Limits of Control

Challenges to Spatiotemporal Analysis of Sub-State War

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Abstract:

Territorial control by violent (non-)state actors (VNSA) in sub-state war features prominently in many fundamental concepts in conflict studies. Though there have been attempts to measure this phenomenon or at least delimit it from a spatiotemporal perspective, these have so far been based either primarily on qualitative expert assessments or rely on dyadic event data to determine contested areas. In this methodological research paper, I present three approaches that can be used to estimate actor presence on basis of spatiotemporal approximation. In doing so, I focus on challenges and obstacles that can be encountered when measuring territorial control via the proxy of territorial contestation. Spatiotemporally disaggregated violent incidence data is used to analyze a small subsample of countries in sub-Saharan Africa in order to determine various ways of visualizing territorial contest. Further points of discussion include the impact of data aggregation, the availability of context data and analytical methods used for these evaluations.

Zusammenfassung:

Territoriale Gewaltkontrolle durch (nicht-)staatliche Gewaltakteure ist Gegenstand einer großen Zahl grundlegender Konzepte der Konfliktforschung. Es existieren bereits erste Ansätze dieses Phänomen zu messen und raumzeitlich einzugrenzen, jedoch beruhen diese Messungen bislang entweder auf qualitativen Einschätzungen von Experten oder – im Zuge der zunehmenden Verfügbarkeit raumzeitlich desaggregierter Daten von Gewaltereignissen – der Bestimmung umkämpfter Areale auf Grundlage bewaffneter Auseinandersetzungen. Im vorliegenden Papier werden drei Ansätze zur näherungsweisen Bestimmung der Präsenz von Gewaltakteuren vorgestellt. Dabei wird auftretenden Hindernissen und Herausforderungen der Messung territorialer Gebietskontrolle durch den Einsatz von Informationen über den territorialen Wettbewerb begegnet. Hierzu werden raumzeitlich desaggregierte Ereignisdaten ausgewählter Untersuchungsländer in Sub-Sahara Afrika exemplarisch genutzt, um die Möglichkeiten der Visualisierung territorialen Wettbewerbs unter Gewaltakteuren und dem Einfluss der Auflösung der Daten nachzugehen. Darüber hinaus wird die Verfügbarkeit von gleichfalls raumzeitlich desaggregierten Kontextdaten und entsprechenden Analyseverfahren diskutiert.

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1. Introduction

In Somalia, a decades-long civil war between multiple factions has claimed countless casualties and caused a great deal of internal displacement. A second look, however, suggests that the violence[1] is not spreading throughout the entire country, but has been concentrated in locations of presumably higher (strategic) "value" such as large agglomerations, the coastline, and the border region. The lower Shebelle region and Mogadishu, the former capital, have seen the largest share of violence (see Fig. 1, next page).

Though there are a multitude of plausible reasons for this variance, most conflict studies base their explanations on the level of contestation between armed groups and that of territorial control. From a spatial-geographic perspective, the theoretical interpretations of these two aspects can be summarized as follows: The higher the level of territorial control, the lower the level of contestation towards the center of control (e. g. Buhaug 2010; Hultman 2008; Kalyvas 2006). Thus Somalia serves as a good example of variations not only in violence, but also contestation and territorial control.

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[1] Violence is defined as the intentional use of material, physical force on a person by an individual or collective, which ultimately leads to the death of that person. Thus only lethal incidences have been taken into account. This definition excludes structural (Galtung 1969) and cultural/symbolic violence (Bourdieu/Passeron 1973; Galtung 1990). For psychological (e. g. deprivation), sexual, verbal and emotional violence, see Gudehus/Christ (2013). The scope of violent incidences ranges from criminal to armed clashes, and is used as proxy indicator of the local characteristics of war.
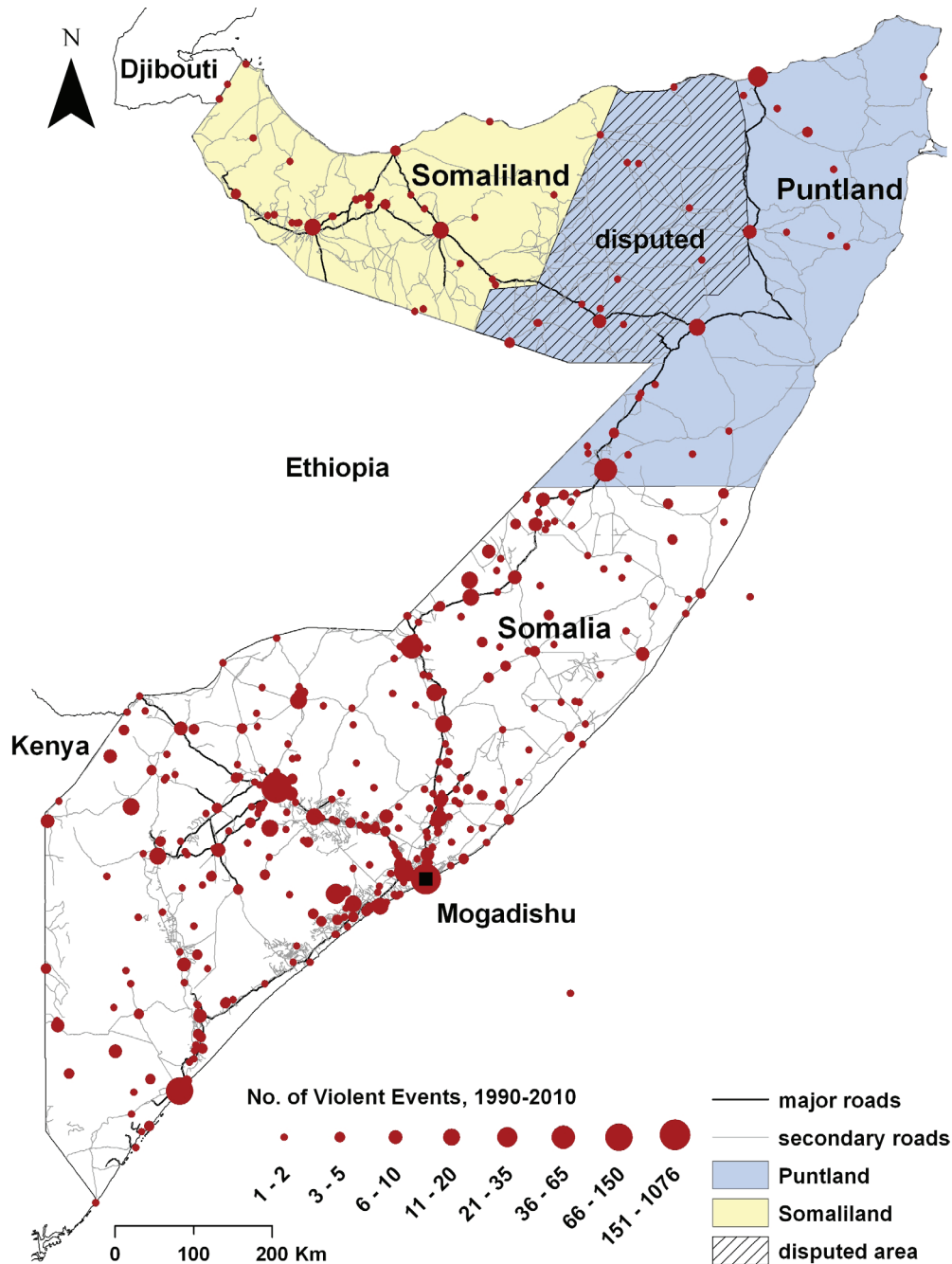
Figure 1: Violence in Somalia 1990-2010 based on EDACS (Event Data on Armed Conflict and Security) (Chojnacki et al. 2012b).[2]

Despite its key significance, there is currently no available information on the level of control. Figure 1 – a visualization based on spatial disaggregated conflict event data – shows only hotspots

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2 Violence in Somalia is concentrated in the central and southern provinces, the coastal region and especially close to the capital Mogadishu. Violence tends to occur in proximity to urban areas. Rudiments of a "quasi" inter-state war (Menkhaus 2006) have erupted in the northern region between the quasi-states Puntland and Somaliland, which Figure 1 highlights as a "disputed area". This should not, however, be misinterpreted or give the false impression that most parts of Somalia were not "disputed".

of violence. Nevertheless, it is difficult to draw conclusions about territorial control from point data that, if anything, marks the contestation of control.

This paper begins with a brief overview of why this issue is of interest in conflict studies and a discussion of the prevalent arguments based on explanatory approaches to investigating this topic.[3] This is followed by a discussion of various ways to measure territorial contest between VNSAs by making spatiotemporal actor presence visible on a sub-state level. I also discuss whether this information can be used to gain insight into armed actors' dominance in space over time. Third, I turn to the disaggregation of context data, because the available level of geographical and temporal resolution of contextual data provides the accuracy of quantitative analysis linking violent incidences to their structural background. Finally, I test the data on basis of a spatiotemporal regression analysis and provide an outlook of future challenges.

This paper comes with a number of austerities that will be named in the following. First, the conducted analysis does not claim to be profound, nor can the findings be generalized. This second limitation is rooted in the small number of countries that serve as case studies in this analysis, namely Somalia and Sierra Leone. These countries were selected because armed non-state actors play a significant role in the conflict dynamics and data is readily available.[4] Moreover, Somalia – in contrast to Sierra Leone – represents a case with a complex actor constellation that is not overlaid by "strong" state actors. Thus these two countries offer different conflict settings, with each respectively fitting into different methodological approaches. The second restriction to the scope of this paper comes from focusing exclusively on violent non-state actors (VNSA)[5] in sub-state war[6] and the limited range of contextual causal variables used, due to the fact that the presented results are intended only as examples of the basic principles.

The following pages trace and summarize the conceptual background of territorial control and contestation between armed groups. These assumptions are then contrasted with possible methodological approaches to approximately measure territorial control proxied by territorial contest. Finally, these measurements are evaluated with regard to applicability by concentrating on available structural data and the analytical tools at hand. In closing, this work-in-progress paper discusses future challenges.

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3   Territorial control and contestation are investigated, for instance, in Political Geography or by the International Relations (e. g. Huth 1998). Within territorial control lies a tied coupling of statehood and sovereignty (Paasi 2003: 113pp.) it is generally utilized to bind space and power together (Agnew 2000). Its significance is therefore also recognized on the sub-state level (McColl 1969).

4   The analyses are based on the Event Data on Armed Conflict and Security (EDACS) dataset.

5   The term violent non-state actors (VNSA) refers to persons, organizations or armed groups that use violence against the monopoly of the state or other non-state actors in an effort to fulfill their objectives. Their motives can be materialistic, political, ideological, religious, or a mixture of these motivations (Chojnacki 2004). Examples of VNSA include mercenaries, rebels or warlords.

6   For the definition of sub-state war, I follow Chojnacki (2004: 203). It can thus be understood as an organized, persistent form of collective violence on an inner- or sub-state level between state and nonstate actors within or beyond the administrative borders of a nation-state.

2. The Contestation of Territorial Control

"War is not all the terror all the time, all over the place" (Korf et al. 2010: 386). In light of this characteristic of war, the core question of geographically disaggregated conflict research can be framed as follows: What causes the variance of violence – of persistent hotspots of violence on the one hand and the temporal absence of violence on the other? One possible cause of this variance can be the extent of territorial control by violent (non-)state actors (VNSA).[7]

A major aim of armed actors, whether state or non-state, is territorial control.[8] For many VNSAs, successfully gaining territorial control is a crucial step in achieving their aims, as territorial control implies control over resources, infrastructure, locations of political- or socio-geographic importance, et cetera. At the same time, armed actors are heavily dependent on the cooperation and control of the civilian population. Controlling deserted space is only of interest if the area harbors resources or has some other strategic or symbolic "value". Nevertheless, civilians are key to successful warfare and war economy. Control of the population can be used to legitimize leadership claims and gain political power (e. g. Elwert 1997; Kongsgård 2010).

All of these factors also vary depending on the relative/perceived "value" of a territory and thus the level of territoriality put forward by the armed actors. The actor's military capacity, actor constellation and conflict dynamics can raise or lower that relative "value" over time. As a consequence, the level of violence – mutual or one-sided violence against civilians – varies distinctly. Assuming the territory is of some strategic "value", territorial control is a central part of many theoretical assumptions in conflict studies, though these mostly concentrate on the inherent, strategic function of violence.

Nonetheless, conflict dynamics and the strategic "value" of a location are not apparent in all circumstances. In instances of one-sided violence against the civilian population, the strategic "value" of a location is no longer the major explanation for violence at that specific place. In such cases, diverse ethnic/ethno-linguistic affiliations,[9] socio-economic interdependencies and the political objective held by armed groups (or their need for legitimacy) can become more relevant.

Conflict studies have identified a set of at least four distinct (possibly concurrent) strategic drivers of territorial control on a sub-state level: the interaction between armed groups and the civilian population (ranging from control to ethnic cleansing and vengeance), competitive resource allocation (to extract, produce, and mobilize assets), procuring a military advantage

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7   Other relevant predictors – including the effect of terrain, state actors, external constraints, different distribution of target resources et cetera – go beyond the scope of this working paper and have been intentionally left out.

8   Exceptions to this include terrorists and criminal organizations, which do not depend primarily on territorial control (though they may welcome it), such as, for instance, the militant Islamist group Ansar Dine in northern Mali in 2012 (BBC 2013).

9   The transition from civil war violence to ethnic conflict does, however, become blurred at this point (see Kaufman 1996).

(over specific locations and infrastructure), and objectives related to legitimization (regarding secession, concessions, or the symbolic nature of the territory). These functions are interwoven and, to a certain extent, derive from the first driver, as different forms of interaction are the basis for resource allocation, military confrontation within populated areas, and the legitimization of one's own rule.

Explanations for the strategic use of one-sided violence against the civilian population focus on different forms of interaction between armed actors, their opponents and civilians. Despite the link between these forms of interaction, there should be a clear differentiation between (indirect) armed contestation and terrorizing the local population. The aim to control and, if necessary, to punish perceived infractions by the population depends on the VNSA's ability to project power within geographic zones of (temporal) territorial control (Boulding 1962; Buhaug 2010; Kalyvas 2006) or to selectively target population which is assumed to support the adversary (Balcells 2010; Kalyvas 2006). Wood (2010: 604), on the other hand, asserts that armed groups abstain from targeting civilians if they are able to provide security and control territory. Another strategic, interaction function of one-sided violence concentrates on killing civilians as a means of communication between armed groups. Defeat in battle (Ziemke 2008) or the loss of territory can be compensated by raising costs for governments (or local armed actors) or by targeting civilians and thereby undermining the population's support and trust towards the opponent (Hultman 2007: 210).

Controlling civilians can also be a way of extracting resources (Azam/Hoeffler 2002). The "value" of a territory determines whether or not armed actors are willing to invest in its occupation and defense. The defensive strength and further deployment of troops lowers the potential desire of other armed actors to attack the territory. This investment in measures of deterrence could, however, tempt adversaries to attack elsewhere (Powell 2008: 1). The nature of the territory and resources at hand are decisive for the intensity of violence that can be expected (Ross 2004). In contrast to remote, rural areas or areas of low (strategic) "value". small geographic areas of relatively high "value" can lead to an intensified competition between the armed actors fighting to gain the territorial control (Skaperdas 2002: 438). Examples include, for instance, urban agglomerations, which inherently have a high population density and thus a higher GDP per capita. This is associated with local conflict escalation, while the economically-driven goal to increase market shares motivates armed groups to redouble their organizational capacities and to invest in territorial control. This second process is systematically linked to a decrease in one-sided violence and the defeat of potential rivals (Branovic/Chojnacki 2011).[10]

Besides the aforementioned interaction/control function and allocative/exploitive drivers – which can overlap if the purpose of the resource allocation is not limited to raiding and looting – territorial control is of course also important when it comes to gaining military leverage. It is essential that armed actors have a safe haven and a base for preparing planned/ongoing

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10 Additional factors include many more aspects such as the lootability of resources (see e. g. Humphreys 2005) and the specific actor constellation. These should be taken into consideration when evaluating the "value" of a specific location and determining the nature of the inherent conflict dynamics.

operations. Armed actors' perception of the (actual) conflict situation is also significant, as territorial setbacks (Hultman 2007) or the proximity of the armed actors' headquarters (Buhaug 2010) and other strategically important sites (e. g. infrastructure, administrative centers, …) can stir local conflict escalation.

Finally, territorial control is the basis upon which armed actors gain legitimacy and acceptance by third parties; this can be the primary goal in secessionist conflicts, at least initially. All of these strategic functions (and perhaps others not mentioned here) are interlinked with territorial contest and control by armed actors. Factors that (in-)directly affect the armed actors and thus their ability to consolidate their local regime are manifold. The complexity of these driving factors is not discussed in this paper. For more details, see Bakke et al. (2012), Branovic and Chojnacki (2011), Cunningham et al. (2012), Fjelde and Hultman (2013), Fjelde and Nilsson (2012), Kalyvas (2006), Mampilly (2011), Pearlman and Cunningham (2012).

3. Exploring the Contestation of Control

Displaying territorial control is first of all tied to the analyst's ability to display territorial contest, which delimits the outer boundary of controlled areas. This option has recently become a possibility with the proliferation of reliable, spatially and temporally disaggregated event data on violent incidences in the context of intra-state war. There is, however, a distinction between displaying territorial control and delimitative proxy territorial contest. It takes another conceptual leap, and sometimes a lot of imagination, to gain an approximate measure of territorial control, if any.

Some datasets, like the Armed Conflict Location & Event Data Project (ACLED) (Raleigh et al. 2010) or the Social, Political and Economic Event Database (SPEED) Project (Nardulli et al. 2011) also code non-lethal violence or even information concerning the location and timing of rebel base establishment or the capturing of a town. But this additional information comes with a slight caveat, namely the sometimes deteriorated data quality and biases due to the lack of reliable, consistent news coverage of non-lethal events, usually on account of their low newsworthiness (for a discussion see e. g. Barranco/Wisler 1999; Chojnacki et al. 2012b; Eck 2012; Öberg/Sollenberg 2011).

The Event Data on Armed Conflict and Security (EDACS) coding criterion controls for many inconsistencies and sources of bias, which can lead to fake trends and propagating errors (see Chojnacki et al. 2012b) as does the UCDP Georeferencing and Event Dataset (UCDP-GED) (Melander/Sundberg 2011). This paper uses EDACS data, as the small number of case countries is irrelevant. Both the data quality and consistency of the EDACS dataset and its country sample are well-suited to testing the methodological approaches outlined in this paper.

EDACS is comprised of seven countries (among them Burundi, the Democratic Republic of the Congo, Liberia, the Republic of Congo, Rwanda, Sierra Leone and Somalia) from 1990 to 2010. Two countries in the EDACS sample (namely Somalia and Sierra Leone) are particularly

pertinent here for several reasons: First, violence is persistently carried out between multiple factions. Second – and this is especially true for Somalia – the governmental forces do not preponderate the conflict dynamics. Their impact on local conflict dynamics is comparatively marginal relative to the non-state contest. In other countries, regional patterns tend to be superimposed by the state, which often serves as point of reference for competing armed actors. EDACS differentiates between different types of violence, ranging from mutual violence to several kinds of one-sided violence. An EDACS event is defined as a "violent incident at a specific location and a specific time with at least one fatality resulting from the direct use of armed force" (Chojnacki et al. 2012a: 3).[11] The focus is on the reliability and accuracy of the coded event data, which is why every violent event is coded by two different coders. The coded information is based on reliable international news sources such as BBC Monitoring, the New York Times and others. The following section briefly describes several approaches that might help with the task of identifying territorial control, as soon as they are evaluated and automated.

First, armed conflict can be thought of as space-time-clusters. In addition, dominance by one or several armed actors within these clusters can be regarded as a form of temporary control. The sequential succession of the dyadic violent incidences between two armed actors can be used to identify the dominant actors. These show which actor was attacked by assorted opponents and was therefore most likely present in that cluster in the time window between the events.[12] The left side of Figure 2 shows fuzzy spatial clusters[13] of violent events; the right panel shows violent events that belong to the same temporal clusters. Combined, these events can be grouped as spatial-temporal clusters. This cluster approach can be particularly helpful in detecting diffusional processes and identifying regions that are notably of high (strategic) value (see e. g. Buhaug/Gleditsch 2008; O'Loughlin et al. 2010; Schutte/Weidmann 2011).

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11 The EDACS "dataset contains detailed information on 1) dates, intensity and type of military action, 2) actors and targets and 3) the geographic location" of violent incidences (Chojnacki et al. 2012a: 3). For further details on the EDACS coding process, see Chojnacki et al. (2012b) and the project website www.conflict-data.org.

12 Alternatives to this stepwise clustering approach include, for instance, scan statistics (Kulldorff/ Information Management Services Inc. 2009) or spatiotemporal hotspots in ArcGIS 10.X (ESRI 2011), though results are rather meager due to the fact that space-time cluster radiuses are heavily skewed by geographic outliers and cluster construction cannot be easily automated, especially with the help of SaTScan.

13 Clustering is generally based on membership to a specific group of entities with similar attributes, in this case event coordinates and event dates. The closeness of events in time and space is assumed to be random. This is called complete spatiotemporal randomness (CSTR). Deviations from this random distribution indicate clustering. The interpretation that can be drawn from this "closeness" is that events that are closer in time or space have more in common than events that are further away from each other (Tobler 1970), and can therefore be grouped. C-means fuzzy clustering (Bezdek 1981), the method used here, is an unsupervised divisive clustering method. Once the analyst chooses the number of clusters, an algorithm determines the most likely cluster centers and evaluates the distance of each object to each center. It is an extension of K-means clustering (MacQueen 1967). "Fuzzy" refers to the fact that it does not assign events to a definite group, but uses weights of relative membership for each event.
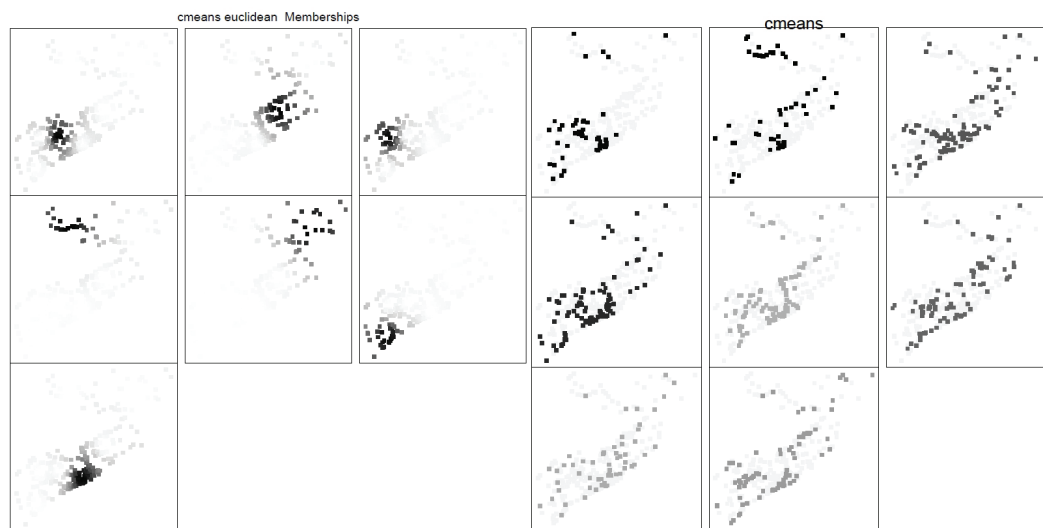
Figure 2: Spatial (left) and temporal (right) clusters in Somalia 1990-2009 (based on EDACS event data).

Figure 3 shows two options for visualizing territoriality. On the left, you see the operating range of the major armed actors in central Somalia in the years 2008 to 2009. The operating range is based on the first, standard deviation of the geographic range where violent events with one of the major armed actors take place. It represents an equivalent to the gravitational field of actor-specific actions within the time window under study. The right map shows dyadic conflict polygons for an analog space-time window. They are similar to the UCDP conflict sites (Croicu/ Sundberg 2012).[14]
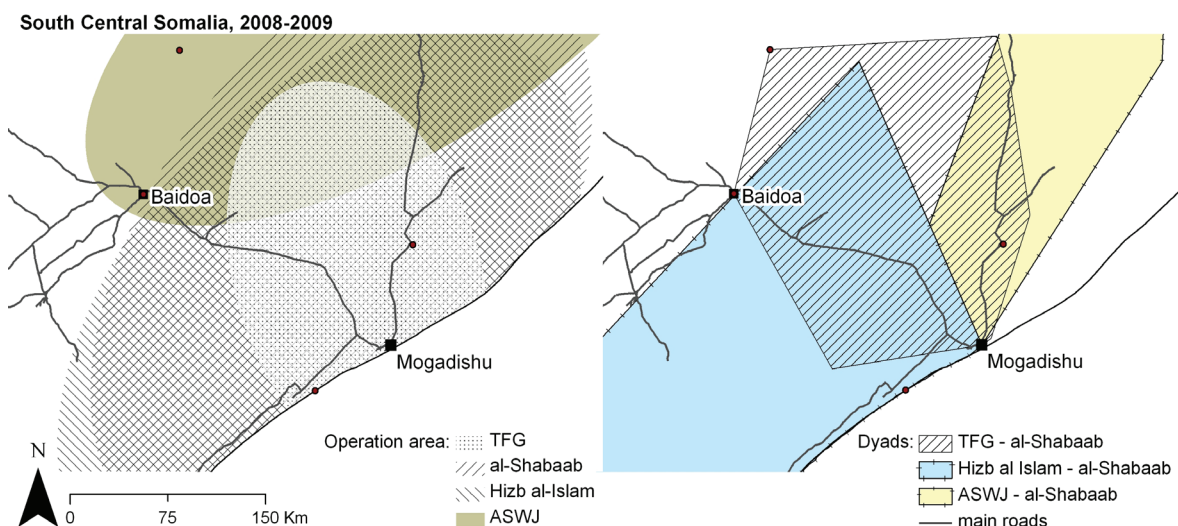
Figure 3: Operational range and dyadic conflict setting of major armed actors in south central Somalia 2008-2009 (based on EDACS event data).[15]

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14 The UCDP conflict sites (Croicu/Sundberg 2012) also differentiate geographic areas, which are formed on basis of dyadic violence between armed actors.

15 In both maps, it becomes obvious that at that time, al-Shabaab militias dominated the lower Shebelle region and the area around Mogadishu. Shortly after this time frame, they allied with Hizb al-Islam, whose operational range matches that of al-Shabaab.

Both visualizations show which areas are highly contested. In the map on the left, the overlapping of operational ranges gives us a hint of who contested who. The same is true for the overlapping of the conflict polygons in the map on the right. They also show which actor was dominant and persistently active in a region and how the frontlines between opponents change over time. These maps allow us to draw conclusions about the actors' military capacity and mobility (e. g. Boulding 1962; Buhaug 2010; Buhaug/Gates 2002; Gent 2011; O'Loughlin et al. 2010). Yet these two approaches only allow us to measure territorial contestation. They do not provide information about territorial control as pacification or alliance building between formerly fighting actors, or the withdrawal of one side for various reasons. Furthermore, this approach is only applicable in complex actor constellations with more than two actors.

In complex actor constellations, statements about actor specific presence can become blurred or even indistinguishable depending on the bustle of the course of the conflict. In dyadic or less complex actor constellations, it is easier to draw conclusions about the direction of operations, and a more precise attribution of actions by actors is easier to come by. In light of this, we turn to a better-suited sample, the less complex case of Sierra Leone, where it was primarily the Revolutionary United Front (RUF) fighting the government.

The third solution presented here provides a more actor-specific spatiotemporal visualization of contestation. It is based on creating cone-sections that mirror the spatiotemporal trending of dyads. The cone-sections can help identify the small but distinct spatial sections, which – provided the geocoding of the event data is accurate – are presumably under control by a specific armed actor shortly before the event takes place. This distinguishes it from the type of information provided by UCDP conflict sites, which only show multiple overlapping areas of dyadic contest (cf. right map in Fig. 3).
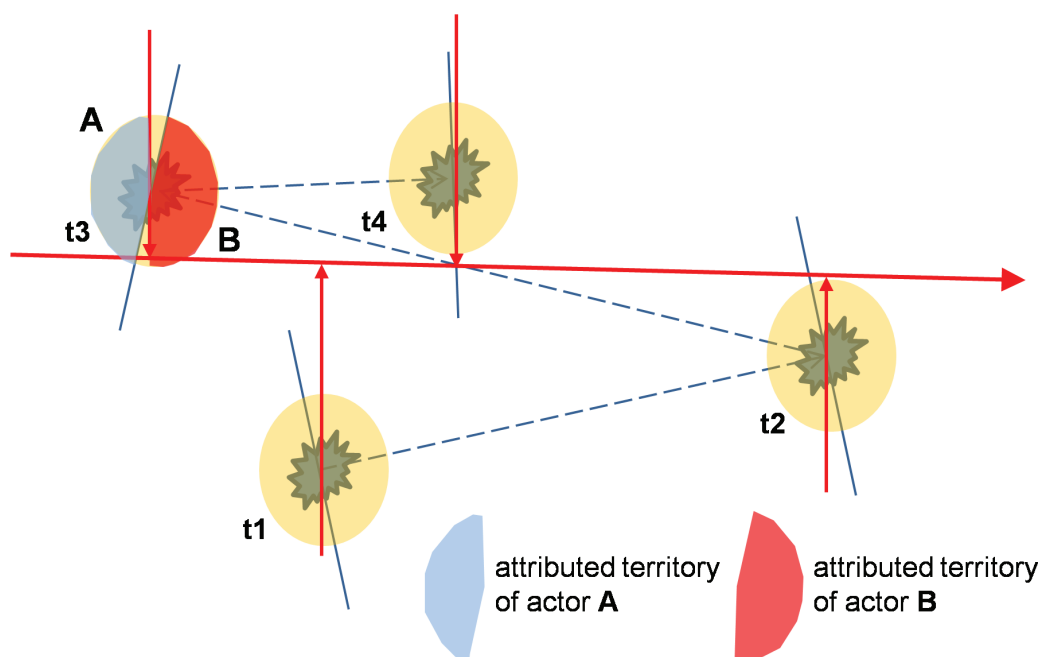

Figure 4: Illustration of the "cone-cutting-technique".

Figure 4 illustrates how the cones are generated. The "cone-cutting technique" builds on buffers[16] placed around dyadic violent events that are attributed to specific dyads between armed actors. These events are labeled t1 to t4, numbered according to their chronological order. The buffers are split using stationary lines that are drawn perpendicular to a trend line (central arrow) of the specific dyad and split again on basis of the connected way the dyad successively takes through space (dashed lines).[17] Using this method, sections of the cones can be attributed for the time-window between two events to a certain armed actor. One-sided violent events committed by one of the actors within the range of the buffers can help adjust its radius and check for inconsistencies.[18]
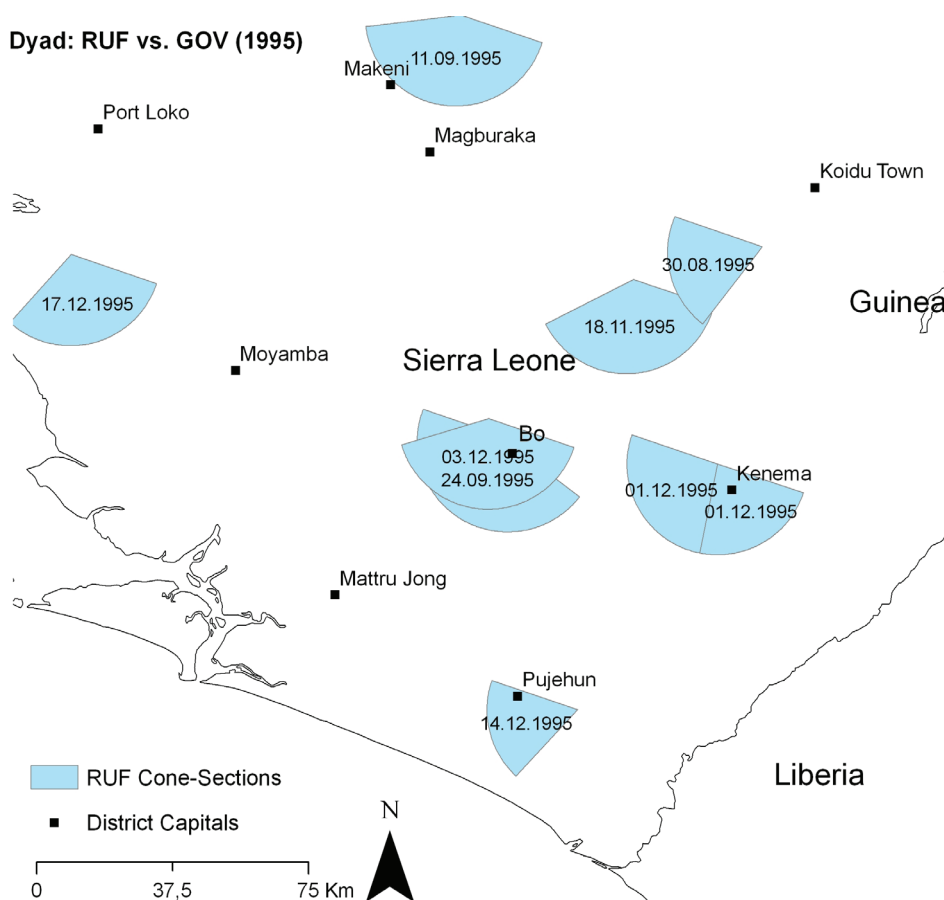

Figure 5: Cones of dyadic trending in the eastern part of Sierra Leone exemplified for the dyad: Revolutionary United Front (RUF) versus the government of Sierra Leone in 1995 (based on EDACS event data).

16 The size of the buffers is based primarily on the geo-precision of the EDACS data, which in many cases is around 25 km, due to the accuracy of the gazetteer data (NGA 2011) employed in the process of geocoding (see Chojnacki et al. 2012a). Another argument for adjusting the buffer can be made based upon e. g. the military capacity and local transport infrastructure, allowing for multi-local operations and the time necessary to deploy troops.

17 The plane angle of the cone-sections is constructed on the one hand via the chronological movement of the dyad in space, and on the other hand narrowed down by the overall trending of the armed contest.

18 EDACS data codes the "active" side in an event, provided respective information is available and reliable. But this is not always the case, which is why this additional information can only be used as an accessory.

Figure 5 shows the resulting cone sections, with the example here illustrating the dyad Revolutionary United Front (RUF) versus the government of Sierra Leone. Combined with additional data on one-sided violence, one sees that the RUF is committing mostly one-sided violence near and within the areas attributed to them. It becomes obvious how the dyad is moving southwards over time, concentrating around the district capital of Bo. This trend coincides with and is followed by crucial developments in the Sierra Leone Civil War. South African mercenaries and Executive Outcomes (EO) entered the war after the RUF seized control over resource-rich areas in the south west of Sierra Leone in the beginning of 1995 (Hsiao et al. 2002). Combined forces of mercenaries, Kamajor militia and government forces drove back the RUF, recapturing RUF strongholds such as Bo. This ultimately led to the defeat of the RUF and the signing of the Abidjan Peace Accord in 1996 (Korniotis 2007).

The construction of dyadic trending cones has yet to be automated and thus remains a time and labor-intensive endeavor. Though the level of empirically-saturated research findings has been rather meager to date, there are a number of imaginable applications for these actor specific-insights on movement-based presence. Again, reflections concerning the impact of the diffusion of violence and the military capacity (see above) seem to be the most prominent link to existing research here. Beyond that, qualitative reports on armed actors can be empirically boosted by this information. Although disaggregated conflict event data is helpful in showing the use of deadly force and allows us to measure contest, it sheds little light on actual territorial control. In order to gain further insight, we would need additional information that would allow us to classify these measurements.

4. Limits of Disaggregation

Approximate information about dyadic local onset, i.e. the where and when of actors contesting each other's territorial control, is of limited use. Additional context information is needed to better understand these exploratory findings (e. g. data on the civilian population, the location of lootable resources, or the economic prosperity of an area). This would, for example, allow us to identify prosperous areas with no fighting and use this as a proxy for pacification in areas presumably controlled by one party. Yet the available context data is rather rough or missing altogether, which brings us to our next step: looking at possible ways to gain spatiotemporally disaggregated context data.

The problem is twofold: first, creating sufficient data for analysis, and second integrating the data without introducing measurement errors or biases. Before we come to the data-generating methods (especially as a way of coping with missing data) we will discuss caveats and problems associated with data aggregation in general. The question of whether or not the variance of the phenomena under study is linked to the data-generating process or the level of aggregation is not entirely new. Although ecology and geography have dealt with this particular problem of

a so-called ecological fallacy[19] for decades (Lennon 2000), no best practice solutions have been found – only advice as to what not to do.

One basic problem is how spatiotemporal data in general can be joined and aggregated[20] without changing the resolution and attributes of the phenomena. Taking the monthly average of the fatality count in order to proxy the conflict intensity will obscure the actual intensity of war on a daily basis. A hundred casualties on one day equal 25 casualties on four days, which no longer reflects the reality. In a different spatial domain (e. g. when transferring point event data into raster-cells or administrative units) the inherent geo-information can be drastically reduced and as a consequence topological relations become distorted or even lost altogether. Gotway and Young note:

> "changing the support of a variable […] creates a new variable [which] is related to the original, but has different statistical and spatial properties" and "how the spatial variation in one variable associated with a given support relates to that of the other variable with a different support is the change of support problem" (Gotway/Young 2002: 634).

This unintended change to the basis of the analysis is too often done without acknowledging the consequences and propagating biases, which can make meaningful interpretation of results virtually impossible. Common "solutions" to this problem include choosing the smallest common factor or (simply) pooling data without taking the differences in the level of support into account.

Event data is especially susceptible to a large range of biases. These include description and selection bias (Earl et al. 2004: 67), plus problems of event localization, temporal inaccuracy, and actor differentiation (see Chojnacki et al. 2012b). One example is urban bias (Kalyvas 2004) due to the higher precision of city-level data, but also the well-known, difficult-to-avoid problem of the higher likelihood of international media coverage of events near urban agglomerations. Urban bias can be deceptive, leading to the erroneous assumption that violence is concentrated in cities while remote, peripheral areas are completely calm and relatively unaffected by war.

Using the approximate measures of territorial contestation described above raises the question as to whether these are valid and valuable units of analysis. There are two major problems here: the first is endogeneity – when using these data-driven units of analysis. A second problem that arises has to do with the arbitrariness of the unit of analysis, leading to incongruity with most

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19 This is mainly caused by misleading impressions based on spatially homogenous data. See also the Modifiable Areal Unit Problem (MAUP) (Lennon 2000; Wu/Hobbs 2007: 117pp.). The core of this scaling problem is the discrepancy between level of analysis and actual real-world occurrence (Madelin et al. 2009: 647).

20 Every type of aggregation is always also a transformation. In most cases, this is a smoothing filtering function (Madelin et al. 2009: 647, 654).

kinds of available context data. These measures prove to be helpful, however, for exploratory spatial data analysis (ESDA).[21]

After covering problems of data aggregation and the issue of choosing the "right" unit of analysis, we turn to contextual data and its level of spatiotemporal coverage. Although highly disaggregated (sometimes biased) conflict event data is readily available, context data is not. Despite the enhanced availability of high-resolution remote sensing data in recent years, there is still one major obstacle when it comes to the contextualization of conflict event data. There is no data available due to differing data resolution and missing retrospective data (such as data from the 1990s, for example).

The discrepancy between various levels of spatial and temporal support is even more pronounced when comparing data of social and political phenomena, which are normally based on macro-data (e. g. data on statehood, governance indicators, and so forth) with geographic variables on spatial entities at the micro-level (e. g. altitude, precipitation, or population density), as the latter has a much higher resolution.[22]

Spatial interpolation and temporal imputation can allow us to overcome this problem, facilitating a more fine-grained spatiotemporal resolution for analysis based on the smallest common factor. In the following, I will illustrate how to gain the necessary spatiotemporal support. The spatial interpolation can be performed using Geographic Information Systems such as ArcGIS (ESRI 2011) or statistical programming languages as R (R Development Core Team 2011). While some degree of aggregation seems unavoidable, I am using raster cells per month as unit of analysis. In this example, the raster cells are sized 25 square kilometers.

For temporal imputation, I use the R-package AMELIA II (Honaker et al. 2011). Below you will find an example of temporally (Fig. 6) and spatially (Fig. 7) interpolated GDP/capita data. GDP/capita data reflects the economic development on a state or regional level, and thus can be used as a proxy for the absence of one-sided and mutual violence – a necessary condition for economic growth.

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21 Another option for retrieving a maximum amount of information consists in merging the event vector points with random points. The downside of this approach is that it comes with an enormous increase in data points. This is particularly true in a spatiotemporal analytical framework, where the increase amplifies the need for computing capacity and boosts an already surmounting zero-excess, skewing the statistical distribution and contradicting statistical assumptions.

22 As mentioned, besides this variation of data resolution between different types of contextual datasets, there is an inherent variation in the accuracy of information on violent incidents. The reason for this is that some events can only be localized in an approximate way, as they last several days or take place throughout an entire region (Chojnacki et al. 2012b).
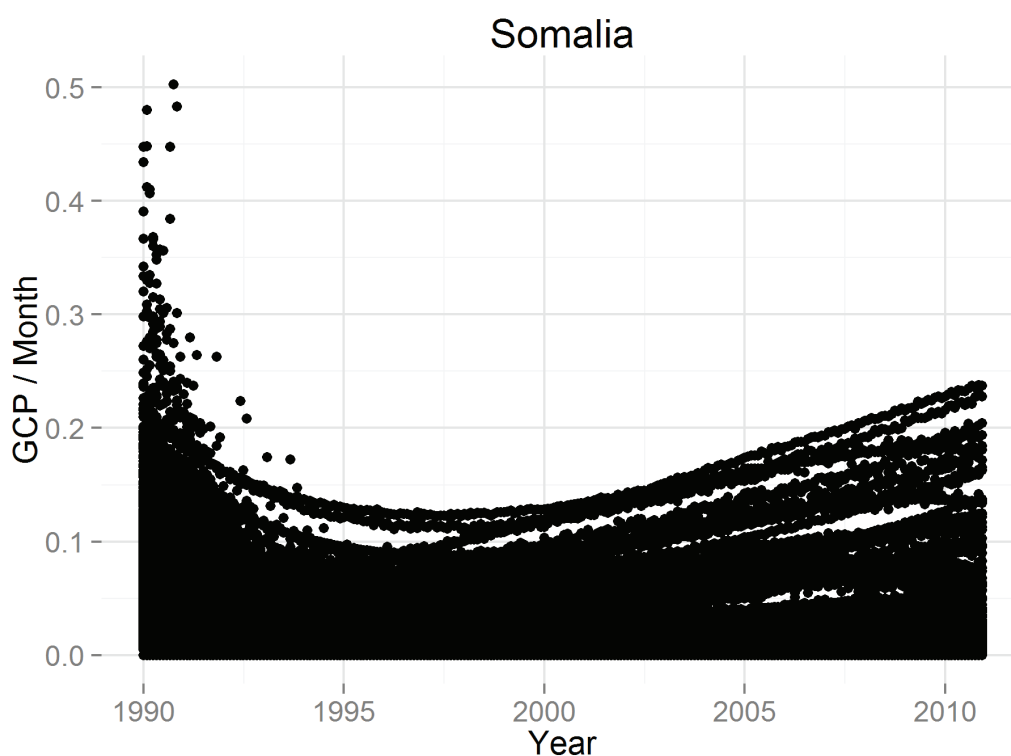
Figure 6: Interpolated times series of G-Econ data for Somalia (1990-2010).

Like the aforementioned demographic data, the majority of (socio-)economic data is spatially invariant or aggregated temporally. Thus the Gross Cell Product (GCP) taken from the G-Econ dataset[23] (Nordhaus 2008) is an exception in that it is spatiotemporally disaggregated and can be used for the integration of economic factors in likewise disaggregated analysis.[24] G-Econ is based on estimates of economic performance in billion U.S. dollars for raster cells, each covering one time one decimal degree for the years 1990, 1995 and 2000, and for many countries the year 2005 as well.[25]

> The value of the GCP equals the "gross value added in a specific geographical region; gross value added is defined as total production of market goods and services less purchases from other businesses [...] GCP also equals the incomes of factors of production located within the region" (Nordhaus et al. 2006: 6).

Temporal gaps aside, the geographic resolution of G-Econ does not correspond to the raster utilized in this paper. In order to cope with this lack of spatial precision, the centroids have

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23 Beyond that, G-Econ comprises also geographic, socio-economic and demographic variables (http:// gecon.yale.edu/). Substantial inconsistencies are indexed in G-Econ via a quality-variable (Nordhaus et al. 2006).

24 An alternative to G-Econ is Night Light Emission Data (NGDC 2011). But on close inspection – especially in the DR Congo – the data contains only a fraction of the human settlements in the region (possibly due to the forest canopy) and is therefore only of supplemental use.

25 Missing values for the years 2005 and 2010 are linearly extrapolated by the difference between the values of the periods of 1995-2000 and 2000-2005 (e. g.: (GCP2000 - GCP1995) + GCP2000). The extrapolation has been conducted in consistency with plausibility checks on the results.

been interpolated with the help of Empirical Bayesian kriging.[26] As a result, the data is spatially joined with the raster used here and the mean value calculated for each raster cell respectively (Fig. 7).
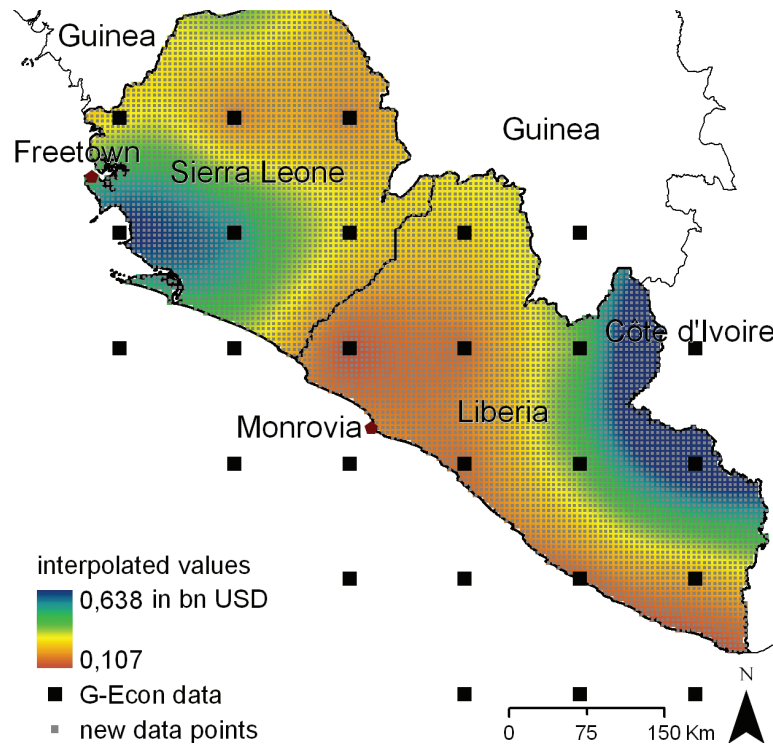

Figure 7: Spatially interpolated G-Econ data for Sierra Leone and Liberia for 2005.

Another example of where this technique can be implemented is population density data. Besides a multitude of other variables, population density is often used as a variable for contextualizing violent events in conflict science, as it provides information on the population at risk in an area.[27] For the population data, I have done the same as described above for the G-Econ data. Yet more work has to be done to introduce a more realistic representation of the spatial distribution of the phenomena, and population density is a good example for that. Population density has to be recalculated not on basis of the area of the raster cells, but on the perimeter of settlements (Linard et al. 2012) and roads (CIESIN et al. 2012). This would disregard empty space and calculate only population density for actual inhabited space. After generating and appropriately adjusting spatially and temporally disaggregated context data, the problem

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26 Empirical Bayesian kriging (EBK) differs from other kriging methods in that it does not use "weighted least squares". Parameterization is carried out automatically with "restricted maximum likelihood" (REML) by splitting the data points in neighbor groups and subsequently simulating the values. The error of estimation of the semivariogram is included in the calculation, thus avoiding an underestimation of the standard errors (ESRI 2011). The EBK calculation is done using ArcGIS 10.1, including eight neighboring sectors and performing a lognormal transformation, 100 iterations for optimization and checking for outliers resulting in small standard errors in cross-validation. The G-Econ interpolation has been done for a 5 km- or 0,045° decimal degree raster.

27 The gridded population of the world, version 3 (GPWv3) from the Center for the International Earth Science Information Network (CIESIN) at Columbia University provides a five-year increment, worldwide coverage and up to five-times-five kilometer geographic resolution (CIESIN 2011). The data gathering and estimation techniques used (and consequently the quality of data provided by public authorities or international organizations) can be affected immensely in civil war areas. Strong fluctuations of the population density due to refugee movement and temporary, spontaneous campsites can distort official numbers even more.

remains: data concerning violent incidences cannot be projected in a comparable way. The following example of an explanative spatiotemporal analysis will illustrate this problem.

5. Explanative Spatiotemporal Analysis

The analysis of spatiotemporally disaggregated conflict event data – even when combined with disaggregated context data – comes with yet another problem, namely an (unavoidable) zero-excess within the count data of violent incidences. Because of this, spatial Tobit models (Wilhelm/Godinho de Matos 2013) or models following a negative binomial distribution (e. g. Croissant 2010) are an appropriate choice. However, in a spatiotemporal setup, this circumstance requires procedures that have yet to be fully incorporated into statistical software packages and thus are not addressed in this paper.[28]

The spatiotemporal approach also requires the specification of a sensibly-chosen spatial neighborhood and time frame that is assumed to have an effect on the analyzed observations. One must define what is regarded as geographic proximity or neighborhood (see Getis 2009) and what is considered a short or long-term effect (see Shellman 2004). For the sake of simplicity, this paper uses binary contiguity weight matrices. But again, this choice must be considered carefully and can distinctly alter results and their interpretive range, which resembles the impact of the level of aggregation (cf. section 4).

The following shows a regression analysis testing whether one-sided violence is influenced by the number of violent non-state actors (NOVNSA); covaries with the fighting intensity, proxied by the number of mutual fighting events (FIGHT) and military deaths divided by the number of events (ESCALFIG). Interpolated data is used as contextual background, namely the average Gross Cell Product (AVG_GCP) and the average population density (POP_DENS). The dependent variable in this setup is one-sided violence against the civilian population (ONE).[29] The regression is performed on basis of a spatial fixed and a spatial random effects lag model (Millo/Piras 2012) as exemplified in the case of Somalia.[30] The variables are lagged to avoid simultaneous causality; the square root of the context variables is taken (due to their skew distribution) and outliers have been removed.

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28 For instance, Bayesian MCMC methods could be used for that (Hadfield 2010).

29 Endogeneity should not be a problem here, because (a) inter-group violence (incidents) is used to establish violent group presence and activity in a given spatiotemporal context; this is used as independent variable and (b) the dependent variable is a special category of violent incidents, i. e. violence by armed groups against the (unarmed) population and this is likely different from (a). Using mutual violence in one region as dependent variable could, however, cause endogeneity, given the linkage between an increase in the number of armed actors in one region and the probability of their contestation.

30 To analyze the linkage between conflict intensity, contest and context, hypothesis can be tested as the following: the number of armed actors is expected to decrease in short-term, as one-sided violence against the civilian population is used to consolidate territorial control and regional dominance. One-sided violence is expected to decrease in the long run, however, along with the number of actors. The latter assumption reflects the growing organizational capacities of armed actors, but also their need for more productive resource allocation and support by the civilians under control (cf. section 2).

Table 1: Results of spatial panel fixed and random effects lag models (Millo/Piras 2012).

Variable	SPFE-Lag	SPRE-Lag
(INTERCEPT)		0.002** (-0.001)
NOVNSA_LAG	-0.027*** (-0.002)	-0.042*** (-0.002)
FIGHT_LAG	0.062*** (-0.001)	0.105*** -0.001
ESCALFIG_LAG	0.005*** (-0.001)	0.004*** (-0.001)
SQRT(POP_DENS)	-0.03* (-0.013)	-0.001 (-0.001)
SQRT(AVG_GCP)	-0.019** (-0.007)	0.017** (-0.006)
Lambda	0.123*** (-0.022)	0.0948*** (0.022)
Log-Likelihood	-	41982.72
N	54014	54014

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05; n, the number of individuals, T, the number of time observations, N, the total number of observations (by month: n = 226, T = 239, N = 54014).

As results show, the number of armed actors and the conflict intensity measurements are highly significant; the average GCP is still important, while the population density has only a marginal significant impact in the fixed effects model (see Tab. 1). A higher number of VNSAs reduces the probability of one-sided violence in Somalia, while more intense fighting increases the victimization risk for civilians. The coefficient of lambda – representing the spatially lagged dependent variable – indicates a prominent level of autocorrelation within the dependent variable. The zero-excess in the dependent count variable could, however, induce a substantial downward bias on the standard errors and distort results. Even if this is a suboptimal solution – due to the immanent degree of autocorrelation – a negative binomial model could be calculated comparatively (e. g. Croissant 2010).

While this exemplary spatiotemporal regression analysis shows that violence against the civilian population depends overall on the number of armed non-state actors, it would be guesswork to infer the inherent logic/functionality of violence and the effect of territorial control on basis of these results. Gaining a profound answer as to whether the variance of violence is rooted in the data used or if it is in fact conflict inherent needs further investigation, and the non-normal statistical distribution of event data needs to be accounted for.

6. Concluding Remarks

The variance of violence can partially be a function of the extent of control, the effect of which is tested here via the proxy of the level of contestation between armed actors. Nevertheless, it would be premature to say (on basis of this working paper) that the manifold problems surrounding the measurement of armed actors' territorial control by making spatiotemporal actor presence visible are close to being solved. All the same, information on the actor specific level of military capacity, the diffusion of conflict, the (strategic) "value" of a location, or a distinct actor constellation can open up the black box of territoriality of armed actors on a sub-state level (at least slightly).

The possible pathways to measure and attribute territorial control via the proxy of territorial contestation presented here go to some extent beyond what has been done so far quantitatively and also beyond the anecdotal evidence of field experts or other qualitative sources. The produced statistics can, however, be complementary to the existing procedures used to delimit and evaluate local/regional VNSAs presence. If contextualized, however, information regarding the probability of armed actors being present at some place within a distinct period of time, between two events or within a temporal cluster, could prove very valuable. One major problem that all approaches share is the lack of contextual background needed to draw sensible conclusions.

This can be the first of many steps that should be taken – but "if our theories are disaggregated, then our empirical analyses and research designs should reflect this" (Cederman/Gleditsch 2009: 490). Spatial and temporal aggregation (Shellman 2004) or disaggregation (Cederman/Gleditsch 2009: 492; Rød et al. 2010) must match our research questions, the phenomena we are looking at and the data at hand. Choosing "downscaling" and the highest possible degree of disaggregation is not always sufficient, nor is it always appropriate. What's more, this data-driven attempt to retrieve every bit of information can obscure underlying processes for which a higher level of aggregation may be more adequate. (Dis-)aggregation is an option, but it should be used in a sensible way and relate to the overall research question.

A combined perspective on territorial contestation and the disaggregation of context data would benefit the analysis of patterns of violence via delimiting contested areas and increasing the level of contextual detail. Though it remains difficult to tell whether the stage of approximation will be overcome and robust prediction will be available. There can be little doubt that the optimal solution – one that is not as labor intensive and time consuming as those presented here – has yet to be found.

The profound usage of remote-sensing data for mapping slash-and-burn practices and crop plantations (e. g. ESDIS 2012) – which could tell us whether there are spontaneous campsites of displaced refugees or whether an armed actor gave the signal that it is safe to return because other armed actors no longer pose a threat and the civilians can harvest what they sowed (Lidow 2010) – will be especially useful in the coming years. There have also been advances with regard

to natural language processing and the coding of non-lethal events from a vast array of news outlets (cp. Ickler/Wiesel 2012). The next steps would be near real-time event data gathering (van der Windt/Humphreys 2012) and combination with regard to remote sensing data.

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The Author

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Research Framework

Governance has become a central theme in social science research. The Collaborative Research Center (SFB) 700 Governance in Areas of Limited Statehood investigates governance in areas of limited statehood, i.e. developing countries, failing and failed states, as well as, in historical perspective, different types of colonies. How and under what conditions can governance deliver legitimate authority, security, and welfare, and what problems are likely to emerge? Operating since 2006 and financed by the German Research Foundation (DFG), the Research Center involves the Freie Universität Berlin, the University of Potsdam, the German Institute for International and Security Affairs (SWP), the Social Science Research Center Berlin (WZB) and the German Institute for Global and Area Studies (GIGA).

Partner Organizations

Host University:
Freie Universität Berlin

University of Potsdam

German Institute for International and Security Affairs (SWP)

Berlin Social Science Center (WZB)

German Institute for Global and Area Studies (GIGA)