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Pastoral conflict on the greener grass? Exploring the climate-conflict nexus in the Karamoja Cluster

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ABSTRACT

The Karamoja Cluster, a cross-border region between Kenya, South Sudan, Uganda, and Ethiopia, where pastoralism has long been the main livelihood, was extraordinarily affected by severe droughts between 2018 and 2023. During this time, pastoral conflict in the region increased to unprecedented levels. Being highly dependent on the environment, pastoralists are expected to be especially vulnerable to climate change in the near future. In our work we use a mixed-methods approach combining informant interviews to highlight the importance of local policies in the debate on the climate-conflict nexus, along with an empirical analysis of the linkage between climate and conflict, evaluating the predictive potential of different environmental variables. We provide a recent assessment of the conflict dynamics in the Karamoja Cluster from 2018 to 2023, a time marked by the COVID-19 pandemic, a locust plague and a series of severe droughts. We found that policies aiming to address multiple crises during this time limited the mobility of transhumant pastoral communities, leaving them exposed to the devastating consequences of climate change. At a broader scale, our analysis shows that higher levels of vegetation were associated with lower conflict. However, conflicts were concentrated on the transition zones between areas of high and low resource availability. Conversely, within the Karamoja Cluster, pastoral conflict occurred primarily "on the greener grass", with peaks observed during periods of environmental scarcity following phases of resource abundance. Finally, we found that vegetation data outperformed other variables, such as rainfall, in predicting pastoral conflict one month in advance.

1. Introduction

Climate change is a threat to livelihoods across the globe, with populations in the Global South particularly affected [1–3]. Those who depend directly on natural resources are especially vulnerable to the climate crisis, as is the case for pastoral communities in East Africa [4,5]. In 2022, East Africa faced the worst drought on record [6], which resulted in more than 50 million people being pushed into a severe food crisis ([79]). In the same year, in the Karamoja Cluster, the number of violent conflicts involving pastoral communities increased considerably, reaching also unprecedented numbers of incidents and fatalities [7].

The cross-border region between Kenya, South Sudan, Uganda and Ethiopia is characterised by highly diverse environmental conditions over short distances, ranging from arid and semi-arid to tropical savanna and rainforest climates [8]. It further presents multiple sets of combinations of wet and dry seasons [9]. This spatio-temporal variability has historically made transhumant

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pastoralism the predominant and most suitable livelihood in the region [10,11]. Being often the only possible response to survive the harsh environment, these movements have also been associated to conflicts on destination pastures with local pastoralists, farmers and other actors [12]. Fighting over resources and cattle raids have long been part of pastoral practices and long-standing traditions in the Karamoja Cluster [13–15]. However, while causing great insecurity and instability, environmental variability and pastoral transhumance have rarely been the sole cause for conflict. Interventions aiming to establish peace in the region and to improve the living conditions have also been identified as conflict triggers, while stigmatising pastoralists at the same time [16–18].

In this article, we attempt thus to adopt a critical perspective when determining whether conflicts among pastoralists have been exacerbated by the recent climate adversities in the region, and to assess the role of local policies and interventions in these conflict dynamics. We build on the established relationship between climate and conflict and focus on a region of high environmental variability, conditions under which climate change presents a highly uncertain future for pastoral societies. The objective of our study is twofold: First, to determine whether the severe droughts in our period of analysis have affected pastoral conflict and to which extent. Hereby we also aim to identify whether there is a predominant direction in the climate-conflict relationship in the Karamoja Cluster and whether there are seasonal recurrent patterns of this relationship. Second, we want to examine the implications of state policies on pastoralists' coping strategies in times of climatic adversities.

Our research focuses on the years between 2018 and 2023, a period during which unprecedented droughts desolated most available resources for pastoral livelihoods, and in which pastoral conflicts increased from 22 events reported in the year 2018 to a total of 396 events in 2023 [7]. We employ a mixed-methods approach, in which we (i) assess the linkage between environmental variables (rainfall and vegetation derived from multi-source satellite data) and monthly pastoral conflict events. and (ii) complement this with ten key informant interviews with representatives from aid organisations and environmental entities in the Lodwar and Loima areas of Kenya.

Our study reveals a negative relationship between available resources and the occurrence of conflict, meaning that less vegetation is associated with more conflict occurrence. This, we find, is due to the concentration of conflicts along the transition zone between humid and arid ecoregions, which belongs to the less vegetated areas within the broader scope, but to the only region with sufficient forage on the smaller scale within the Karamoja Cluster. By comparing different environmental variables, we further find that vegetation serves as a better predictor for conflict than rainfall. This finding highlights the potential of processed optical satellite imagery particularly in the context of societies largely dependent on the local environment. In addition to this, our interviews revealed highly relevant contextual information on the adoption of policies in response to multiple crises affecting the Karamoja Cluster (such as the desert locust plague and the COVID-19 pandemic). These policies had a severely detrimental impact on pastoralists' mobility and resilience, ultimately leading to more conflict.

The paper proceeds as follows: In Section 2, we review the existing literature on the link between climate change and pastoral conflict, from which we derive our research objectives. Section 3 describes the study area in which we conduct our analysis. Section 4 presents the data used in this study, while Section 5 outlines the methodology. In Section 6, we present our results, which are discussed and compared with previous findings in Section 7, before we reach our conclusion in Section 8.

2. Pastoral conflict and climate change in the Karamoja cluster

Pastoral conflict in the Karamoja Cluster is not a new phenomenon. Due to the high seasonal and regional climatic variability, transhumant pastoralism has been for long the predominant economic activity in the region, allowing herds to move to areas of higher resource availability throughout the year [10,19]. However, this mobility also introduces challenges, including competition over pasture and water in shared or contested areas [20]. Historically, while mobility and seasonal convergence in resource-rich areas have been identified as inherent aspects of pastoralist systems and conflicts, they do not solely explain the elevated levels of conflicts observed in the Cluster [21]. In contrast, other regions with highly mobile pastoralist systems experience lower levels of conflict due to factors such as stronger governance structures, effective customary institutions, and active disarmament exercises. For instance, along the South Sudan-Ethiopia border, pastoralists have developed cooperative land management practices supported by local governance systems, which mitigate potential disputes over seasonal grazing areas [22]. Government interventions through state-building initiatives in pastoral resource governance have helped to strengthen the relations between migrants and host communities by keeping grazing routs open [23–26]. These findings underscore that while mobility and resource convergence may create conditions for conflict, the intensity of conflict in the Karamoja Cluster is driven by a complex interplay of environmental, social, and political factors.

The relationship between climate and conflict has been a subject of intense debate in the academic literature over the past few decades, resulting in very differing outcomes considerably depending on the local context [27–32]. There are cases where a reduction in resources due to climatic adversities can give rise to increased competition (e.g. Ref. [33,34]. Conversely, a reduction in resources may also result in enhanced cooperation, at times even bringing peace to conflict areas [35]. On the other hand, more rainfall can result in conflict as there are more resources to fight over [36–38] and can cause damage to infrastructure and crops, leading to immediate conflict onset [30].

Most studies on the climate–conflict nexus use rainfall as an explanatory variable ([20,39–41]; [78]; [28]), while others use temperature [27,34], also when focusing on pastoral conflict [12,34]. However, rainfall and temperature act through different channels on conflict occurrence. In the case of pastoral conflict, the climatic effect may be channelled through phytomass growth, the primary resource for sustaining livestock. This variable depends not only on the interplay between temperature and rainfall (high temperatures evaporate the available rainfall, impeding plant growth) but also on soil characteristics (precipitation does not always fall on fertile ground, limiting the growth of plants and thus livestock resources). In contrast, as mentioned above, high rainfall levels can also lead to soil erosion and the deterioration of pastureland or infrastructure, demonstrating that more rainfall may not always be better. Thus, integrating vegetation data derived from satellite imagery has also shown promising results in studies addressing the interaction of environmental stressors and pastoral conflict [42–44]

While environmental factors are an important driver of pastoral conflict, they usually only exacerbate the primary root causes of conflict. In the Karamoja Cluster, livestock raids have been an integral part of long-standing traditions and have also led to the formation of historical rivalries between tribes [45]. Interestingly, while the objective of these raids has been to replenish herds that had been depleted often due to resource scarcity, they frequently occur when resources are more abundant, given that the animals acquired through these raids need to be fed [46]. Consequently, an increase in conflict occurrence can also be expected in times of more resource availability.

Additionally, the impact of political measures contributing to pastoral conflict should not be neglected. The colonial regime, which imposed artificial borders between the 1920s and 1950s, led to new land distributions, which in turn deteriorated the relationships between ethnic groups and increased violence in the 1950s [16,47]. In the mid-20th century, and particularly after the 1980s, the absence of state forces and an uneven distribution of weapons among pastoralists in the Karamoja Cluster led to an increase in violent cattle raids and lethal conflicts [14]. Following this period, and having lost many, if not all, of their herds, many pastoralists were encouraged by the government and non-state actors to give up their transhumant way of life and sedentarise [16]. While these policies sought to address the survival of pastoral communities following the immediate challenges of loss of herds and droughts, they also led to a stigmatisation of pastoralists, marginalising and often neglecting them in public policies [18,19,48,49].

Our study area, being a border region, is not only characterised by divergent national and regional policies, but also by a highly complex climatology [50]. This challenges the predictability of conflicts and the ability to find solutions across borders. Although peacebuilding initiatives have historically been effective in preventing major conflicts between pastoralists, they have not been successful in solving conflicts associated with resource scarcity caused by climate change [51]. In 2019, the Kenyan and Ugandan governments signed a memorandum of understanding for a Kenya–Uganda (Turkana/West Pokot–Karamoja) cross-border programme for sustainable peace and socio-economic transformation for the Karamoja Cluster. Since then, pastoral conflicts have increased exponentially in the area. Also, while several disarmament exercises conducted since May 2022 initially appeared successful, they ultimately proved ineffective afterwards [52], resulting in the highest number of conflict events and conflict-related fatalities in 2022 (based on ACLED data), as the most severe drought on record hit the region.

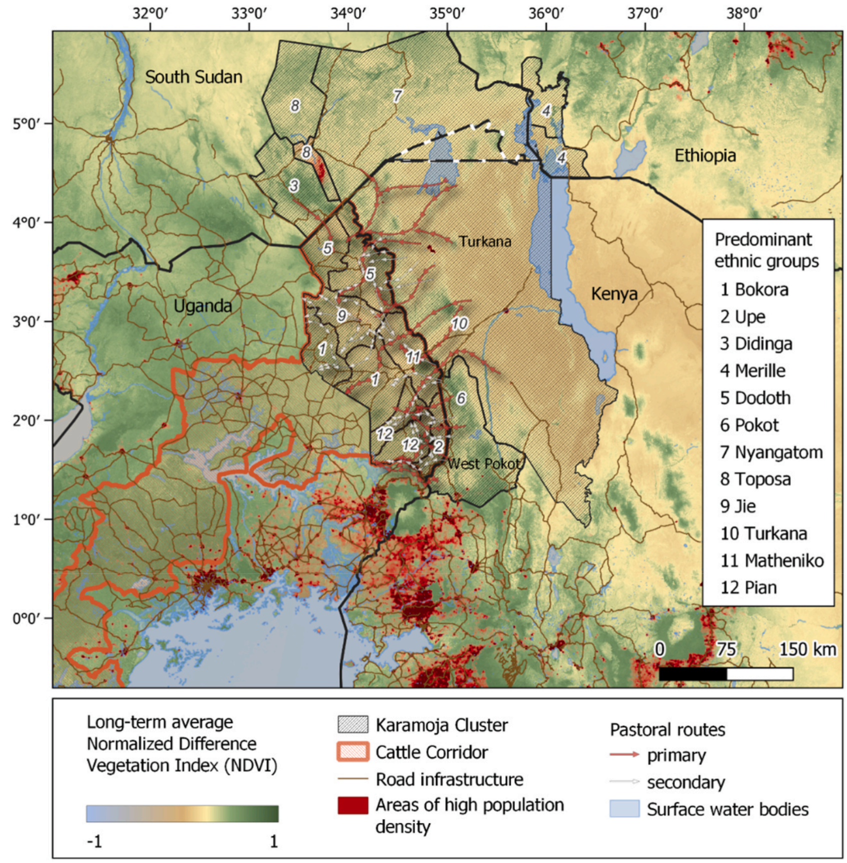


Fig. 1. Study area Karamoja Cluster overlaps the Cattle Corridor in Uganda and is in a four-country border region of high socio-ecological diversity. Sources: Administrative boundaries of Ethiopia, Kenya, South Sudan, and Uganda from the Large Scale International Boundaries dataset by Ref. [74]. Ethnic groups in the Karamoja Cluster based on [17] and personal communication with a representative from Karamoja Herders of the Horn, formerly Karamoja Development Forum in 2024. Extent of the Cattle Corridor based on [54]. Normalised Difference Vegetation Index (NDVI) derived from 1997 to 2017 Landsat imagery [61]. Population density by Ref. [75].

3. Study area

Our study area is located between 31° and 39° east longitude and −1°–6° latitude. This encompasses both the Karamoja Cluster, at the border between South Sudan, Ethiopia, Uganda and Kenya, and the so-called Cattle Corridor that crosses Uganda diagonally from north-east to south-west (Fig. 1). We focus on this region because of its high climatological and environmental variability across short distances, as well as its long history of interventions by governments and NGOs, which have yet to resolve the conflict problem. While many studies have focused on the climate-conflict nexus and pastoral conflict in Sub-Saharan Africa, the climate in East Africa is not only characterised by a high complexity, making climate-related conflict predictions more difficult, but has also been affected by unprecedented drought events in the very recent past. In addition to the environmental characteristics, in the cross-border region, four different policy systems converge, presenting additional challenges for sustainable peacebuilding.

The Karamoja Cluster is characterised by its poor (road) infrastructure and low population densities, especially on the Kenyan side. Pastoral communities follow several routes across the borders, mainly towards the south-west [53], partly joining the Cattle Corridor [54].

The pastoral communities in the Cluster are of diverse ethnicities and live and move with the seasons in search of water and food for their herds [19]. It is also worth noting that the purely nomadic type of pastoralism is becoming increasingly rare in the region and that their transhumant activities are often combined with the cultivation of crops [10,55]. For a detailed description of the most recently identified typologies of pastoralist practices, read further in Ref. [56].

Also the climate in the study area is characterised by considerable diversity throughout the year and across the region [9]. There are regions with multiple wet seasons (West Pokot in Kenya, see Figure A 1a in Appendix A), a bimodal wet season (like Uganda's 1st and 2nd season rains, Figure A 1b, South Sudan, Figure A 1c, and Nyangatom and Dasenech in Ethiopia, Figure A 1d), while Turkana county is marked by arid conditions all year round (Figure A 1e). The vegetation patterns for the same period reveal a similar spatial and temporal variability as precipitation data. They also indicate a temporal lag of one to two months after rainfall events, with a peak in May and June in all areas and the lowest values occurring in March, the end of the hot, dry season common to all regions from December until February (see green curve in Figure A 1).

4. Data

In our analysis we divide the study area into grid cells of 50 km × 50 km. We use monthly georeferenced conflict event data from which we extract incidents involving pastoralists. We also use monthly data for rainfall, vegetation, and land surface temperature to test and compare their prediction power for conflict occurrence, intensity, and lethality. Furthermore, we include an annual control variable for population density due to the high heterogeneity of the study area. We additionally control for other types of conflict as well as the night light emissions. We filter our data geographically and by years (2018–2023) and compute mean values for vegetation, population density and land surface temperature; the mean of the sum of precipitation data; and conflict and fatality counts for each grid cell. The following subsections describe our variables and their specifications, and in the case of vegetation data, the required pre-processing steps applied on satellite imagery.

4.1. Conflict data

The conflict data used in this study is drawn from the Armed Conflict Location and Event Data (ACLED) Project [57].[1] We apply a keyword filter by using the keywords "PASTORAL" OR "HERD" to extract conflicts where pastoral livelihoods were affected or involved. This resulted in a total of 1,038 out of a total of 8,336 conflict events for the years covered in this study. The filtered data allows to preliminarily identify hot spots of pastoral conflict in space and time but also contains additional information on the nature of conflict, helping to get a better understanding on the conflict dynamics in the cross-border region. We further filter the data by the country of origin of the involved actors to assess whether cross-border movements (e.g. from Kenyan drylands to resource abundant counties in Uganda) play a role. We also extract conflict events where state actors were involved, to see how they have shaped the conflict landscape in the Karamoja Cluster. To analyse the climate-conflict linkages we measure conflict using three different variations: conflict occurrence (CONF), which is a dummy variable that measures the occurrence of conflict; conflict intensity, which is a count variable measured by the number of conflict events (CONF_CO) and finally, conflict lethality, which is a count variable that measures the number of fatalities per month and within a grid cell (CONF_F).

[1] Two of the most used databases for the recording of conflict events are the Uppsala Conflict Data Program (UCDP) and the Armed Conflict Location and Event Data (ACLED) Project. These databases differ in the criteria employed to define an incident as a conflict. While UCDP records conflict events that have resulted in at least 25 deaths in a battle within a year, the ACLED database includes not only battles but a broader range of events, such as protests, riots, explosions and violence against civilians. It also includes non-violent events, with no minimum number of fatalities. For each event, the number of fatalities is reported as well. This makes the ACLED database more suitable for our intended purpose of analysing small-scale conflicts focusing on pastoral communities. These conflicts may include the destruction of infrastructure in acts of revenge or the theft of cattle. Based on the literature listed above, these acts are often carried out by pastoralists or affect them and do not necessarily involve fatalities. A detailed comparison of UCDP and ACLED data can be found in Eck [76]. The ACLED database is updated weekly and includes, besides geo-coded level data, details about the actors involved.

4.2. Environmental data

4.2.1. Vegetation

Our vegetation variable is derived from multispectral satellite imagery and provides pixel-wise information on the presence or absence of vegetation and the level of vegetation density. While we acknowledge that high vegetation density does not necessarily provide edible resources for herded animals, as would be the case of tropical and subtropical moist broadleaf forests, we argue that the predominant ecoregion in the study area are tropical and subtropical grasslands, savannas and shrublands [58], which lends validity to our approach.

We compute the Normalised Difference Vegetation Index (NDVI) [59] with values ranging from −1 to 1. Negative values are indicative of non-vegetated areas, including water bodies and clouds. Conversely, positive values indicate the presence of vegetation, with values near 0 often indicating bare soil, values between 0.1 and 0.5 representing sparse vegetation and values above 0.6 denser vegetation. In this paper, we will use the terms 'NDVI', 'vegetation' and 'resource' interchangeably. We calculate the mean NDVI for each month and each grid cell in the cloud-based geoprocessing environment Google Earth Engine (GEE) [60].

The long-term vegetation trend analysis is based on the Landsat 5, 7 and 8 Surface Reflectance Collection 2 datasets [61], while we use the Copernicus Sentinel-2 Surface Reflectance product [62] and PROBA-V Top of Canopy Daily Synthesis data [63] for single-year and monthly analyses. All datasets have been accessed and pre-processed in GEE.

We apply cloud-masking algorithms to all surface reflectance datasets using the quality assessment pixel "PIXEL_QA" bands for Landsat 8 images and, additionally, the "QA_RADSAT" band for Landsat 5 and 7. For Sentinel-2 (S2) data, we use the "QA60" band. We then calculate NDVI using the red and near-infrared bands as in the formula by Ref. [59]:

$$NDVI = \frac{NIR - Red}{NIR + Red} \tag{1}$$

The PROBA-V product accessed through GEE is atmospherically corrected, and composites are created daily, resulting in a high temporal resolution for the period 2013–2021. While they include an NDVI band, we also compute the index based on Eq.(1. The Landsat datasets have a lower revisiting frequency but cover the longest period of analysis (see Table 1). Consequently, we merged all Landsat datasets (LS) to estimate the long-term monthly mean. We then rescaled the merged LS and the S2 datasets to a 100m pixel size. For the years of analysis 2019–2023, we use S2 data, for 2018, we use the PROBA-V TOC imagery, which has a 100m resolution.

4.2.2. Rainfall

We use the CHIRPS Pentad dataset (Climate Hazards Group InfraRed Precipitation With Station Data, Version 2.0 Final) by Ref. [64] to incorporate rainfall data into our analysis. The CHIRPS Pentad dataset, which has been available since 1981, incorporates satellite imagery with a 0.05° resolution and in-situ station data to create gridded rainfall time series. We access the data through the Google Earth Engine Catalogue and compute the mean sum of precipitation for each month in each grid cell [65].

We also include a value to determine the deviations from long-term means for the precipitation and vegetation variables ($Env_{anom_{t,i}}$, as detailed in Eq. (2. To this end, we use the long-term monthly NDVI (derived from the merged Landsat dataset) and precipitation averages ($LTEnv_{t,i}$) from the period 1997–2017, which we subtract from the year of analysis' monthly average ($Env_{t,i}$) in each grid cell (i):

$$Env_{anom_{t,i}} = Env_{t,i} - LTEnv_{t,i} \tag{2}$$

Negative values mean the year of analysis had a lower value than the long-term average, positive values reveal the year of analysis had a higher value than the long-term mean.

4.3. Other controls

In our analysis, we control for the mean land surface temperature (LST) to ascertain whether changes in this variable are a contributing factor to the levels of conflict, as was shown in studies such as [34]. We use the GCOM-C/SGLI L3 Land Surface Temperature (V3) dataset from the Global Change Observation Mission provided by the Japan Aerospace Exploration Agency [66] in GEE to calculate the monthly mean LST per grid cell. As with our conflict and environmental data, LST is measured on the month-cell level.

Additionally, we also control for the population density per cell, which also showed to have an effect on pastoral conflict in studies like Döring [67]. We gather this data from the LandScan Population Dataset provided by the Oak Ridge National Laboratory [68] to the GEE Data Catalogue [69]. The LandScan dataset offers a global population distribution dataset at 30 arc-second resolution for the time period 2000 to 2022. Due to the unavailability of the data on population until our most recent observation (December 2023), we divide the grid locations based on data from 2018 to 2022 into high population density and low population density.[2]

We also include the presence and total area of night lights per grid cell and year as a control variable, obtained from the VIIRS Stray Light Corrected Nighttime Day/Night Band Composites Version 1 dataset provided by the Earth Observation Group, Payne Institute for Public Policy, Colorado School of Mines, and accessed via GEE [70]. With this variable we aim to account to some extent for wealth, as social inequality has also been identified as a driver for communal conflict by Fjelde and Østby [71]. We additionally control for all conflicts excluding pastoral conflicts using data from ACLED.

[2] We use the mean of the population variable to divide the cells into cells with higher and lower population concentrations.

Table 1
Sensor specifications.

	Landsat 5 Thematic Mapper (TM)	Landsat 7 Enhanced Thematic Mapper (ETM+)	Landsat 8 OLI/TIRS	Sentinel-2 Multispectral Instrument (MSI)	PROBA-V C1 Top of Canopy Daily Synthesis
Temporal availability in study area	1984–2012	1999–2023	2013–2023	2019–2023	2013–2021
Spatial resolution of visible and near-infrared bands	30 m	30 m	30 m	10 m	100 m
Revisiting frequency	Every two weeks			Every five days	

5. Methods

Our approach includes an aggregate analysis of the climate variability and conflict trends in the Karamoja Cluster, as well as a series of regression models to discern the direction and magnitude of the relationship between pastoral conflict and climate in the study area. We also conduct a qualitative analysis including semi-structured interviews with key informants in Turkana, Kenya.

5.1. Regression analysis

To investigate the empirical link between climate and pastoral conflict occurrence, we use a probit model:

$$Y_{t,i} = \beta_0 + \beta_1 Env_{t,i} + \beta_2 Env_{(t-1),i} + X_{t,i} + \alpha_{t,i} + m_{t,i} + \gamma_i + e_{t,i} \quad (3)$$

where $Y_{t,i}$ represents the dependent variable (CONF), which measures conflict occurrence by taking a value of 1 if in grid cell (*i*) in month (.) a conflict took place. $Env_{t,i}$ and $Env_{(t-1),i}$ are the main explanatory variables. In parallel models, we measure the levels of vegetation and precipitation for the month prior to the conflict $(t-1)$ and for the month in which the conflict occurred. $X_{t,i}$ are the control variables, namely a lagged value that accounts for pastoral conflict count in the same cell in the previous month, a lagged value that accounts for all unfiltered ACLED events, land surface temperature, annual population density and night lights. $\alpha_{t,i}$ accounts for grid cell fixed effects, $m_{t,i}$ controls for month fixed effects, while γ_i controls for year fixed effects, and $e_{t,i}$ is the error term.

Similarly, we carry out Poisson regressions where our dependent variable ($Y_{t,i}$) represents the number of conflict events (CONF_CO) in grid cell (*i*) in month (*t*). This analysis aims to determine the impact of our environmental variables on conflict intensity. In another regression series, we use the total number of fatalities (CONF_F) in grid cell (*i*) in month (*t*) to determine the impact of these variables on conflict lethality.

5.2. Qualitative analysis

We conducted an exploratory study in Turkana County, specifically in Lodwar and Loima areas, in which we conducted ten key informant semi-structured interviews. Data collection took place between 17 February and 19 April 2024. The selection of informants involved individuals with in-depth knowledge of the conflict dynamics in the region and those involved directly through different initiatives within the Karamoja Cluster. Men, women, and youths in Lodwar and Loima were purposively sampled due to their knowledge and the nature of their work. This includes pastoral communities, county, and national officials as well as aid organisation officials working in the Cluster. The objective of the interviews was to identify the root causes and impacts of conflicts with a view to capturing the diverse range of local insights. The collected interviews were transcribed, translated, and analysed thematically to identify significant conflict dynamics within the Cluster.

6. Results

6.1. Conflict dynamics and environmental trends

A preliminary assessment of the conflict data indicates that the number of conflicts has increased considerably over time as shown in Fig. 2. The number of conflicts increased from 22 in 2018 to 345 in 2022 and to 396 in 2023. At the same time, lethal conflicts have also experienced a notable increase, rising from 16 in 2018 to 205 in 2023. The trend analysis shows a steady growth during the period of analysis of both lethal and total pastoral conflict events. The trend of total fatalities has decreased and stagnated at the beginning of 2023, still remaining at higher levels than before 2022. The seasonal decomposition of the time series reveals maxima in both lethal and total conflict events after onset of the hot dry season between January and March, which becomes especially visible in the last three years when conflict events have reached highest numbers on record.

Country-wise we find differences among countries throughout the period of analysis, with Kenya being the country with the highest counts for pastoral conflict in all years (see Figure A 2 in Appendix A), followed by Uganda and South Sudan. When only focusing on the Karamoja Cluster itself, the numbers differ slightly, being Uganda in the lead with a total of 201 events over the years, followed by Kenya with 143, South Sudan (5) and Ethiopia (1). Nevertheless, our work considers the entire area within and around the Karamoja Cluster, in order to identify the interplay of different variables that affect pastoralists beyond its boundaries.

By covering a broader area than the Cluster itself, we found that in contrast to *all conflict* records (not keyword-filtered), which were

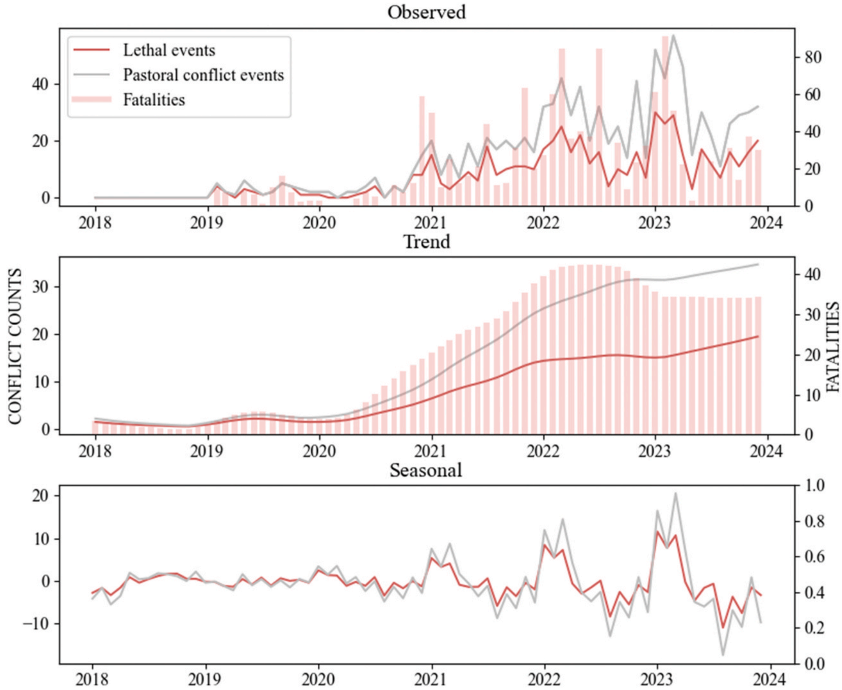


Fig. 2. Seasonal decomposition of pastoral conflicts. Sources: ACLED (2018–2023).

concentrated in areas of higher population density as shown in Fig. 3, pastoral conflict events (keyword-filtered[3]) were located within and around the Cluster, in areas of medium infrastructure and population density. The areas with the lowest population and infrastructure density (in Kapoeta, South Sudan and in Nyangatom and Dasenech in Ethiopia) showed the lowest numbers of conflicts reported within the Karamoja Cluster.

Our findings indicate that within and surrounding the Karamoja Cluster, conflicts occurred especially on the "greener grass", a finding that we attribute to the transhumant nature of pastoralists and the increasing competition for destination pastures. This is also consistent with the temporal patterns of conflict occurrence, with the highest levels of conflict occurring during the hot, dry season between January and March (see Fig. 2).

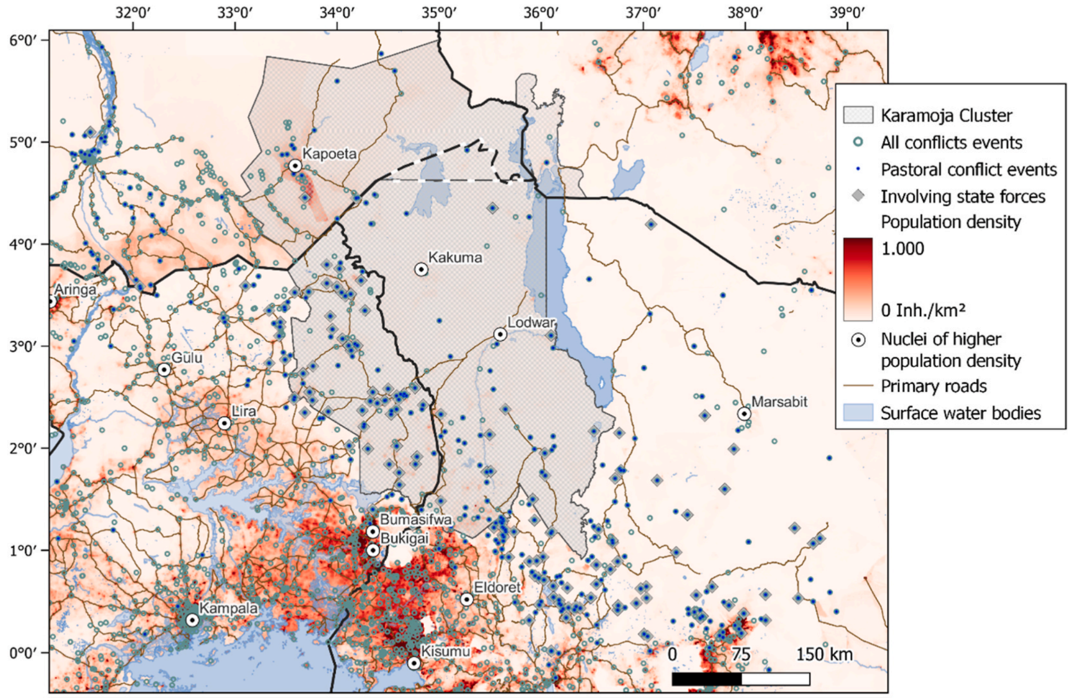
Given the different environmental characteristics across the borders and based on the assumption that pastoral movements towards greener pastures would lead to more conflict on the "greener grass", we filtered the conflict data to assess the "foreign involvement" of actors from neighbouring countries. Surprisingly, the number of conflicts caused by external actors was comparatively low throughout the period of analysis despite of the cross-border location of the study area. Over time, Kenya has experienced a reduction in the number of conflicts involving foreign actors, while Uganda and South Sudan have seen an increase in the number of actors, particularly of Kenyan origin (see Figure A 3 in Appendix A). We observed that Ugandan actors were not involved in conflict events in other countries throughout the entire period of analysis.

Another aspect we analysed was the involvement of governmental actors, such as police and military forces, in pastoral conflict. Here, the share was considerably high in the last two years of our analysis (see Figure A 4). Regarding their spatial distribution we found they were highest within the Cluster in Uganda, and outside the Cluster in Kenya (see Fig. 3).).

The drought year 2022 was not homogeneous in the entire study area (see Figure A 5). In the north and the east, positive rainfall anomalies (Figure A 5a) were registered, while the area around Lake Victoria registered the lowest rainfall compared to the long-term mean. We find that conflict events were not located in the areas with highest neither with lowest vegetation cover, but in the transition line between ecoregions. It is also this area which despite of registering above average rainfall in 2022, turns out to present negative vegetation anomalies (see Figure A 5b), possibly attributed to the fragility of the lower vegetation density characteristic of this region (see Figure A 5c), which furthermore was affected by the 2021 drought.

We find that the period of analysis can be divided into two sub-periods of diverging environmental characteristics and conflict frequency. The turning point happens at the end of 2020, after which conflict records start to increase considerably and the severity of negative rainfall anomalies exacerbates the living conditions in the years following (see Figure A 6). This occurs after a long period of positive precipitation and vegetation anomalies that starts in May 2019 and ends in May 2021. After that time, weak negative anomalies persist until the severe drought of 2022 sets on, when conflict events reach the highest numbers ever recorded.

[3] Pastoral conflict events included in our analysis were categorised according to ACLED as violent conflict events (mainly "violence against civilians" and "battles").



Sources: Administrative boundaries of Ethiopia, Kenya, Southern Sudan, and Uganda from the Large Scale International Boundaries (LSIB) dataset by the U.S. Department of State, Office of the Geographer. Primary roads and cities by OpenStreetMap 2023. Population density by Worldpop 2020. Conflict data from the ACLED database (Raleigh et al., 2012), filtered by years (2018-2023) and keywords for conflicts involving pastoral livelihoods and pastoral conflict involving state forces.

Fig. 3. Population density, primary roads and conflict events involving pastoral livelihoods. Sources: Conflict data from the ACLED database (Raleigh et al., 2012), filtered by years (2018–2023) and keywords 'pastoral' and 'herd'. We filtered ACLED data by "ACTOR1" and ACTOR2″ belonging to governmental entities to extract events involving state forces. Administrative boundaries of Ethiopia, Kenya, South Sudan, and Uganda from the Large Scale International Boundaries (LSIB) dataset by Ref. [74]. Population density by Ref. [75].

6.2. The prediction potential of vegetation variables

Our regression analysis showed that the probability of conflict occurrence as well as conflict intensity, are associated with lower levels of vegetation (see model (1) Table B 1 and models (1) and (2) in Table B 2, respectively in Appendix B). The impact of rainfall on conflict (see models (3) and (4) in Table B 1 and Table B 2) was less significant and much weaker than the effects of vegetation. Higher temperatures were associated with the probability of conflict occurrence (see models (2) and (4) in Table B 1) but not with consistently higher conflict intensity (see models (2) and (4) in Table B 2) when accounting for all controls. Conflict lethality was similarly associated to lower levels of vegetation and rainfall, and while all environmental variables had a significant effect, the magnitude of vegetation surpasses all other variables' impact on the number of fatalities (see Table B 3).

For predictive purposes, we also analysed environmental variables from the previous month. Contrary to the linkages found between vegetation levels of the month of conflict occurrence, the lagged vegetation variable had a positive and significant effect on conflict intensity (see models (1) and (2) in Table B 2), meaning that higher vegetation levels in the previous month were associated with a higher number of conflict events one month later. Lagged rainfall had no significant effect on conflict intensity (see models (3) and (4) in Table B 2), confirming the higher short-term prediction potential of vegetation data. A detailed description of the results obtained from the regression analysis can be found in Appendix B.

6.3. Unveiling a polycrisis environment in the Karamoja cluster

Our interview data provides insights into the challenges pastoral communities face that go beyond climatic factors and that considerably exacerbated conflicts also prior to the severe droughts of 2022 and 2023.

According to an interview with an official working with Caritas Uganda in Lodwar,[4] the desert locust outbreak and prolonged drought significantly reduced pasture and water availability within the Karamoja Cluster between February 2020 and March 2021. These environmental stressors led to diminished rangeland productivity, aggravating food insecurity and competition for scarce

[4] Interview with Caritas Uganda project coordinator in Lodwar, 27 March 2024.

resources. This often resulted in violent raids and livestock theft to secure livelihoods.

In response to the COVID-19 pandemic, Kenya and Uganda adopted policy measures that included movement restrictions and livestock market closures, which forced communities to quarantine with their livestock, affecting their social and economic activities. This situation increased pressure on limited local resources. The reduction in income-generating activities and the imposition of mobility restrictions further heightened the vulnerability of these communities, leading to an increase in livestock theft and violent raids as alternative means of survival.[5]

In response to the increased insecurity in the area, governments introduced corral protections (*kraals*) and the heavy deployment of the Uganda Peoples' Defence Forces (UPDF). These policies, while aimed at stabilising the situation, often led to increased tensions between the military and local pastoral communities. These forms of militarisation and tensions further complicated the security landscape. While vegetation improvements were reported in 2021, conflicts increased due to socio-economic pressures from COVID-19 policies, the locust plague and increased cattle rustling activities within the Cluster.[6]

In addition to the multiple crises that were already threatening pastoral livelihoods during this period, a series of unfortunate events in 2022 led to the implementation of new policies that had tragic consequences for many pastoralists and eventually added to the worsening of the situation. In March 2022, five people mapping mineral areas on a mining site (three geologists and two military officers) were killed in Karamoja in north-east Uganda by Turkana herders. Normally, Turkana are nomadic pastoralists who cross over into Uganda from north-west Kenya via the Lokiriama border for pasture and water during drought and have always maintained peace even if they carry their guns. According to a Turkana elder and leader of Ng'ibanga Kraal in Matakul Village,[7] the bandits must have assumed that these were government officials spying on the Turkana community in the area and thus shot them. In reaction to the incident, Ugandan President Yoweri Museveni issued Executive Order No. 3 of 2023 stipulating that Turkana should not cross borders into Uganda with illegal firearms and that doing so would be labelled as "terrorism". The second ultimatum was directed to the Kenyan government, demanding the extradition of the perpetrators so that they could be prosecuted. Furthermore, the Turkana ethnic community was instructed to return 2,245 animals that the UPDF forces claimed were stolen from the Karamoja people in Moroto. Failure to comply would result in their expulsion to Kenya.[8] The absence of bilateral legal frameworks in both countries to address cross-border cattle rustling cases has led to the expulsion of 30,000 Turkana from areas such as Kaabong', Napak, Moroto and Kotido districts as one respondent states:

> "… we were forced to flee with our livestock back to Kenya because of the growing tension between Kenya and Uganda along the border … the executive order by Uganda made the condition worse for us as we would be harassed by the UPDF soldiers even if we just graze peacefully … we have pleaded with the president as a community because this is a collective punishment to the entire tribe … our governor even went to beg the president and offered 250 bulls as compensation of the five Ugandans that were killed … we hope our politicians would help as our president Ruto has not said anything yet …"[9]

Many Turkana who came back complained that they keep losing livestock as there is still drought in Turkana County and they cannot go into West Pokot for pasture due to the tensions with the Pokot as well over boundary conflicts stating that;

> "… not all of us planned or knew about the attack; these raids are always planned in secret. What the Ugandan authority is doing is an injustice to the entire community as we continue to lose more livestock here in Turkana due to drought …. The irony is, some Pokot also killed an area member of county assembly, and their politicians went begging for more pasture so that more animals can cross to Uganda, and no one expelled the Pokots …. Their politicians who defend them, live in Moroto, but we Turkana don't have our leaders inside Uganda, we are disadvantaged …"[10]

The executive order also separated families. In an interview, a Turkana woman who was married to an Ugandan but had to move back to Turkana County with her three children to be with her family for rear of arrest stated:

> "… It's really hard for me to be here; I had to uproot my life, and it's already been a year and nothing has happened … I fear my husband will be forced to marry another woman …, also I used to take my kids to a good school in Moroto and we had food. Where I live in Loima, there are no schools or better health facilities. I am in a village …, so since we came, my children have not gone to school …. The main challenge I have gone through as a Kenyan is also the harassment by UPDF, not having an identification card. …. When you go to graze and don't have an ID card …, you get arrested. It's really hard for us …"[11]

Although there is a Protocol on the Prevention, Combating and Eradication of Cattle Rustling in Eastern Africa, known as the Mifugo Protocol, to help resolve cross-border issues arising from cattle rustling, member states have so far not ratified it. The Protocol could help provide a framework for law enforcement, joint security operations and extradition of criminals within the region. The Turkana politicians also claimed that since the executive order, thirteen people have been killed and 800 livestock stolen from the community by the Dodoth ethnic group in Kaabong and that the UPDF has done nothing to protect the innocent community who are

[5] Interview with Turkana Pastoralists Development Organization-TUPADO official, Loima, 17 February 2024.

[6] Interview with community mobiliser of Moroto Nakapiripirit religious leaders' initiative for peace (MONARLIP) in Lodwar, 16 April 2024.

[7] Interview with a Turkana elder and leader of Ng'ibanga Kraal in Matakul Village, 19 February 2024.

[8] Interview with County government of Turkana secretary in Lodwar, 4 March 2024.

[9] Interview with a Turkana elder who had fled Uganda with his livestock and family on 9 March 2024 and who now lives as an internally displaced person in Loima.

[10] Interview with a Turkana youth expelled from Kotido district in Lodwar, 18 March 2024.

[11] Interview with expelled Turkana woman living in Loima village with her family, 22 February 2024.

now being judged as criminals.[12] An official from the National Drought Management Authority in Lodwar stated that if the situation is not addressed, the Turkana will lose all their livestock, and this will increase insecurity in the entire cluster as they will be forced to restock as they still own illegal firearms. He further stated that the Memorandum of Understanding signed between Kenya and Uganda in 2019 by President Museveni and Uhuru Kenyatta was meant to promote cross-border coexistence in terms of resource sharing between Turkana, West Pokot and Karamoja ethnic groups. This memorandum failed to address the conflicts as it was never implemented by the two states, and now the relations between Kenya and Uganda are deteriorating.[13]

7. Discussion

The impact of climatic factors on conflict has been studied extensively [30,39,41], and the consensus remains on the highly contextual nature of this relationship [27,28]. In our study, we want to support this claim by underlining the importance of considering contextual factors when such linkages between climate and conflict are being identified. This was done by applying a mixed-methods approach that combined an empirical analysis of environmental and conflict data along with qualitative interviews with local actors who witnessed the current polycrisis in the Karamoja Cluster. Confirming the claim, our study revealed that the unprecedented increase in pastoral conflict in the recent past was only ignited by climatic factors, while other factors were the underlying root causes.

Methodologically, we have tested different environmental variables to predict climate-related conflicts. Our methods revealed that the use of vegetation has great potential in the case of pastoral conflict prediction. The main advantage against rainfall data is that the natural resource availability is measured, whereas the use of precipitation data requires assumptions to be made about vegetation growth. This may not always be the case, for example when torrential rains following a dry period lead to soil erosion and cause loss of vegetation. Furthermore, vegetation data can also reflect the impact of pests, such as a locust plague [72]. Following Coulibaly and Managi [41]'s example, we analysed monthly data, due to the high variability characteristic of the study area. This provided important insights into the seasonal patterns, which could be contrasted with those from the conflict data. We found that the dominant direction of the climate–conflict relationship in the Karamoja Cluster is one of higher conflict in times of resource scarcity, rather than raiding when resources are most abundant. When including the one-month-lag vegetation variable, there seem to be different mechanisms influencing conflict occurrence and conflict intensity: The probability of conflict occurring is primarily driven by the current resource availability; when resources are scarce, competition increases and conflict is more likely to occur - vegetation levels from the previous month do not play a role here. On the other hand, once conflicts occur, the number of conflict events (conflict intensity) is affected by the previous month's vegetation levels. This mechanism can be due to the movement of herds towards areas of higher resource availability, which then leads to resource competition on destination pastures, as has been described in previous studies, but also due to the higher amount of well-fed livestock which can create an incentive to raiding, increasing the number of conflicts after a period of good conditions.

When looking at the spatial dimension, the predominant pattern found was a concentration of conflict along the transition line between the arid lands on the Kenyan side of the border and the greener areas on the Ugandan side. While there is also evidence of pastoral routes moving towards the south-west and crossing the border during the wet season [53], following the Cattle Corridor across Uganda [73], our filtered conflict dataset shows that pastoral conflicts have not moved from the border region to the Ugandan inland. On the Kenyan side, pastoral conflict spreads further inland towards the southeast still following the same transition line between humid and semi-arid ecoregions outside the Karamoja Cluster. This region is particularly special when it comes to the impact of climate anomalies on conflict. Our regression analysis that included vegetation anomalies showed that there was no significant linkage to any of the analysed conflict variables. This is possibly due to the generally lower vegetation levels in this transitory ecoregion where conflicts are concentrated, which presents much lower deviations from the long-term mean than the more humid regions, where almost no conflicts are reported. On the other hand, the little vegetation available for forage is critically reduced here, explaining the significant negative relationship between current vegetation and conflict.

Analysis of the interview data suggests that the region's security dynamics are strongly influenced by government policies, restrictions on movement and the socio-economic consequences from previous periods of scarcity. This is further corroborated by the ACLED data analysis: pastoral conflicts involving state actors represented a considerable share, especially on Ugandan side, where these conflicts are the predominant phenomenon within the Cluster. The contrary is the case in the other countries, where state involvement in conflict is low within the Karamoja Cluster. The results of our interviews have also revealed that relations between Kenya and Uganda at the border region have deteriorated as a result of increased cattle rustling among the groups. In addition, the lack of legal frameworks to guide cross-border resource sharing —such as the failure of the East African Community member states to ratify the Mifugo Protocol and also the failure to implement the 2019 Memorandum of Understanding, which was meant to support peaceful coexistence in the Cluster— has also contributed to the deterioration of the security landscape. Unprecedented climatic adversities have further exacerbated pastoral conflicts.

An analysis of trends in conflict dynamics revealed that conflicts have increased over time. During the period of analysis, a major disarmament exercise took place in Uganda in May 2022. However, this did not significantly reduce the number of lethal conflicts, although the number of conflicts in 2023 was lower than in 2022, but still high compared to previous years. This is consistent with the theory that unequal disarmament can lead to even more lethality [17]. In addition, a reporting bias may have led to lower reporting in areas of lower population and infrastructure density, which coincide with areas of lowest vegetation growth in the study area. Such access may have played a crucial role in the reporting of such events [41] but may also contribute to a higher likelihood of conflict (Ackermann et al., 2021). It is worth mentioning that although Turkana County in Kenya was affected by major policies, there were hardly any conflict events

[12] Interview with former member of county assembly (MCA) in Loima, 26 February 2024.

[13] Interview with National Drought Management Authority (NDMA) in Lodwar Turkana County, 14 April 2024.

reported there throughout the period of analysis. This leaves open the question of whether conflicts were indeed taking place where the grass is greener, and Turkana pastoralists were not being attacked, or whether they never reported these events.

8. Conclusion

This paper applied a mixed-methods approach to analyse the spatio–temporal patterns of environmental and pastoral conflict dynamics from 2018 to 2023 in the Karamoja Cluster. During this period, unprecedented droughts were accompanied by unprecedented levels of conflict. While environmental stress significantly impacted pastoralist communities, our work highlights that its combination with a series of unfortunate policies has made the region particularly vulnerable to climate change.

Our analysis shows that while pastoral conflict increased with decreasing vegetation levels across the broader study area, it is on the transition zones between areas of lowest and highest vegetation cover within and beyond the Karamoja Cluster, where pastoral conflicts are most likely to occur. Given this concentration on areas with relatively low vegetation cover, the magnitude of negative vegetation anomalies (deviations below the long-term average) was comparatively small. However, small deviations could cause considerable damage to the low vegetation cover, having the de-facto available vegetation a significant effect on conflict in this ecologically fragile area. For conflict prediction we found that our vegetation variable from one month prior to conflict was a better predictor for conflict intensity than rainfall, but not for the other conflict variables (occurrence and lethality). Interestingly, conflict intensity tended to increase following periods of better vegetation conditions.

Contrary to common assumptions, cross-border conflicts were relatively rare, despite the role of transhumance in driving competition over greener pastures. Additionally, our analysis showed that state actors were often involved in pastoral conflicts despite the region's generally low state capacity. Moreover, our qualitative analysis revealed that environmental conditions and local policies reinforced each other, jointly contributing to escalating conflict. Our interviews provided important insights into the impact of the COVID-19 pandemic and other policy implications that not only affected pastoral livelihoods but also contributed to intercommunal tensions among pastoralist groups in the region.

Overall, this study provides valuable insights into the emerging dynamics between environmental conditions and conflict in the Karamoja Cluster. Our findings emphasize the need for transboundary and climate-sensitive policymaking to mitigate conflict risk and build resilience in the region.

CRediT authorship contribution statement

Rebecca Navarro: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Lamis Saleh:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Evelyne Owino:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Data availability statement

The source code used to generate the datasets for the grid cell analysis can be found in the following repository: https://github.com/rbcnavarro/pastoralConflict.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Abbreviations

ACLED	Armed Conflict Location & Event Data Project
GEE	Google Earth Engine
LS	Landsat
LST	Land Surface Temperature
NDVI	Normalised Difference Vegetation Index
NIR	Near Infrared
S2	Sentinel-2
TOC	Top of Canopy
UPDF	Uganda Peoples' Defence Forces

Appendix A

A.1 Study area description

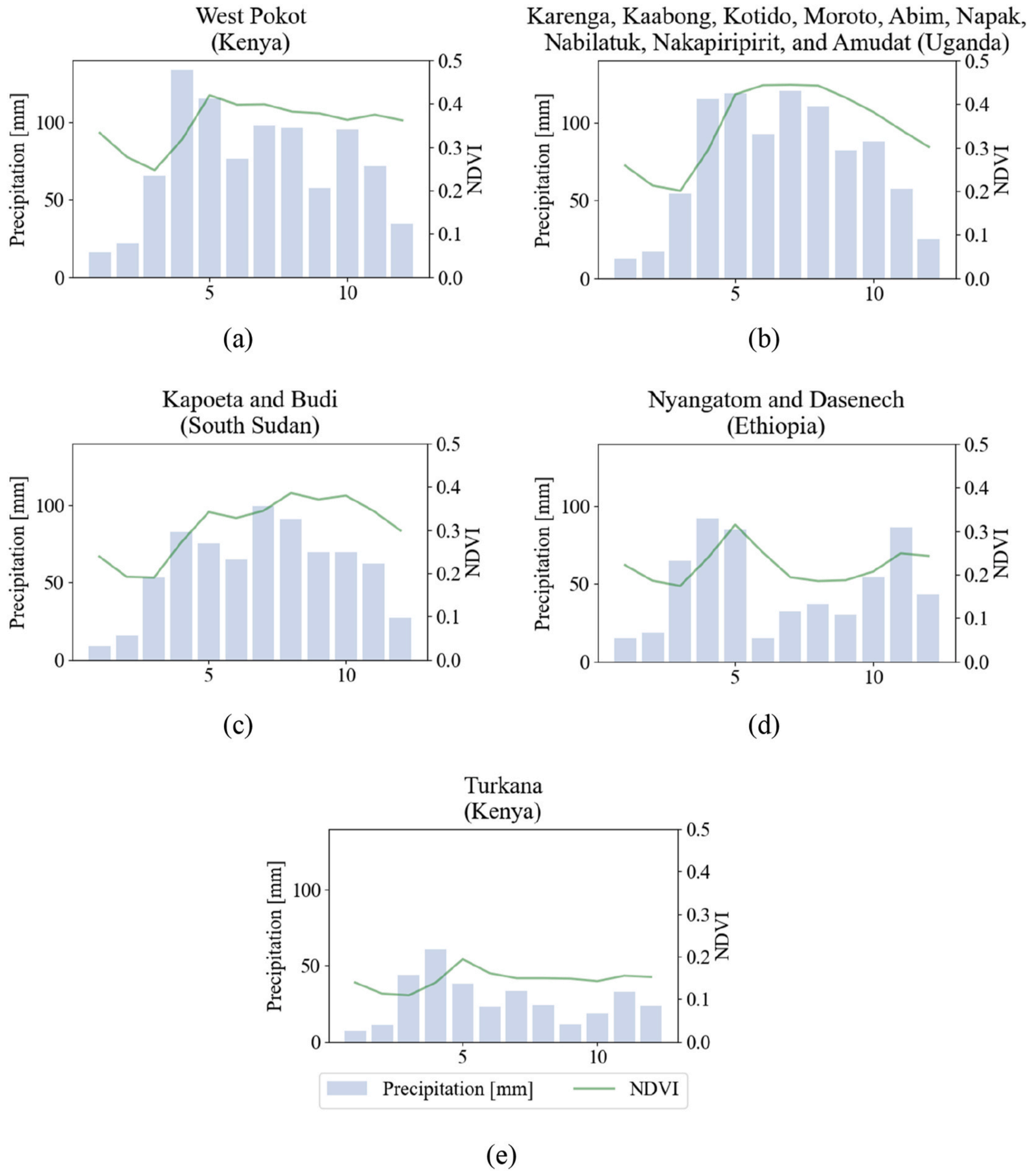


Fig. A 1. Long-term (1997–2017) average of precipitation (blue bars) and vegetation growth (green line) based on NDVI computed from Landsat data [61] in different counties within the Karamoja Cluster.

A.2 Conflict dynamics and environmental trends

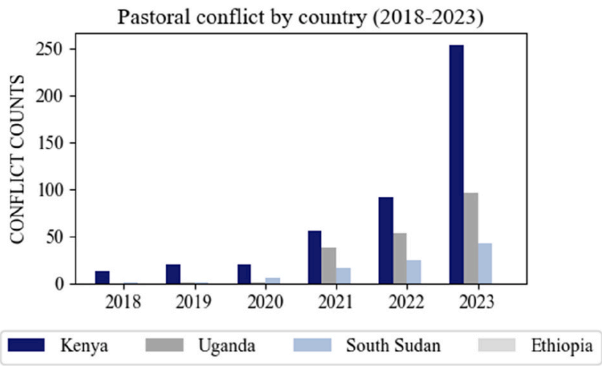


Fig. A 2. Yearly counts of pastoral conflict events by country. Source: ACLED (2018–2023).

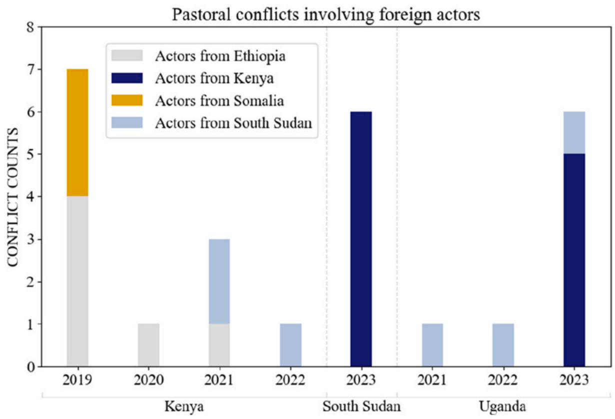


Fig. A 3. Pastoral conflicts involving actors from other countries. Source: ACLED (2018–2023).

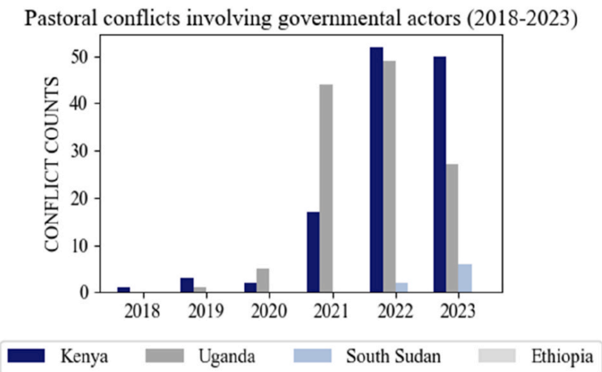
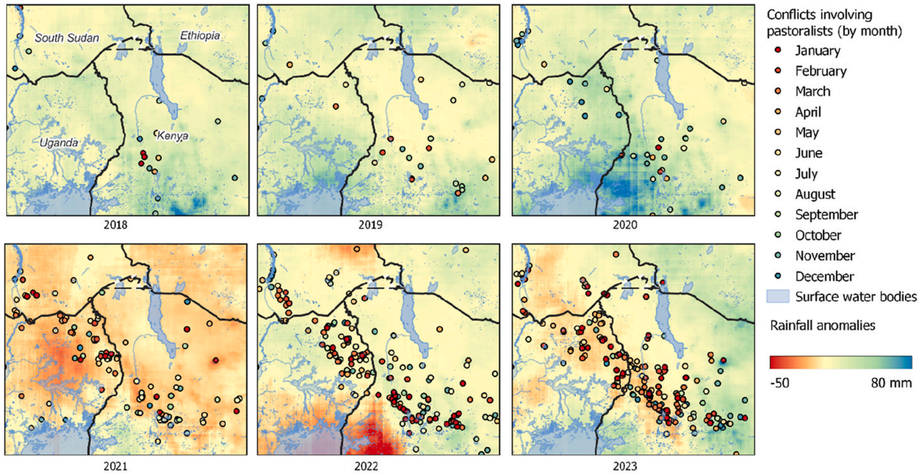
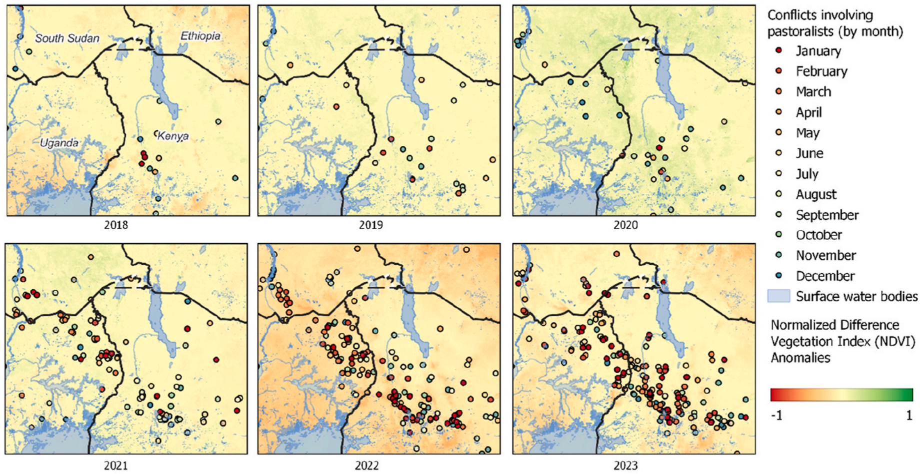


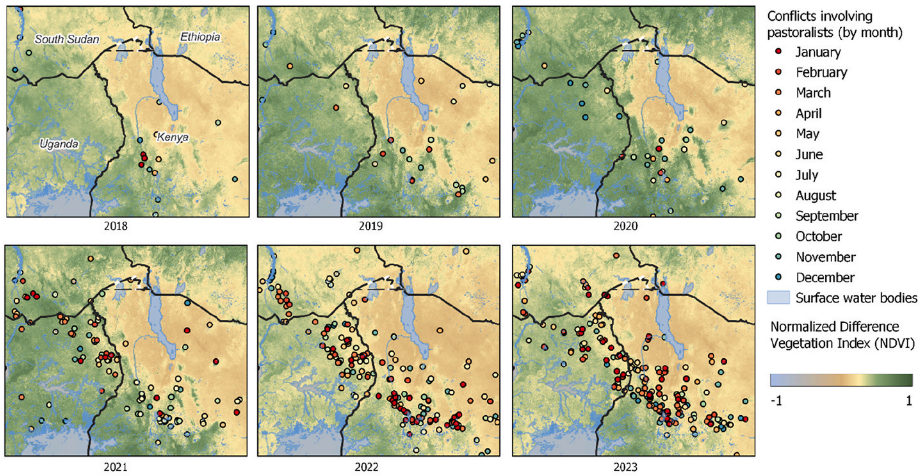
Fig. A 4. Pastoral conflict events involving governmental actors. Source: ACLED (2018–2023).



(a)



(b)



(c)

Fig. A 5. Precipitation (a) and vegetation (b) anomalies for the years 2018–2023, obtained by subtracting yearly mean from long-term (1997–2017) average. Actual vegetation (c) based on annual mean NDVI computed for each year of analysis. Pastoral conflict events are coded in different colours for month of occurrence as displayed in the legend. All data sources used are described in section 4. Surface water bodies are displayed for visualisation purposes and obtained from OpenStreetMaps, 2022.

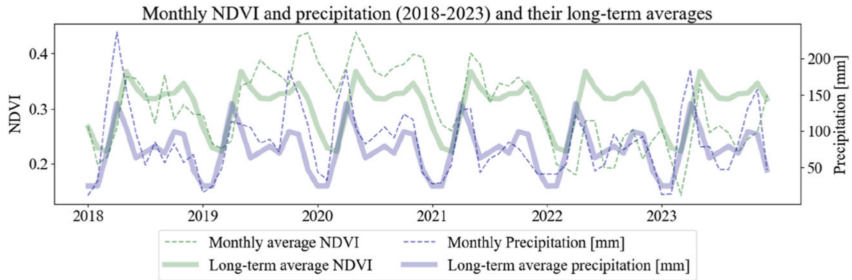


Fig. A 6. Monthly precipitation sums' average [mm] over the study area and monthly mean NDVI values. Sources: Normalised Difference Vegetation Index (NDVI) monthly average computed from PROBA-V and Sentinel-2 data [62] and long-term monthly average computed from PROBA-V [63] and Landsat 5, 7, 8 [61]. Rainfall data was retrieved from the CHIRPS dataset [64].

Appendix B

B.1 Regression Analysis

B.1.1 Conflict Occurrence

In a first step, we analysed the impact of vegetation on the occurrence of pastoral conflicts and found a negative and significant correlation between vegetation and the occurrence of conflict (−0.0149, p-value = 0.03). We then proceeded to our probit regression analysis (see Table B 1 below). Model (1) presents the results when accounting for vegetation and lagged vegetation and in model (2) we add the controls. We found that higher vegetation levels are associated with a lower probability of conflict occurrence. These results are significant. However, when we added the controls in model (2), we found that conflicts happening in the prior month increase the probability of conflict occurrence, as well as a higher temperature. We move then to models (3) and (4) to present the probit regression results of the impact of our second variable, namely precipitation. We found that unlike vegetation, the amount of rainfall does have a small and not so significant effect on the probability of conflict occurrence, especially after accounting for all controls.

Table B 1Pastoral conflict occurrence

	Dependent variable:			
	CONF			
	(1)	(2)	(3)	(4)
NDVI	−0.844***	−0.526		
	(0.302)	(0.337)		
NDVI(t-1)	0.081	0.062		
	(0.168)	(0.168)		
Pastoral Conflicts (t-1)		−0.094		−0.093
		(0.075)		(0.075)
Conflicts (t-1)		0.030**		0.031**
		(0.014)		(0.014)
Temperature		0.0004**		0.0005***
		(0.0002)		(0.0002)
High Population		0.149		0.164
		(0.511)		(0.512)
Night lights		0.004		0.005
		(0.007)		(0.006)
Rainfall			−0.001*	0.0001
			(0.001)	(0.001)
Rainfall(t-1)			−0.0004	−0.0005
			(0.0004)	(0.0004)
Constant	−7.206	−13.005	−7.375	−15.272
	(701.389)	(699.419)	(702.408)	(700.679)
Observations	20,719	20,509	20,719	20,509
Log Likelihood	−1,647.858	−1,642.381	−1,649.847	−1,642.800
Akaike Inf. Crit	3,907.717	3,900.762	3,911.695	3,901.599

Notes: Standard errors in parentheses. *, **, and *** indicate significance at the 10, 5, and 1 % level, respectively. Columns show probit models' regression results. CONF is a binary indicator that equals one if at least one pastoral conflict is observed in time *t*. All regressions include cell (α), month (t), and year (γ) fixed effects.

B.1.2 Conflict intensity

In this section, we focus on the intensity of conflict by measuring the impact of environmental variability on the number of pastoral conflict events. We again found a negative and significant correlation between the number of conflicts and the vegetation levels (−0.014, p-value = 0.034). Table B 2 uses monthly vegetation levels (models (1) and (2)) and precipitation means (models (3) and (4)) as the main explanatory variables. The results indicate that the higher the levels of vegetation, the lower the number of pastoral conflicts is. This effect is robust and significant even after the inclusion of the controls. We find a positive effect of preceding vegetation levels. Additionally, the number of conflicts in the previous month does increase the number of pastoral conflicts in the month after. However, we found no impact of precipitation or precipitation lags on the number of conflicts.

Table B 2
Pastoral conflict intensity

	Dependent variable:			
	CONF_CO			
	(1)	(2)	(3)	(4)
NDVI	−1.080**	−0.841*		
	(0.429)	(0.462)		
NDVI(t-1)	0.476**	0.443**		
	(0.243)	(0.243)		
Pastoral Conflicts (t-1)		−0.114		−0.103
		(0.100)		(0.099)
Conflicts (t-1)		0.043*		0.046*
		(0.018)		(0.018)
Temperature		0.0003		0.001***
		(0.0002)		(0.0002)
High Population		0.693		0.717
		(1.092)		(1.092)
Night lights		0.009		0.012
		(0.011)		(0.011)
Rainfall			−0.0003	0.001
			(0.001)	(0.001)
Rainfall (t-1)			−0.0003	−0.0003
			(0.001)	(0.001)
Constant	−22.824	−28.246	−22.905	−32.948
	(2,820.603)	(2,809.663)	(2,823.989)	(2,816.899)
Observations	20,719	20,509	20,719	20,509
Log Likelihood	−2,439.200	−2,434.652	−2,444.450	−2,437.217
Akaike Inf. Crit	5,490.400	5,485.304	5,500.901	5,490.434

Standard errors in parentheses. *, **, and *** indicate significance at the 10, 5, and 1 % levels, respectively. Columns show Poisson models regression results. CONF_CO is a count variable that measures the number of pastoral conflict incidents that took place in time *t*. All regressions include cell (α), month (t), and year (γ) fixed effects.

B.1.3 Conflict lethality

To illustrate the significance of our previous findings, we now focus in Table B 3 on the impact of vegetation ((1) and (2)) and precipitation ((3) and (4)) on conflict lethality. We measure lethality by the number of fatalities that result from a conflict incident. In line with our previously presented results, we find that higher vegetation levels are associated with fewer pastoral conflict fatalities. We do not find an effect of lagged vegetation levels. Higher temperature levels increase the number of fatalities resulting from pastoral conflict. We also find that more conflicts in general increase the number of fatalities resulting from pastoral conflicts. The vegetation effects found in this model, though as significant as other models, are much higher in their magnitude.

Table B 3
Pastoral conflict lethality

	Dependent variable:			
	CONF_F			
	(1)	(2)	(3)	(4)
NDVI	−2.390***	−1.599***		
	(0.344)	(0.380)		
NDVI(t-1)	−0.035	−0.064		

(*continued on next page*)

Table B 3 (*continued*)

	Dependent variable:			
	CONF_F			
	(1)	(2)	(3)	(4)
	(0.201)	(0.201)		
Pastoral Conflicts (t-1)		−0.518***		−0.522***
		(0.125)		(0.124)
Conflicts (t-1)		0.032***		0.026*
		(0.016)		(0.016)
Temperature		0.001***		0.001***
		(0.0002)		(0.0002)
High Population		0.109		0.118
		(1.226)		(1.226)
Night lights		0.004		0.006
		(0.008)		(0.008)
Rainfall			−0.006***	−0.004***
			(0.001)	(0.001)
Rainfall (t-1)			−0.0001	−0.0003
			(0.0004)	(0.0004)
Constant	−21.532	−38.785	−22.164	−35.458
	(2,828.141)	(2,795.224)	(2,832.909)	(2,804.977)
Observations	20,719	20,509	20,719	20,509
Log Likelihood	−3,945.323	−3,916.830	−3,934.902	−3,914.247
Akaike Inf. Crit	8,502.646	8,449.660	8,481.804	8,444.494

Standard errors in parentheses. *, **, and *** indicate significance at the 10, 5, and 1 % level, respectively. Columns show Poisson models regression results. CONF_F is a count variable that measures the number of fatalities that resulted from pastoral conflict incidents. All regressions include cell (α), month (t), and year (γ) fixed effects.

We deduce that vegetation does have an impact on how lethal a pastoral conflict can be. We find however, that rainfall levels also have an impact on the lethality of conflicts. Higher rainfall reduces the number of fatalities resulting from conflict. Temperature has the same effect as before.

B.2 Robustness Checks

In this section, we extend our regression analyses further. We rely on vegetation as the main explanatory variable. In Table B 4, we focus our analysis on the vegetation anomalies. Model (1) presents probit regressions where conflict occurrence is the dependent variable, while models (2) and (3) present the Poisson regressions, where the number of conflict events and the number of fatalities are the dependent variables. The results indicate that vegetation anomalies are not associated with conflict.

Table B 4
Regressions for conflict and vegetation anomalies.

	Dependent variable:		
	CONF	CONF_CO	CONF_F
	probit	*Poisson*	*Poisson*
	(1)	(2)	(3)
NDVI Anomalies	−0.180	−0.467	0.169
	(0.347)	(0.478)	(0.386)
Pastoral Conflict (t-1)	−0.092	−0.105	−0.518***
	(0.075)	(0.099)	(0.125)
Conflicts (t-1)	0.030**	0.045**	0.029*
	(0.014)	(0.018)	(0.016)
Night light	0.005	0.012	0.009
	(0.006)	(0.011)	(0.008)
Temperature	0.0005***	0.0005**	0.001***
	(0.0002)	(0.0002)	(0.0002)
High Population	0.158	0.708	0.100
	(0.511)	(1.092)	(1.226)
Constant	−14.780	−30.609	−44.647
	(702.029)	(2,819.649)	(2,803.746)
Observations	20,509	20,509	20,509
Log Likelihood	−1,643.540	−2,437.577	−3,925.638
Akaike Inf. Crit	3,901.080	5,489.153	8,465.276

Standard errors in parentheses. *, **, and *** indicate significance at the 10, 5, and 1 % level, respectively. CONF is a binary indicator that equals one if at least one pastoral conflict is observed in time *t*. CONF_CO is a count variable that measures the number of pastoral conflict incidents that took place in time *t.* CONF_F is a count variable that measures the number of fatalities that resulted from pastoral conflict incidents. All regressions include cell (α), month (t), and year (γ) fixed effects.

In summary, our findings provide evidence of a negative link between natural resource availability and pastoral conflict. We differentiate between different measures of environmental variability, namely vegetation and precipitation. Our findings indicate that higher levels of vegetation are associated with a lower probability of conflict occurrence, a lower number of conflict incidents and a lower fatality rate resulting from conflict. However, when measuring the effects of precipitation, these are neither robust nor significant. Our analysis suggests that rainfall only has an impact on the lethality of the conflicts.

Data availability

I have shared the link to the code in the manuscript.

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