UCL

Final Coursework

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The Patterns of War:

A fatality-weighted spatio-temporal KMeans clustering analysis of conflict events in Yemen, 2016 - 2018

Introduction

In war humans perpetrate unconscionable harm; the ethics of war has been a topic of debate since antiquity (The Bible, Deuteronomy 20:19-20, Qur'an 2:190-193). Lanchester (1916) observed that in modern warfare resourced adversaries commit violence at a scale not previously possible. Given each human's fundamental right to life (UN General Assembly 1948) and evidence that a substantial proportion of fatalities in the past century's wars have been civilians (Eckhart 1989), a moral imperative exists to prevent war, and to minimize harm caused by ones that do occur.

The ongoing civil war in Yemen is causing immense human suffering; all sides "could be guilty of war crimes" (UN News 2018). This analysis will seek to improve our understanding of the conflict by analyzing event-level data of incidences of organized political violence. These insights may aid peace-oriented actors in efforts to mitigate the loss of human life and damage to property and the environment.

Research Question

What clusters of Yemen civil conflict events emerge based on location, time and fatality counts? What characteristics do the clusters exhibit? How might consideration of these clusters provide a more sophisticated and accurate understanding of the nature and progression of the ongoing conflict?

Literature Review

Civil conflicts occur within a country between organized violent actors seeking to gain political control or induce political change (Fearon 2007). Very often one actor is the incumbent government (Hironaka 2005). This challenge from within to the state's monopoly on violence (Hobbes 1651) is often intensely harmful to the people, economy, infrastructure and institutions of the affected country; negative effects can reverberate long after the conflict's official end (Hoeffler 2003). Civil conflicts are increasingly more common than interstate ones (O'Loughlin 2005) and present difficult ethical, legal and economic questions to observing countries concerned with human rights, rule of law and economic self-interest (Cassesse 2008, Powers 2014) - should, and how should, they intervene or disengage (Clinton 1998, Obama 2013, Kim 2012)?

Early attempts to mathematically model warfare (Lanchester 1912) have evolved into sophisticated quantitative techniques to analyze and understand the outbreak, progression and end of violent conflict (Richardson 1960, Karmeshu 1990, Epstein 2002, Baudains 2015).

Country-scale analyses of conflicts indicate that they tend to cluster in space and affect neighboring countries (Gleditsch 2007, Buhaug 2008). Less explored, however, are the patterns of conflict at more local levels, a gap in enquiry largely attributable to data scarcity. New empirical data describing conflict at the event level and including spatial and temporal dimensions are enabling analysis of conflict at an ever-finer scale (Raleigh 2010, Lacina 2005, Uppsala Conflict Data Program 2018, VDC 2018). Fujita (2017) analyzed death tolls in the ongoing Syrian conflict, "infer[ring] attack strategies, warn[ing of] potential occurrence of future events, and hopefully avoid[ing] further deaths." Others have used quantitative techniques to identify early indicators of the outbreak of war (Chadefaux 2014) and forecast conflict (Brandt 2011).

Yemen is currently experiencing a complex civil conflict (Sharp 2018). While it is overly reductive to pinpoint a single specific cause, a confluence of social, political, economic and environmental factors triggered the Arab Spring protests (BBC 2011), which resulted in an attempted political transition in November 2011 (Khaleej Times 2011). Three and a half years after this transition's failure (BBC 2018), formal hostilities between Houthi and government forces began in March 2015 (Ayoub 2015). The complexity of the conflict cannot be overstated - both internal and extra-territorial state and non-state violent actors involved themselves early based on myriad justifications (Sharp 2018). 2018 witnessed a surge in hostilities (Beaumont 2018), though a recent ceasefire (Wintour 2018) has provided a glimmer of hope that this tragic war may soon be resolved.

Data

The Armed Conflict Location and Event Data

Project has provided data describing incidents of organized political violence since 2010 (Raleigh 2010). From 1 January 2016 to 17 December 2018, the project published details of 26286 violent events within Yemen's borders, including "information on the type, agents, exact location, date, and other characteristics of political violence events, demonstrations and select politically relevant non-violent events" (ACLED Data 2018). This analysis considers the dimensions of longitude, latitude, event date and fatalities with the aim of clustering observations with similar ones.

Precision

ACLED provides location and time information for each observation included in their data (ACLED Data 2018). Over half of the Yemen dataset reported the highest spatial precision score (1), though 43.7% of observations only were precise to "part of region" (2) or "region" (3). While this imprecision will almost certainly affect clustering assignment, we opted to include all data points provided.

Coding of fatalities

Our interest in weighting observations by fatality counts was constrained by stated uncertainty by ACLED. The dataset likely underreports total fatality counts due to coding guidelines regarding ambiguity in or discrepancy between the original conflict event reports. For example, "if a report mentions 'dozens', this is recorded as '12' fatalities" - clearly lower than the likely true fatality count. However, given that a more accurate alternative does not exist, we based

Table 1: Key Statistics, Yemen Conflict Events

Statistic	Value
n observations	26286
Total fatalities	61437
Longitudinal extent	[41.8353, 54.0223]
Latitudinal extent	[12.3173 17.77]
Start date	1 January 2016
End date	17 December 2018

Figure 1: Daily event and fatality counts

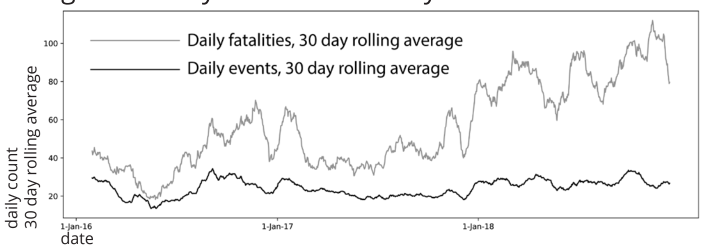
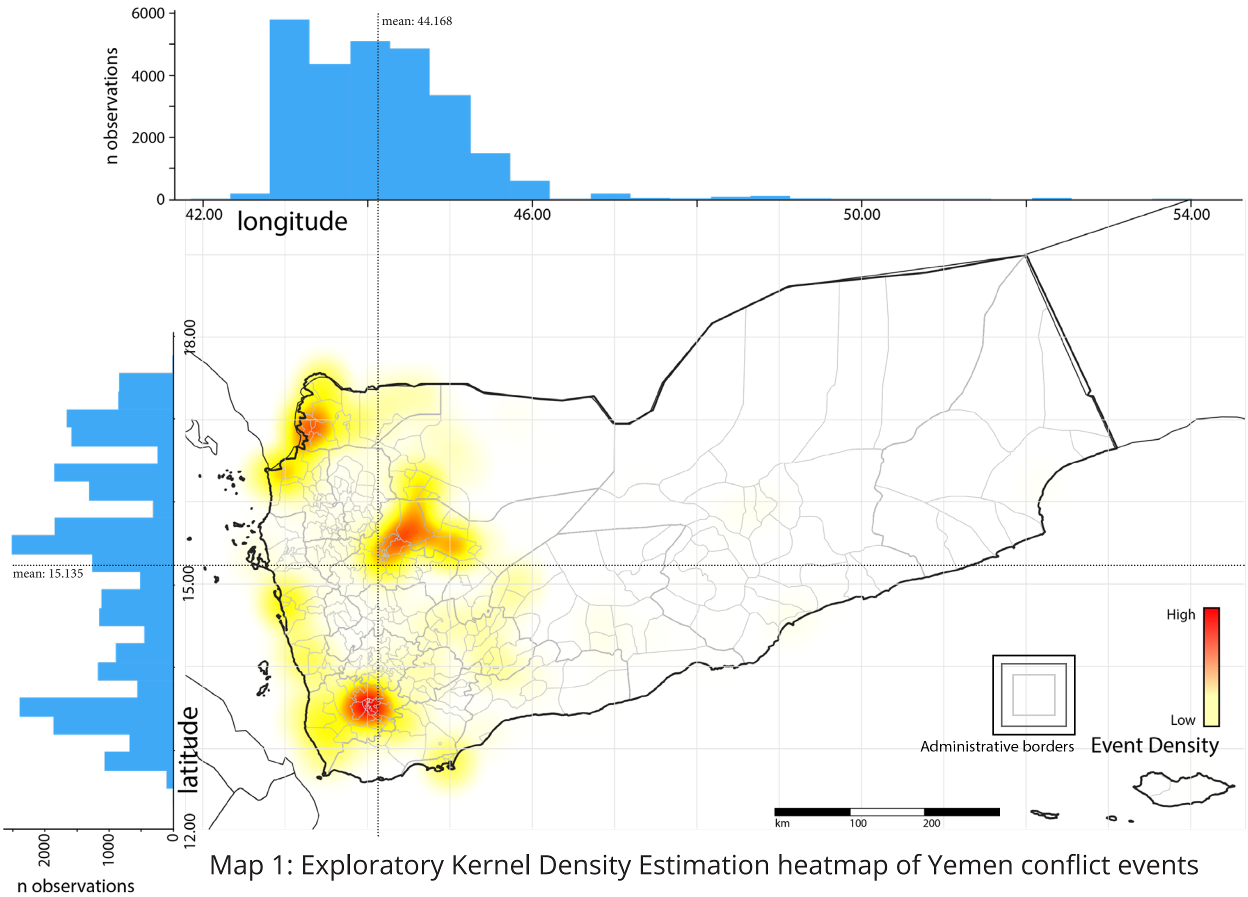


Figure 2: Map-aligned frequency distribution of Yemen conflict events by longitude



Map 1: Exploratory Kernel Density Estimation heatmap of Yemen conflict events

Figure 3: Map-aligned frequency distribution of Yemen conflict events by latitude

our analysis on the fatality count values provided by ACLED (ACLED Data 2018).

Methodology

KMeans

To identify clusters in the Yemen conflict event data we performed an unsupervised KMeans clustering analysis (MacQueen 1967). This iterative algorithm assigns each point to its nearest of K cluster centroids (initially placed using the k-means++ scheme (Arthur 2007)), calculates updated centroids based on each cluster of assigned points, and repeats the process until point reassignments cease to occur. Our initial analysis performed several iterations, assigning each point to each of $K = 3 \rightarrow 50$ clusters.

Normalization

The reliance of the KMeans clustering algorithm on the geometric distances between points means relative scale matters immensely. The geographic coordinates were provided by ACLED in decimal degrees; specific event dates were also included spanning 1058 days. To compare spatial and temporal dimensions, we chose to normalize the time dimension to span the same range as the larger spatial range.

$$d_{i_{norm}} = (d_i/d_{max}) \times (lon_{max} - lon_{min})$$

This meant that two events occurring in the same place on the first and last day of the observed range would be of the same calculated distance as two events occurring on the same day on opposite sides of the country. In this way the datetime dimension was normalized to span from 0 to 12.187.

Observation weighting

Due to the intrinsic value we place on human life, our method sought to assign weights to observations proportionate to the number of fatalities reported to have occurred at the event, thereby incorporating a measure of intensity of violence into our analysis - deadlier events were assigned greater weights. To achieve this we duplicated observations with $f > 0$ reported fatalities f times (Anderson 2016, Prune 2015) (Table 2).

With observations weighted by fatality count and dimensions normalized, we could conduct our computations.

Table 2: Raw (A) and Expanded (B) Observations

Date	Longitude	Latitude	Fatalities
1-Jan-16	45.0367	12.7794	1
4-Jan-16	44.2197	15.4763	0
3-Feb-16	44.4734	15.6445	4

↓

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Validation

A mean silhouette coefficient (Rousseeuw 1987) and sum of squared errors calculated for each number of clusters (K) enabled selection of the K that fit the data best for further analysis. The silhouette coefficient represents how well-matched an observation is to its assigned cluster compared to its nearest neighboring cluster; analyzing the sums of the squared distances of each datum from its assigned cluster centroid provides a way to select the K which balances minimization of both K and the sum of squared errors (Thinsungnoen 2015).

Results

Which K?

With each point assigned to a cluster for each of $K = 3 \rightarrow 50$ clusters, analysis of the sum of squared errors (Figure 4) and silhouette scores (Figure 5) provided a basis to select the best-fitting number of clusters.

Figure 4: Sum of squared errors by K

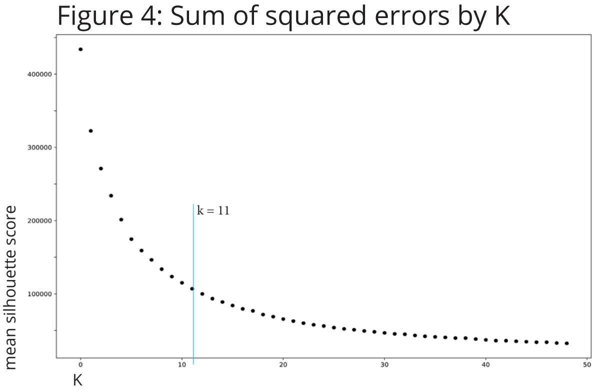


Figure 5: Silhouette scores by K

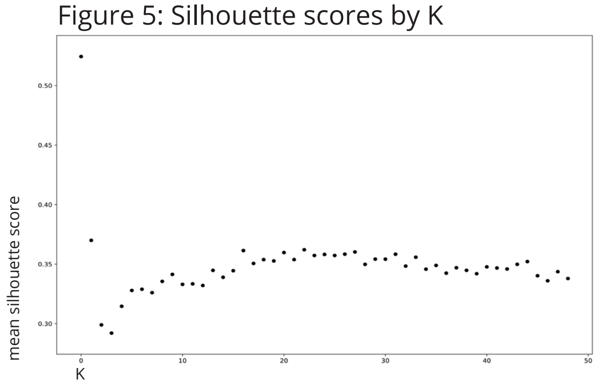


Figure 6: Event and fatality counts by week, Clusters A - K

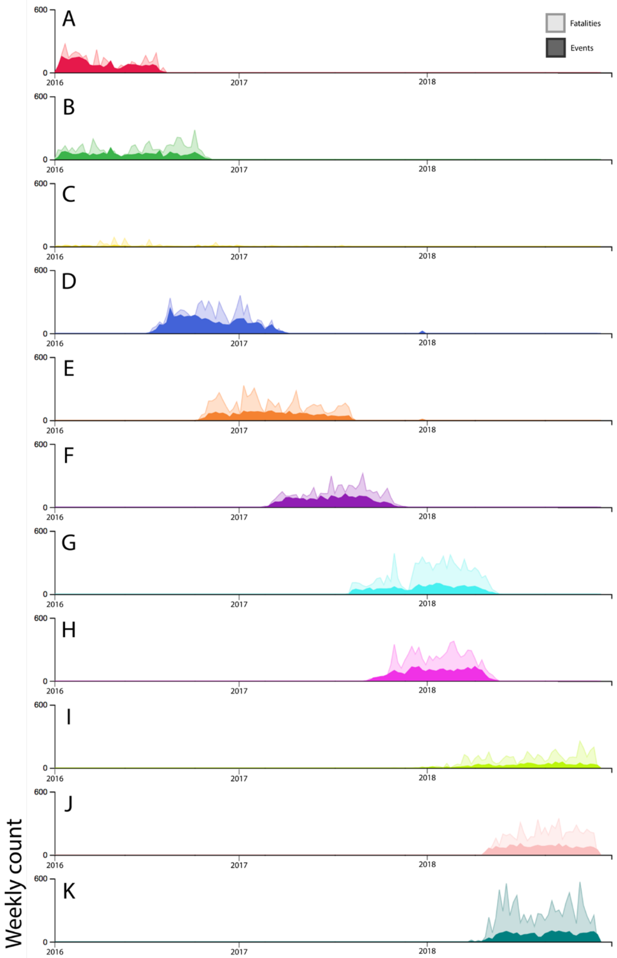


Figure 7: Cluster-specific frequency distributions, longitude

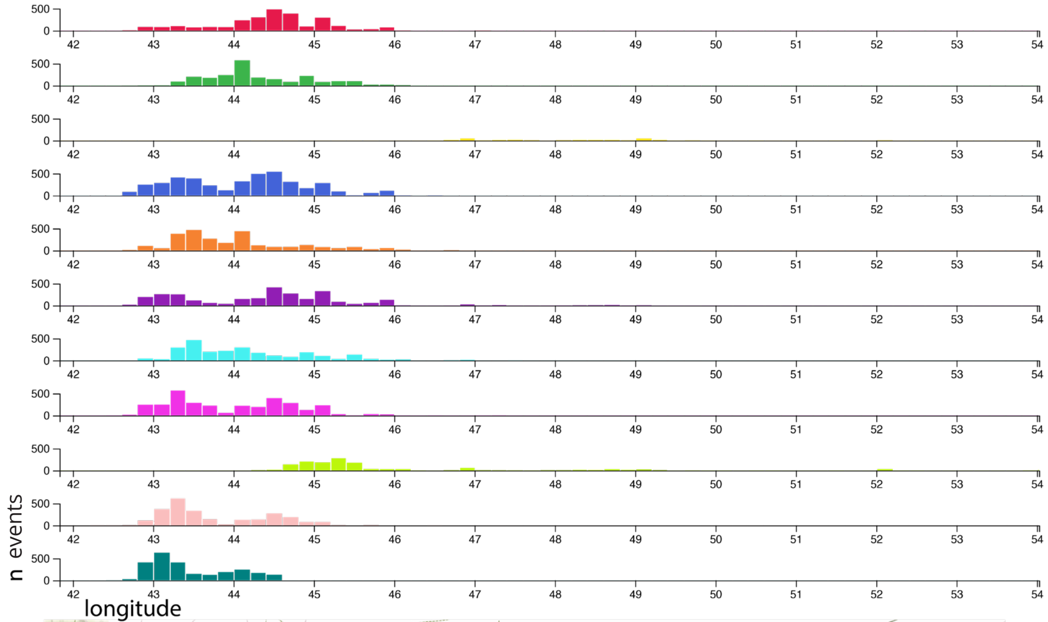
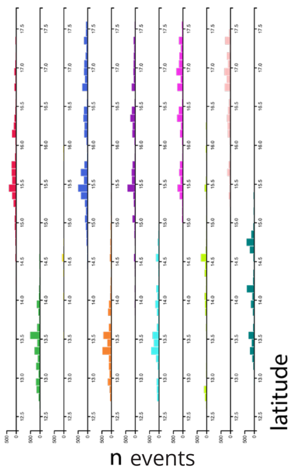
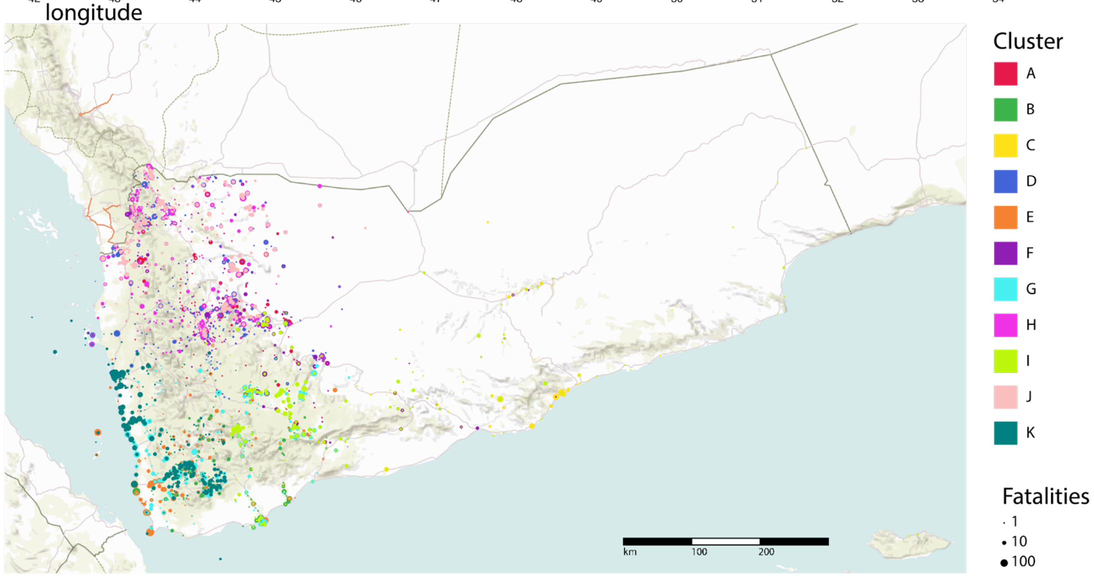


Figure 8: Cluster-specific frequency distributions, latitude





Map 2: Fatality-weighted clustered conflict events, Yemen 2016 - 2018

Clustered conflict events

Figures 6 depicts weekly event and fatality counts by cluster over time; Figures 7 and 8 depict frequency distributions of individual clusters across space. Map 2 displays color-coded event points in space; diameter reflects observation fatality count. For disaggregated maps see Appendix A.

Table : Summary statistics for clusters A - K

Cluster	Event count	Fatalities	Date			Longitude			Latitude		
			Start	Median	End	Minimum	Mean	Maximum	Minimum	Mean	Maximum
A	2491	3365	01 Jan 2016	09 Mar 2016	02 Aug 2016	42.662	44.432	47.01	14.085	15.744	17.538
B	2225	4527	01 Jan 2016	19 May 2016	27 Oct 2016	42.742	44.275	46.166	12.632	13.429	14.886
C	205	632	01 Jan 2016	02 Aug 2016	18 Nov 2017	46.5	48.264	54.022	12.65	14.788	17.77
D	4124	6326	27 Jun 2016	20 Oct 2016	28 Mar 2017	42.61	44.08	46.424	14.211	16.06	17.553
E	2599	6351	06 Oct 2016	27 Feb 2017	10 Aug 2017	42.61	43.983	46.714	12.657	13.585	15.335
F	2762	5191	12 Feb 2017	03 Jul 2017	25 Nov 2017	42.61	44.348	49.124	13.52	15.944	17.538
G	2429	8042	02 Aug 2017	14 Jan 2018	29 May 2018	42.89	44.122	47.449	12.657	13.62	14.946
H	3163	7009	08 Sep 2017	25 Jan 2018	23 May 2018	42.508	43.946	47.245	14.934	16.394	17.561
I	1315	4345	04 Nov 2017	10 Aug 2018	15 Dec 2018	44.231	45.87	54.022	12.631	14.275	17.77
J	2488	6393	01 May 2018	25 Aug 2018	15 Dec 2018	42.296	43.75	46.424	15.172	16.61	17.538
K	2485	9256	02 Apr 2018	06 Sep 2018	15 Dec 2018	41.835	43.454	44.601	12.317	14.125	15.542

While the mean silhouette scores do not clearly indicate an optimal K, the "elbow" on Figure 4 lies at $K \approx 11$.

With each datum assigned to one of 11 clusters, new patterns in the data are discernible.

2016

Ordered by median date, spatial and temporal trends in the data are revealed. In four clusters median event dates occurred in 2016; geographic centroids suggest that Clusters A and D contain many of the incidents occurring in northwestern Yemen in 2016. Cluster B represents extensive hostilities between adversaries in southwestern Yemen during 2016; its centroid lies approximately 30 km from Taizz, a city under government control besieged by the Houthis for much of 2016 (Gunter 2016). Cluster C exhibits unusual behavior, spanning a relatively long duration and containing low event and fatality counts. This may be because it contains many events occurring in the eastern extents of the conflict, where Yemeni government forces have largely sustained control throughout the war.

2017

The median dates of Clusters E and F occurred in 2017, though substantial portions of clusters D, G and H took place during the year. Cluster E contains much more fighting in southwestern interior and coastal Yemen, near the geostrategic Bab al-Mandeb strait, one of the world's busiest shipping lanes (Lee 2018). Cluster F centers further north, approximately 60 km from the capital city of Sana'a, and notably contains points spanning a relatively broad geographic extent.

2018

The second and third deadliest clusters by fatality count, clusters G and H appear similar to cluster pairs (B, A) and (E, F): each pair spans roughly concurrent date ranges, with one grouping in northwestern Yemen (A, F, H) and one in the southwest (B, E, G).

Late 2018 contains three clusters, again adhering to the pattern of incidents centering relatively to the country's northwest (J), southwest (K) and center (I). The year contained the greatest number of reported fatalities and events, as well as the most fatalities per event.

Discussion

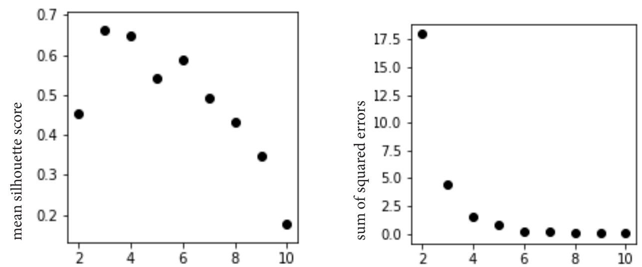
Our aim to examine event-level data describing the ongoing Yemen civil conflict through a fatality-weighted KMeans clustering analysis yielded a new dimension with which to examine the data. Conducting an additional KMeans analysis on the 11 clusters' geographic centroids corroborates the visual observation that three groupings of clusters emerge, located in Yemen's northwest (Clusters A, F, D, H, J), southwest (B, E, G and K) and central regions (I, C) (Map 5). This evidence that these areas are epicenters of fighting could prove valuable for a range of actors including peacemakers and humanitarian workers, analysts and military strategists.

The two deadliest clusters - G and K, with 8042 and 9256 fatalities respectively, both occurred in the southwestern centroid cluster. That this region has been subjected to such intense recent violence may inform aid organizations where to direct limited

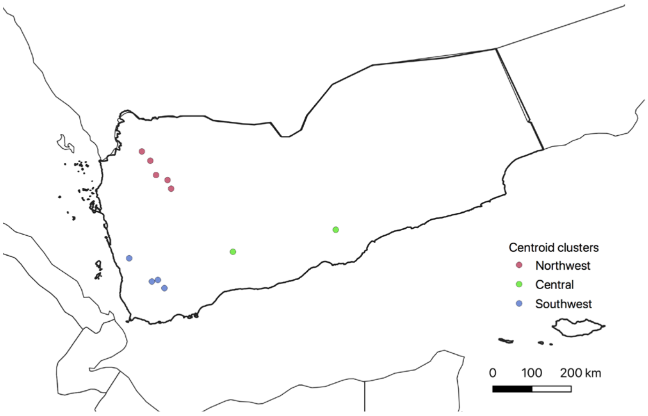
KMeans analysis on cluster centroids

Figure 9: Mean silhouette scores

Figure 10: Sum of squared errors



Map 3: Calculated centroid clusters



resources.

Examining the temporal dimension revealed that 2016 and 2017 exhibited roughly consistent levels of violence, but that 2018 witnessed a dramatic upsurge in both event counts and total fatalities. Specifically, both Clusters J and K - the first and fourth deadliest clusters respectively - may relate to Operation Golden Victory, the government coalition initiative to recapture Hodeidah, one of the key supply ports under Houthi control, which commenced in June 2018 (BBC 2018). The highest fatality : event ratios were observed in these two clusters.

Limitations

The KMeans algorithm's sensitivity to dimensional scale and related suitability to detecting geometric clusters based on point to point distance (i.e. radii) may produce misleading results - further investigation, including the employment of alternative clustering algorithms such as hierarchical (Müllner 2011), DBSCAN (Ester 1996) or alternatives (Lu 2009) should be conducted. While quantitative analyses my yield important insights, experts familiar with the situation in the "real world" should be consulted to corroborate these findings.

Incorporating cluster assignments into the full event dataset would enable further analysis of cluster dynamics including regarding event type, involved actors, etc.

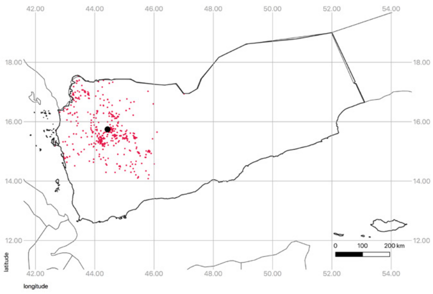
Conclusion

Developments in global interconnectivity have resulted in the creation of data describing incidences of violent conflict at an increasingly local scale, affording quantative researchers the opportunity to study war through an ever-finer lens (Raleigh 2010). The human and environmental costs already incurred by the ongoing civil conflict in Yemen are profound, and appear to be increasing. By studying the patterns of violence we may discern strategies to reduce the harm inflicted.

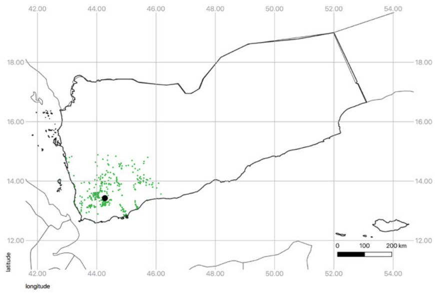
(1976 words)

Appendix A: Spatial distributions of clustered events

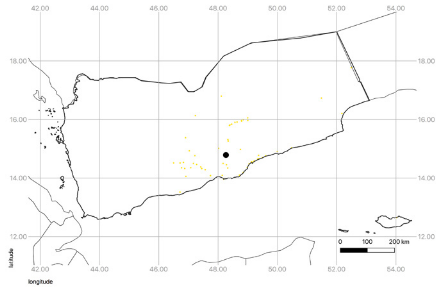
Cluster A



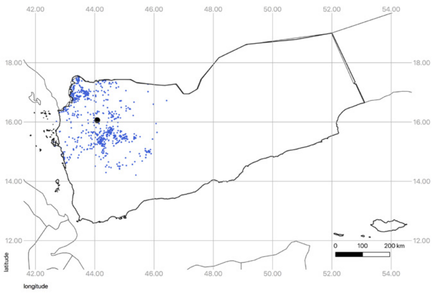
Cluster B



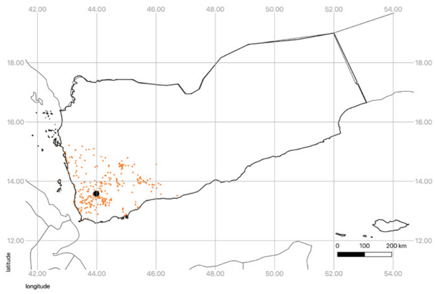
Cluster C



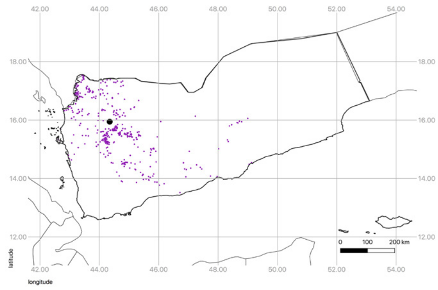
Cluster D



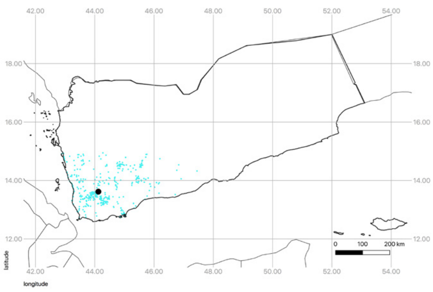
Cluster E



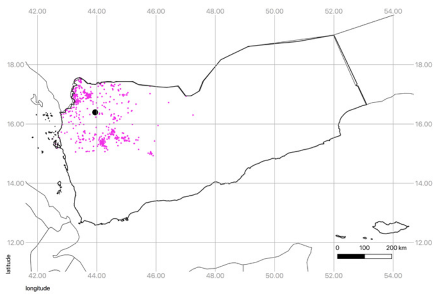
Cluster F



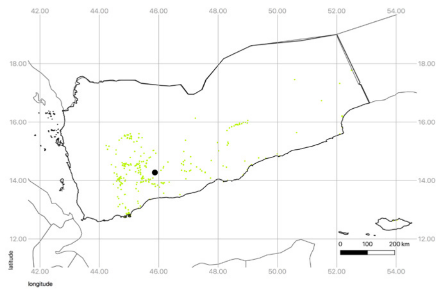
Cluster G



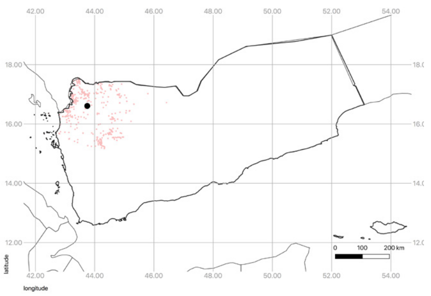
Cluster H



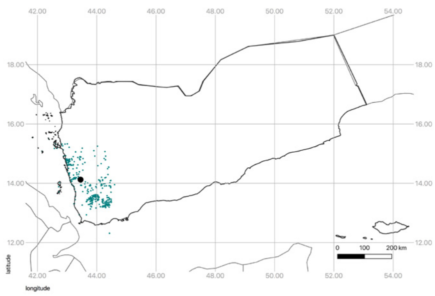
Cluster I

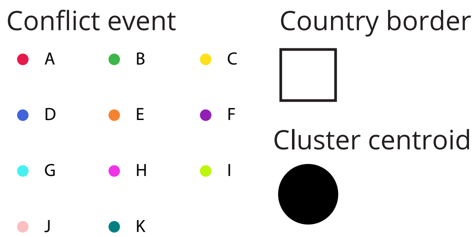


Cluster K



Cluster L





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