, particularly in arid and semi-arid regions. Projections suggest that Sudan, South Sudan, and Somalia will face increased drought severity, while Kenya, Uganda, and the Ethiopian Highlands may experience decreased or unchanged levels. These climate changes significantly impact agricultural production, pastoralism, and fisheries, posing threats to income, development processes, and food security in the region.

Furthermore, East Africa is plagued by a multitude of conflicts, violence, and insecurities, making it highly fragile. The devastating consequences of civil wars, coupled with increasing extreme weather events, have led to a staggering 11.71 million internally displaced persons (IDPs) in East Africa, facing severe food insecurity and in desperate need of assistance (UNCHR, 2023). Additionally, conflicts over natural resources, particularly related to cattle rustling, have witnessed a significant escalation over the past decade, impacting mainly Ethiopia, Kenya, and Uganda (Sax et al., 2022).

So far, existing empirical studies on the topic have predominantly focused on statistical analyses and qualitative assessments to uncover potential pathways connecting climate variability and extremes to various socio-economic vulnerabilities, as well as to understand their influence on conflict risks and outcomes (Ide, 2017). While these efforts have shed light on important aspects, there remains a significant gap when it comes to implementing innovative methodologies and specifically identifying sub-national hotspots that are most susceptible to compounding climate and conflict risks. This critical aspect has received limited attention thus far, indicating a pressing need for further research and analysis to better understand the localized dynamics and complexities at play. By analysing the co-occurrence between climate-conflict interactions and socioeconomic vulnerabilities such as nutrition, access to healthcare services, and education indicators, Earth Observations (EO) methods can be a significant resource for supplementing qualitative analyses with more localised information.

This study adopts climate EO data and conflict data from Armed Conflict Location and Event Data Project (ACLED) (Raleigh et al., 2010) to identify spatial hotspot via spatial pattern based analysis of similar categories. The spatial categories are determined based on pre-defined 20 km^2 grids termed as mega-pixels. Adoption of the mega-pixel framework enabled ease of integration of different EO data with varying spatial resolutions while also accommodating sufficient samples of conflict events. Moreover, the mega-pixel framework is meant to accommodate bias in acquisition of ACLED data and its subsequent use for sub-national analysis (Eck, 2012). Lastly, profiles of vulnerable groups within each mega-pixel were determined by extracting information from extreme tails of socio-economic data. Consequently, the integrated framework could answer two questions, that is, **WHERE** are the most vulnerable areas to climate induced insecurities and risks and **WHO** are the vulnerable groups to climate induced insecurities and risks?

2 Materials and Methods

2.1 Data

Climate, conflict, and socio-economic data were used to identify co-occurrence of climate-conflict hotspots and vulnerable groups. Temperature and precipitation from (Boogaard et al., 2020; Funk et al., 2015) including climate water deficit (CWDF) actual and evapotranspiration (AET) (Abatzoglou et al., 2018) with temporal range of 1981–2022 were used as climate parameters. Conflict events with temporal range between 2012 and 2022 were obtained from ACLED (Raleigh et al., 2010). This data consists of locations, dates, actors, fatalities, and types of all reported political violence and protest events around the world. The information is collated from four sources namely:

traditional media (media outlets governed by journalistic principles of verification), international institutions and non-governmental institutions' reports, local partners' data, and new media (e.g., Twitter, Telegram, and, WhatsApp). Lastly, socio-economic data namely: estimated net migration (Center for International Earth Science Information Network - CIESIN - Columbia University, 2018), inequality indicators (access to drinking water and sanitation access from Institute for Health Metrics and Evaluation (IHME1)), undernutrition (stunting, wasting, and underweight prevalence also from IHME) was used.

2.2 Study area

This study focused on some countries in East Africa and Greater Horn of Africa (EAGHA) namely: Sudan, South Sudan, Ethiopia, Somalia, Kenya, and Uganda (Figure 1). The Horn Africa is a region vulnerable to climate change with extreme weather events intensifying in the recent past. For instance, in the recent past the region has experienced five consecutive failed rains with Intergovernmental Authority on Development (IGAD) announcing that forecasts for the upcoming June - September 2023 season shows high chances of drier than usual conditions across the Northern parts of the Greater Horn of Africa. Consequently, Central and Northern Ethiopia, western Kenya, Northern Uganda, and most of Sudan and South Sudan are expected to receive low rainfall. Temperature projection according to Coupled Model Intercomparison Project Phase 6 (CMIP6) (Eyring et al., 2016) data also show that parts of Northern Kenya, North and South-Eastern Ethiopia, Northern Somalia, and Northen Sudan will experience temperatures as high as 1.6°C by 2040 assuming business as usual emission scenario. Overall, the entire region will experience at least an increase of 0.6°C by 2040 based on the Shared Socioeconomic Pathway (SSP) 5 that envisions a world of fossil fuelled development facing high challenges to mitigating greenhouse gases with anticipated emissions rising to radiative forcing to 8.5 W/m^2 (i.e., a Representative Concentration Pathways (RCP8.5) with a high emission scenario).

[1] https://cloud.ihme.washington.edu/s/bkH2X2tFQMejMxy?path=%2F

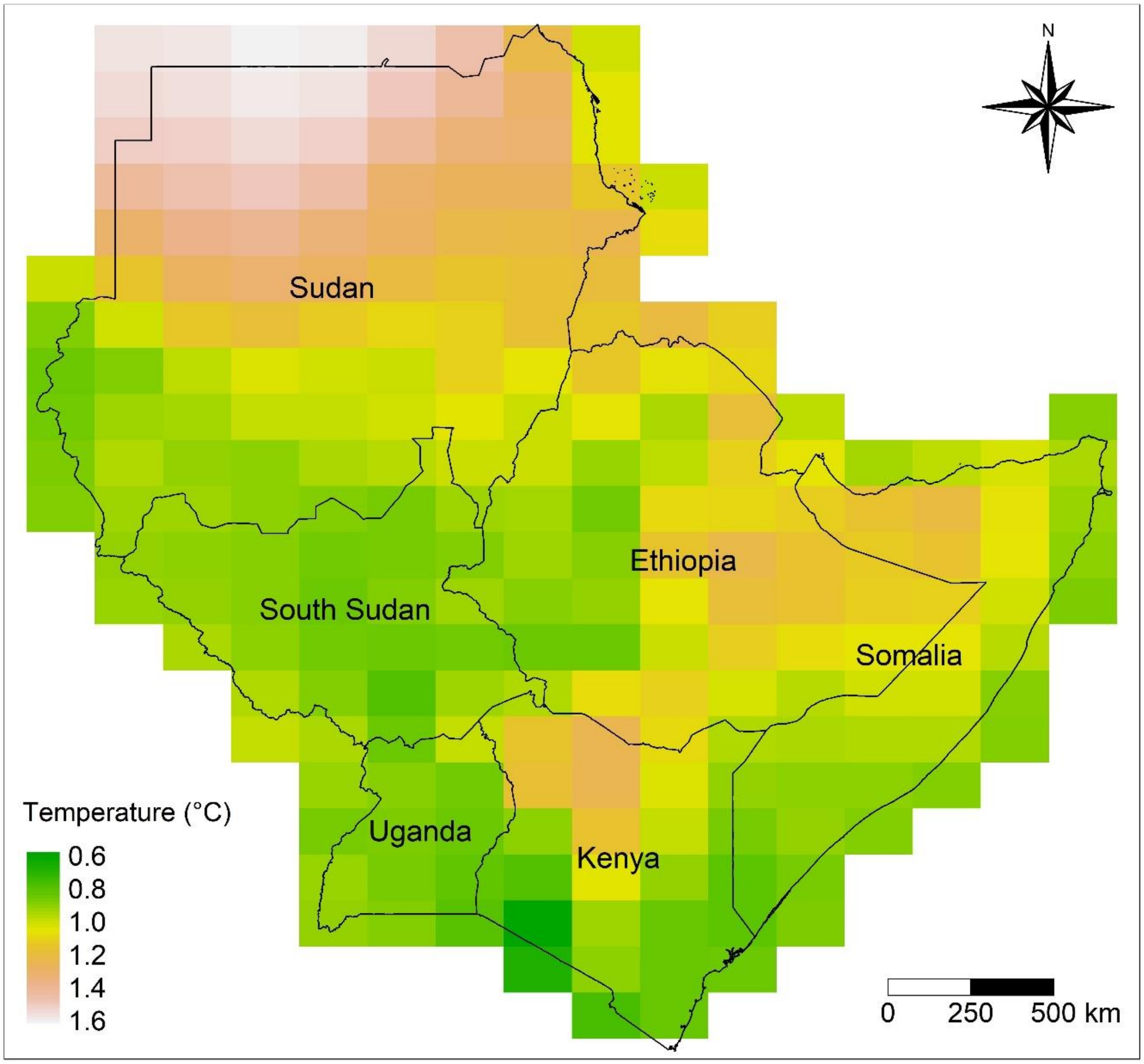

Figure 1: Estimated average increase in temperature assuming business as usual scenario (SSP585) based on ACCESS-ESM1 General Circulation Model 2021-2040 projections versus 1995-2014 reference period. Disclaimer: this map is not an authority on boundaries.

2.3 Methods

Hotspots analysis through spatial pattern based analysis (Nowosad, 2021) of climate data and machine learning clustering of ACLED conflict data were adopted to answer the "WHERE" and "WHO" questions. Spatial pattern based analysis enables rapid detection and descriptive analysis of places and communities at risk from climate, security, and socioeconomic impacts (Achicanoy Estrella et al., 2023). The analysis is based on mega-pixels that are generated over the study area. Mega-pixels, regular grids of approximately 20 km2, were adopted in order integrate climate data from different sources and resolutions, to bias in collection of ACLED data see (Eck, 2012), and achieve enough spatial-temporal conflict data sample to categorize a megapixel's conflict severity. The overall framework consists of three components: 1) determination of climate clusters, 2) determination of conflict clusters, and 3) identification and mapping of the most relevant socio-economic vulnerabilities.

Climate features, that is, coefficient of variation, median, and the Sen's slope trend estimator were computed from temperature and precipitation time series data. The same features were also computed for Number of days with waterlogging (NLWD), in addition to AET and CWDF. Computed climatic features form the key data inputs into a pattern-based spatial clustering approach in Nowosad (2021). This clustering approach exploits the idea that all categorical raster data can be characterized by spatial signatures. Spatial signatures are developed using the integrated co-occurrence histogram (Incoh), which quantifies the composition (number of mega-pixels for each category in an area) and configurations (context) of spatial patterns in each area using input data. The Incoh signature is robust because it can integrate spatial patterns from multiple features as well as the relationships between them. Essentially, the signatures form a fundamental element of hierarchical clustering of spatial patterns based on the calculated dissimilarity of signatures across all regions. Three climate conditions clusters, that is good, moderate, and harsh, are eventually mapped using the signatures.

The second step of the framework involves classifying spatial-temporal conflict events in each mega-pixel into three categorical conflict clusters (high, moderate, and limited). Classification is based on unsupervised k-means machine learning (ML) algorithm. Conflict categorical information are added into mega-pixels with climate clusters as attributes that finally indicate the co-occurrence of conflict and climate hotspots.

Profiles of vulnerable groups in areas with different co-occurring climate-conflict intensities is determined using extreme tails of socio-economic data distribution. This is done by computing extreme percentiles (10% or 90%, depending on the variable) for the top 10 most relevant variables identified via the network analysis. For instance, 10^{th} percentile for piped water access as an indicator of inequality or 90th percentile for stunting and wasting as an indicator of undernutrition. Finally, they are aggregated by socio-economic categories (inequality, low productivity, migration, and natural resources scarcity).

3 Results and discussion

Figure 2 illustrates the co-occurrence of different climatic conditions and conflict in EAGHA. Somalia has the highest cases of co-occurrence of harsh weather and conflict incidences. However, it is important to note that the relationship between climate change and conflict is complex and not necessarily direct because there are other intervening factors like adaptative capacity, institutions, and governance. For instance, the lack of proper governance in Somalia plays a role in reported cases of conflict while climate variability only acts a multiplier. This is illustrated by the vulnerability exposure especially in Northern areas of Somalia near the horn of Africa as per the Socio-Economic Vulnerability (SEV) index in Figure 3. Generally, the area experiences high cases of undernutrition depicted through cases of wasting stunting, underweight in children. People living in the area also experience inequality in terms of access to healthcare and education that further weakens their coping capacity.

Ethiopia has co-occurrence of high conflict and moderate climatic conditions around Addis Ababa. Tigray, Amhara, parts of Afar, and Dire Dawa experiences significant cases of moderate conflict with different climatic conditions co-occurrence. The Afar region has high socio-economic vulnerability as indicated by the SEV index.

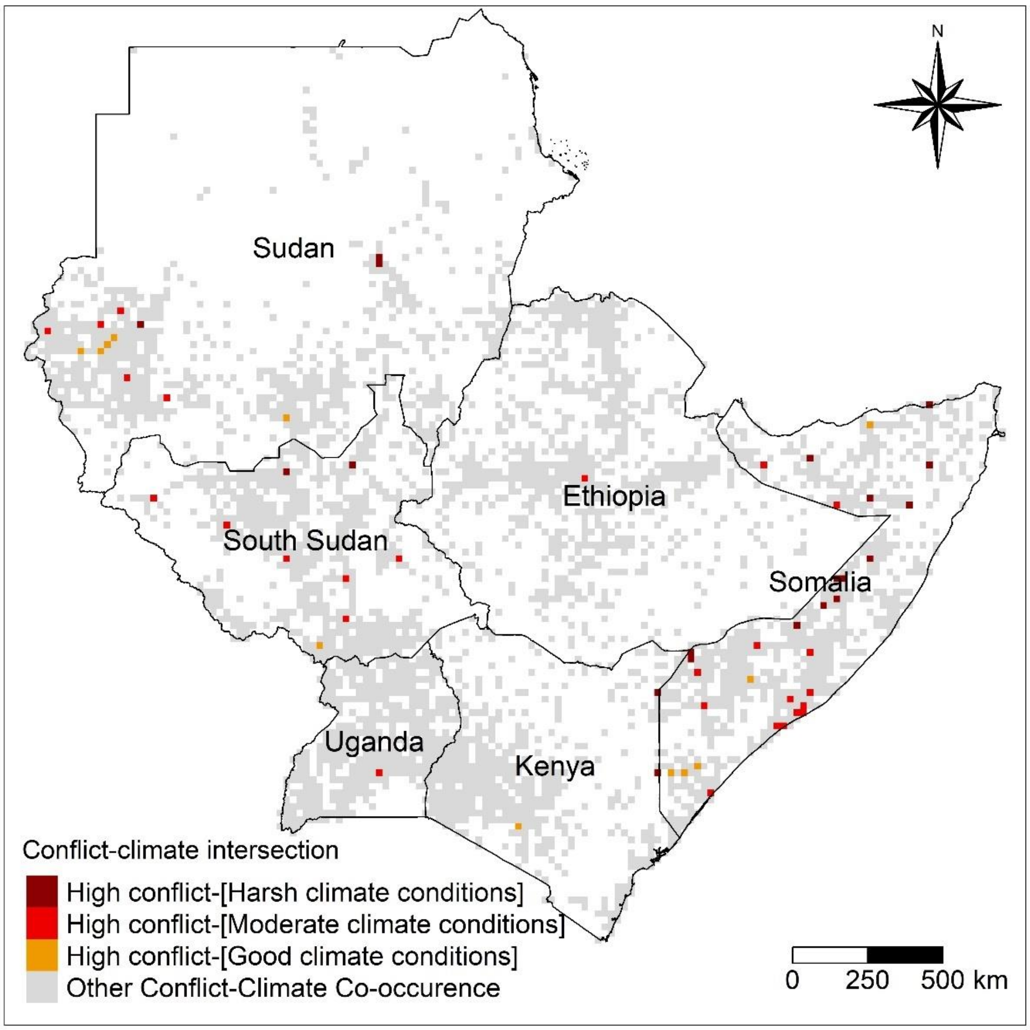

Figure 2: Co-occurrence of conflict and different climatic conditions within the EAGHA. Most the countries are dominated with co-occurrence of low to moderate conflict, as represented by the other Conflict-Climate Co- ccurrence symbol on the legend, with varying climate conditions i.e. either harsh, moderate or good conditions. Disclaimer: this map is not an authority on boundaries.

Sudan and its neighbour, currently the youngest country in the African continent, equally experiences significant co-occurrence of conflict and harsh climatic conditions. In Sudan, projections show that regions with hotspots of conflict-climate intersection will experience the highest temperature increase by 2040 (Figure 1).

Hotspot areas include, Alfashir, Blue Nile, Sennar, Khartoum, and other areas that experience low to moderate conflict-climate co-occurrence. Violence against civilians, protests, battles, and explosions are the main historical conflict events. Nevertheless, battles, and violence against civilians have resulted to main number of fatalities in high conflict cluster. Areas North of South Sudan, that is around Malakal, Wau, and Bentiu, are also hotspots due to cross-border conflicts. The coping capacity of these areas is also low due to high undernutrition and inequality with respect to access to education and healthcare.

Uganda and Kenya, have low cases of high conflict intersection with different climatic conditions from a regional perspective over the 10 year period of ACLED data. However, nationally conflict events are highly concentrated in specific areas around the cities: Gulu, Lira, Kitgum, Kalongo, Moroto, Kampala, Fort Portland, and Rukoki in Uganda. High conflicts occur in Kampala and the districts around the border of Victoria Lake, Fort Portland, Gulu, Lira, and northwestern Uganda. Moderate to low conflict cluster covers most of the rest of the country. Violence against civilians, battles, and riots are the main conflict categories and they have attributed the major number of fatalities in both high and moderate conflict clusters. In Kenya climate-conflict hotspots co-occurrence occur at the border between Kenya and Somalia around Dhobley, Elwak, and Ceelwaq. The region experiences between 60%-80% SEV which co-occurs with climate-conflict hotspots.

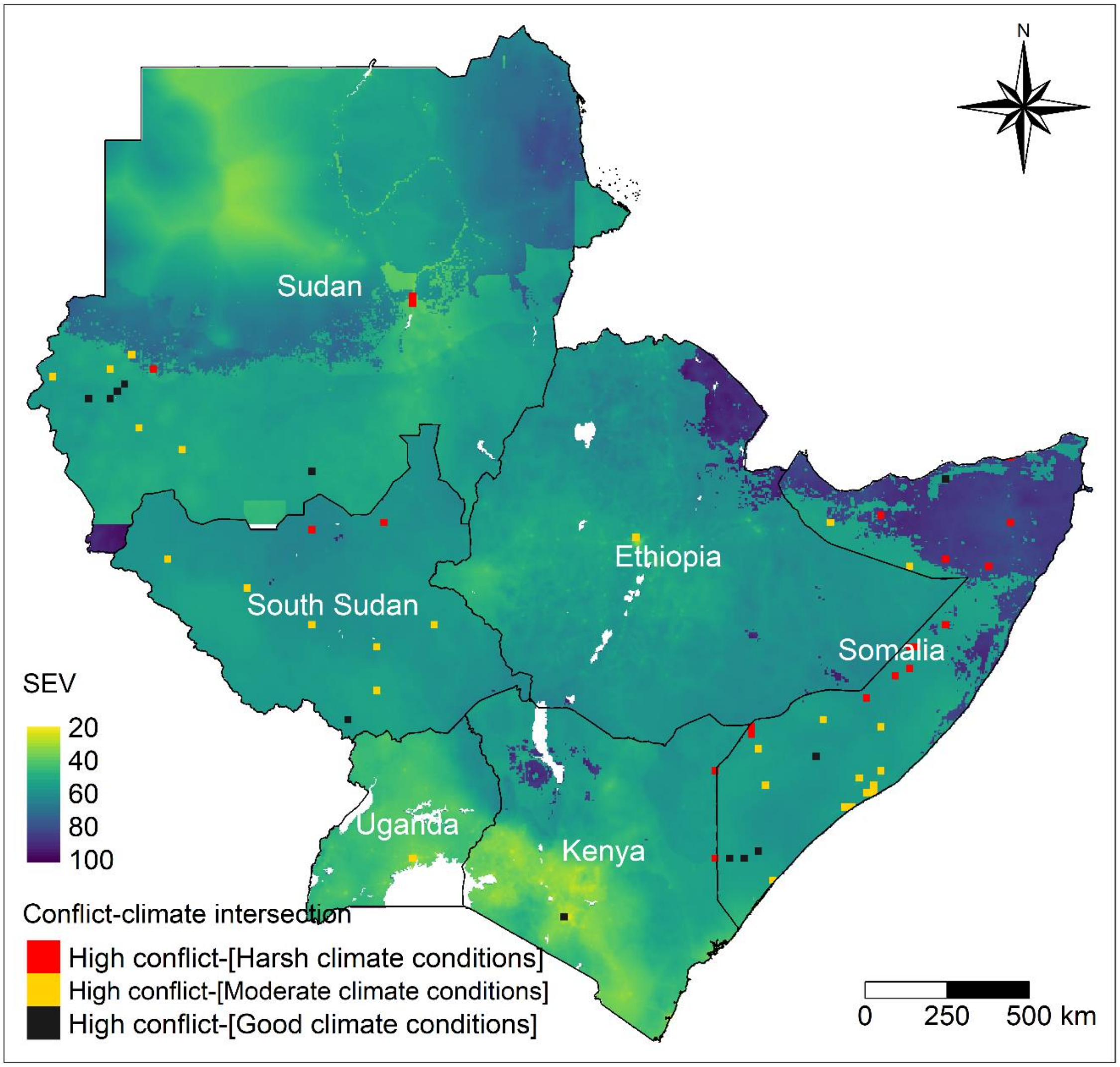

Figure 3: Vulnerability composite index is generated from an average of normalized nutrition indicators (stunting, wasting, and underweight), access to healthcare services, and education indicators (disaggregared by gender) intersected with megapixels illustrating a high presence of conflict and different climatic conditions. Disclaimer: this map is not an authority on boundaries.

It is clear from EAGHA analysis that conflict, vulnerability, and harsh climatic conditions continue to co-occur. As conflict continues to intersect with climatic conditions like droughts in most EAGHA region and floods in South Sudan, massive populations have been displaced and others forced to flee in search of new safe settlement areas. More often, this may lead to new conflict due to limited resources in settlement areas. According to Intergovernmental Panel on Climate Change (IPCC) (2022), regions and people with considerable development constraints are more vulnerable to climatic hazards. IPPC's observation is very clear in EAGHA where most SEV, conflict, and harsh climatic conditions co-occur. Further, the IPCC describes the region as amongst global hotspots of high human vulnerability.

4 Conclusion and outlook

This study designed a framework that identifies areas with co-occurrence of harsh climatic and conflict events and profiles of persons in the regions in respect to SEV. The mega-pixel framework allows sub-regional analysis that enable programmatic planning and targeting up-to spatial coverage of 20 km^2.

Therefore, climate adaptation programmes can be designed to specific relevant areas enhancing contribution to peacebuilding in the region. Due to static visualization limitation, other intersections of conflict, i.e., moderate and low, were group together. Notable, if the analysis is restricted to a country the categories of conflict clusters may change because for instance whatever is high in a particular country may be low in another.

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