

## **A Review and Assessment of Spatial Analysis and Conflict: The Geography of War**

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## **Introduction**

Within the fields of political science and international relations, the analysis of civil and international conflict has become markedly more sophisticated in the past two decades. Research emphasis has shifted from the study of international conflicts to the identification of societies that are susceptible to civil war, as these are the most common type of conflicts since the end of the Cold War (Harbom et al. 2008). The theories that animate the study of conflict have emphasized a combination of economic and ethnic-ideological motivations, with additional consideration of political and systemic factors such as alliances, support from external benefactors, and the role of diasporas in supporting rebel movements. Domestic political instability, fluctuating incomes, and conflict in surrounding regions are related to increased civil war risk (see Hegre & Sambanis 2006). However, few studies have presented a coherent and compelling narrative about the persistence and patterns of conflict since 1945 and the conclusions of the most-cited study (Fearon & Laitin 2003) have been challenged by follow-up studies (see Hegre & Sambanis 2006; Hegre & Raleigh 2008). The quantitative literature on understanding the causes and duration of civil war has somewhat stalled.

The reason for the recent limited progress in civil war research, ironically, may be related to conceptual approaches, methods and data in use. A mismatch persists between the broad ambitious theories that purportedly explain conflict proliferation and the data and methods used to model such theories. Most theoretically-oriented studies are oriented to understanding the national correlates of civil wars, not their causes, dynamics, or regional and local contexts. For example, the roles of national outputs (usually measured by GDP), resource dependence, and political institutions all relate to the violence

variability across states rather than to internal dynamics. Locally-oriented approaches continue to be refined (see Kalyvas 2006 and Boone 2003 as examples). Conflict researchers have sought to redress the gap between theory, empirics, and conflict patterns by changing the focus of data collection from “country-years” (conflict measures for a large sample of states over a long annualized time series) to geographically (downscaled) and temporally (daily or weekly) disaggregated data. By matching disaggregated data to appropriate geo-statistical methods to describe and test general theories about conflict on the local level, civil war analyses will benefit from the integration of spatial theories and methods with the study of the political conditions that give rise to conflict.

A critical and related issue is how sub-national geographies can be integrated into civil war studies. Often, in the attempt to “spatialize” the study of war, researchers have included coarse contextual measures (see, for example, Buhaug & Rød 2006). We argue in this chapter that many studies incorporating sub-national indicators have substituted simplified “geometries” for complicated geographies, relying on abstract and vague notions of distance, as well as simple measures such as straight-line distances for measuring the range of conflicts and a loss of strength gradient or crude terrain indices to test arguments about the propensity of an area to foster and sustain a civil struggle. These indices relate to the larger issue of how ‘proxy’ indicators are used in studies of developing countries; but ‘distance’ proxies are particularly egregious. Absolute distance is viewed as a meaningful predictor of government and rebel strengths, public good provision, and political marginalization (see its use in Buhaug & Rød 2006; Buhaug & Gates 2002; Alesina & Spolare, 2003 as examples). In effect, many civil war studies have misconstrued the nature of political geography by ignoring the complicated social,

cultural, economic and political relations that combine to give locales their special character (O'Loughlin 2000). Further, the use of typical statistical models for spatial data frequently violates model assumptions. Exploratory and confirmatory spatial statistical analyses are needed to identify and correct for the biases present in spatially dependent (values in one geographic unit influenced by values in surrounding units) or spatially heterogeneous data (systemic distributions of key measures along regional or other geographic divisions). Examples of predictive models that take these geographic considerations into account are few in the civil war literature, but represent a path forward as civil war studies turn to localized measures of disaggregated conflict.

Many conflict studies that consider spatial phenomena ignore the particularities of the data and the context of spatial relationships. Although recent advances in spatial analysis and spatial econometrics remain relatively unknown within the conflict community, these methods offer opportunities for significant empirical and theoretical advancement. The questions that can be addressed with spatial frameworks, data and tests range from simple to complex. We cannot address all these methods here, but our call for a reintegration of contextual analysis into civil war studies builds on the few existing works, illustrates some of the key methodologies, and suggests possibilities for further extension.

We begin with a review of early works that added a spatial dimension to international conflict study and consider the contemporaneous development of spatial statistical analysis after the publication of Cliff and Ord's key work on *Spatial Autocorrelation* in 1973. In the post-Cold War period, renewed attention to civil conflicts demanded an appraisal of developing country characteristics and patterns of

'greed' motivated wars (Collier & Hoeffler 2004a). Research on internal conflicts created a need for new data that are geographically and temporally disaggregated in character, and the application of new geo-statistical methodologies that are paired with geocoded data storage and retrieval and graphical displays in Geographic Information Systems (GIS).

After appraising how spatial analysis has contributed to both qualitative and quantitative research, we turn to its components, and apply new tools, which are particularly helpful in understanding conflict patterns. We illustrate this through a brief exploration of the conflicts in the Democratic Republic of Congo (DR Congo, formerly Zaire). Finally, we summarize the unique contributions that a spatial perspective can bring to the study of conflict and make some suggestions for further spatial analyses of war.

### **Conflict Dynamics and Spatial Analysis**

Studies of civil war onset and to a lesser extent, civil war duration, now account for most of the recent literature on conflict. Broadly, there are three main avenues of spatial inquiry (developing chronologically over the past 40 years) within quantitative conflict studies. The first analyzed international war patterns and diffusion; the second concentrated on civil war patterns, diffusion and correlates; and the third examined sub-national/local variations in civil war correlates. While most spatial analytical work to date has been descriptive in nature, such as the identification of clusters of conflict (equivalent to hot spot analysis in crime and disease patterns), inferential models are hindered by the lack of information for predictors at a level of disaggregation (e.g. for grids of 100 km) that match conflict data.

For conflict studies that consider geographic elements, the scale of the spatial variation of incidents must be considered. Spatial phenomena generally exhibit characteristics of both first order and second order spatial effects; the null expectation, by contrast, is that phenomena exhibit neither systematic variation across space or dependence between neighboring areas (random distribution) (Bailey & Gatrell 1995). *Spatial heterogeneity* is a first order spatial effect characteristic of processes that vary systematically over large areas or regions. For a global-scale study, for example, spatial heterogeneity might be visible in higher rates of conflict in the sub-Saharan Africa region, while a more localized study may find an overall trend of more violence near roads or checkpoints. In contrast, *spatial dependence* refers to the local-scale effects or clustering of a process. The presence of such second order effects mean that a value in one area depends at least partially on the values of the surrounding areas. Spatial dependence is often measured using spatial autocorrelation statistics. These neighborhood effects are present at multiple scales of analysis (e.g. country, district, and town) where surroundings tend to have similar levels of violence or peace. Spatial phenomena are said to be stationary if the dependence and heterogeneity are constant over the study area. In practice, it can be difficult to distinguish between them. Spatial dependence and heterogeneity are strongly present in data on wars, with immediate neighbors exerting the greatest influence on war risk, while second and higher order neighbors have a contributory, but lesser, impact on the likelihood of war diffusion.

#### *International War Patterns and Diffusion*

Early work in the spatial analysis of conflict focused on how neighboring states influence the propensity for the international spread of disputes. Critically important to the merger

of international relations theory and spatial analysis was the rediscovered importance of contiguous effects in the diffusion of conflict, elaborated in Most and Starr's (1980) concept of "opportunity and willingness". In their formulation, a country's borders offer opportunities for conflict (more borders, more conflict possibilities); the sense of vulnerability from multiple borders can lead to military preparations and a willingness to fight. They identified four processes in international conflict; a) positive reinforcement where war leads to more war involvement in the same state, b) negative reinforcement in which war reduces further war involvement in the same state, c) positive diffusion in which war generates conflict across borders with surrounding states, and d) negative diffusion in which war reduces conflict across borders with surrounding states.

Most and Starr's diffusion analyses relied on simplified contiguity scores for states (the so-called black-white or chessboard measure in spatial autocorrelation analysis). Their analyses of global and African wars (Starr & Most 1983) updated Sir Lewis Richardson's (1960) approach that examined the tendency of conflicts to involve neighbors across "warring borders" and continued his approach of comparing war occurrences and border counts (Richardson found a correlation of +0.77 between these two variables). Starr and Most, however, recognized the complex nature of borders by examining both colonial and non-colonial types for their studies of conflict in the Cold War years.

Building on the Starr-Most approach and using the spatial analysis tools developed in the 1970s and 1980s, O'Loughlin (1986) and O'Loughlin and Anselin (1991) identified domestic and neighborhood contexts as a strong factor in African war patterns. Using correlation matrices of lagged neighboring war involvement and a typical

suite of controls (population, institutional characteristics, GDP, etc), spatial dependence was found to be more important than domestic characteristics in affecting war risk for both international and civil conflicts. In work that extended the original Starr-Most “opportunity-willingness” model, Siverson and Starr (1991) found that war risk is contingent upon both the location of a state in war-prone regions and on individual belligerent neighbors. States with warring neighbors are significantly more likely to enter into international wars. This interaction component to war risk is believed to strongly determine the participants and diffusion patterns of international wars. These kinds of studies quantified the level of heterogeneity present across regions with respect to war risk.

Rosh’s concept of the “security web” emphasizes the importance of regional configurations in developing state security. Security webs are primarily determined by geographical proximity. Rosh found that security in developing states is “uniformly affected by that state’s immediate external environment while the particularities of a state’s geographic region serve to shape the policies differently” (Rosh 1988: 692). In a similar vein, the causes and processes of “regional conflict formations” (identified by multiple interacting conflicts within and across state borders, such as West Africa in the 1990s) could best be determined by investigating the interplay between specific regional conditions with global economic and political forces (Väyrynen 1984).

Earlier works found that heterogeneity and diffusion patterns amongst neighboring states and larger regions had a considerable effect on the likelihood of a state entering an international conflict (Diehl 1991). Intra-regional conflict diffusion is more common than inter-regional conflict spillovers (Bremer 1982); Houweling and Siccama



(1985) concluded that both international conflict outbreak and participation are clustered in time and across countries. In particular regions (i.e. Africa and developing states), this neighboring influence was stronger than the effect of domestic characteristics in determining war risk. Though the theoretical formulation of “opportunity and willingness” depended generally on the notion of diffusion, the IR community was alerted to the parallel developments in the spatial analysis literature by the paper that brought the two traditions together, written by a geographer and a political scientist (Kirby & Ward 1987).

#### *Civil War Patterns and Diffusion*

A second generation of studies on civil war risk and patterns focused on models of how these conditions were affected by factors in neighboring states. The results, to date, have been inconclusive partly due to inconsistent empirical specifications including different data sets, varying definitions of conflict and explanatory variables, use of different spatial weighting schemes and time periods (e.g. post WWII or post Cold War). While a number of researchers dismiss the effect of neighbors in increasing or decreasing civil war risk (Fearon & Laitin 2003), others find strong support for neighboring effects on civil war risk while controlling for the usual explanatory variables including GDP, political regime type, governmental instability and population density (Benson & Kugler 1998; Collier & Hoeffler 2004a; Sambanis 2004; Gleditsch 2007). Gleditsch (2002) concluded that neighboring and regional relationships set the trajectory (peaceful or warring) for individual states. States in high-risk regions experience “double jeopardy”, as their unstable domestic politics result in high civil war risk that neighbors with high domestic risk compound. Hence, within developing states, domestic politics are as much

influenced by external relationships as by internal political, economic and social dynamics.

There are considerable indirect neighboring influences on civil war risk. As Sambanis (2001) observed, stable democratic institutions are more important in ethnically-divided societies than in those in which political opportunities and access to power are not framed in ethnic terms. Sambanis (2001:268) further posited that “bad neighborhoods” – those defined by an absence of democracy – will have weak political institutions that “can only exacerbate political and economic grievances in other countries as a result of the uncontrolled domestic ethnic antagonisms.” He concludes that the level of democracy in a region, as well as internal political structures, influences peace outcomes, thus supporting Gleditsch’s (2002) conclusions concerning the equal importance of external characteristics in civil war risk assessment. Higher levels of domestic and regional democratization are associated with peaceful prospects, but instability across neighboring democracies is associated with higher levels of conflict such that it may counteract the benefits of democratization (Gleditsch 2002). Additionally, Gleditsch (2002: 109) found that “democratizing states located among relatively democratic neighbors have significantly lower risks of experiencing civil war than do countries located in a zone of more autocratic and less constrained polities.”

Recent evidence suggests that economic and trade characteristics of low income developing states generate higher conflict risks. Murdoch and Sandler (2002) concluded that a neighboring civil war has adverse effects on economic performance in states that is unrelated to migration, human capital or investment. Instead, damage to economic growth is tied to country-specific effects. Civil wars decrease neighboring economic growth

rates by approximately 0.9% and states only return to pre-war growth rates a decade after the cessation of a conflict (Collier & Hoeffler 2004b). Adverse spillover economic effects are of critical importance since fluctuating GDP is the strongest factor affecting a poor, unstable state's descent into civil war (Hegre & Sambanis 2006).

It remains unclear which regional component matters most in the onset and proliferation of civil war. Enterline (1998) noted that the patterns of conflict that appear to evolve across political regions is less tied to the particular institutional type of regime (democratic, autocratic, or anocratic) but instead, is affected by the extent to which regimes are stable and well-established. Although the risk of civil war clusters within regions, it is unclear whether high neighboring risk is related to unstable and poorly-controlled border regions (Salehyan & Gleditsch 2006), rivalry across neighboring states, or to similar socio-economic conditions (Murdoch & Sandler 2002). Porous, unstable borders and refugee flows can promote war diffusion, as evidenced by DR Congo and Rwanda. But the refugee-related conflict in DR Congo is considered an exception to the general rule of peaceful refuge, as multiple annual cases of interstate refugee flows result in little overall conflict diffusion (Lischer 2005). In other cases, including Uganda/Sudan, Chad/Sudan, or Sierra Leone/Liberia, rebel organizations existed before any refugee flows or direct cross-border activity. It is more likely that these countries share political characteristics that drove civil unrest before the additional instability wrought by cross-border rebel action.

The conclusions from the second generation of spatial analysis of conflict support both spatial heterogeneity and dependence explanations of civil war patterns in developing states. The findings indicate that the propensity of a state to experience civil

war is partly exogenously determined. Furthermore, due to this dependence, regions can become “bad neighborhoods” where states experience double jeopardy—domestic characteristics make them more prone to civil violence; equally unstable neighbors then compound this risk. Despite these important findings, this line of inquiry is imperfect due to data and modeling choices. Researchers are rarely able to point with certainty to which sub-national characteristics of a state lead to internal conflict, or which aspect of a conflict results in diffusion.

### *Sub-national Patterns and Civil War*

A third strand of research incorporates space into quantitative civil war studies by modeling how sub-national characteristics affect civil war onset risk. These studies explicitly recognize that the state is neither a monolith nor is its territory an ‘event surface’; instead, significant political, economic, social and physical variation exist across regions and locales. Conflict often begins in a small part of a state due to local demands and grievances, and though many conflicts diffuse from their initial locations, most conflicts do not expand across more than a quarter of a country’s territory (Raleigh et al. 2009).

The study of internal conflicts demands the use of disaggregated data and associated techniques. Similar to the first generation of studies noted above, researchers employ spatial lag models to model the propensity of a location (instead of a state) to experience conflict. The sub-national unit is a critical component in these studies. A useful unit of analysis is the grid square (of variable size), which is helpful because a researcher can specify the ‘scale’ of the analysis (local, regional, etc) based either on a theoretical framework of expected conflict distributions or on available sub-national data.

A set grid size across a study area does not avoid the issue of the Modifiable Area Unit Problem (MAUP) – the effect that levels of aggregation influence, often dramatically, the results of statistical analysis – but multiple grids of varying size can be used to test the sensitivity of statistical results to the MAUP. Publically available socio-economic information, however, is rarely formatted as a grid and researchers usually construct their own based on some expectations of the range of spatial effects and the geographic size of the study region. (For additional information on the MAUP, see the key 1979 work by Openshaw and Taylor and subsequent research by Fotheringham and Wong in 1991 and Gotway and Young in 2002).

Grid-based modeling has produced several conclusions, mainly concerning separatist conflicts: these conflicts tend to occur at greater distances from national capitals, are more likely in sparsely-populated regions near the state border, and in territories without significant rough terrain (Buhaug & Rød 2006). This relationship may be endogenous, as rebel groups in smaller states are unlikely to launch a secessionist campaign, while in larger states, rebels have a comparative advantage for secession due to sizeable territory for maneuver, and ethnic group differences. Conflict over control of the state apparatus (i.e. revolutionary conflict) is more likely to occur in densely-populated areas, near lootable resources and proximate to the capital (Buhaug & Rød 2006). Such patterns may be explained by the ability of governments to access peripheral areas or to create pro-government sentiment.

These conclusions regarding grid-analyses are susceptible to the “geometry” critique raised earlier where generalized conflict zones (defined by a center location and radius) are compared to physical geography indicators (terrain, distance, forest cover),

which are used as proxy measurements for government access and control (Rustad et al. 2008). By contrast, other sub-national studies have focused on how environmental factors, such as terrain, precious minerals, and natural resources, affect civil war risk without implying an overt 'political' proxy to physical geography measurements. The results of these disaggregated studies speak to the role of physical geography and demography in influencing civil war dynamics by modeling the specific locations of conflict. Rezendes and O'Sullivan (1986) used a correlation analysis to find that rough terrain and population density are unrelated to war probability. Hegre and Raleigh (2009), using Cox regression with spatial terms, concluded that road density and distance from capital areas are not positively correlated with locations of higher conflict risk. Instead, locations with high population densities that are furthest from the capital have the highest civil war risk. The importance of distance is considerably less than that of the population predictor, except when combined with population concentration. Conflict events occur in peripheral regions, but the Hegre-Raleigh analysis indicates that the picture of African internal conflicts as primarily rural events is inaccurate. The risk of conflict depends on the strategic or economic value of the location, which can be approximated by the size of the population that resides there. Though the effect of distance is less than that of population concentration, the results still indicate that countries with populations that are largely concentrated around the capital have less internal conflict than countries with populations that are spread out or, even more significantly, are concentrated in locations far from the capital.

Although the effects of distance, terrain, and population density on conflict propensity are actively debated, environmental influences on conflict are clearer. Using a

grid analysis and comparing georeferenced environmental degradation indices to conflict patterns in Africa, water scarcity, degraded land, population growth, and locations of precious resource are not directly related to higher localized civil war risks (Raleigh and Urdal 2007). Instead, these factors serve as a motivation for conflict when access to resources is hindered by discriminatory political policies by state agencies. This conclusion is supported by other case studies of environmental stress and conflict (Suhrke 1993; Barnett 2000; Barnett & Adger 2007).

Researchers that have analyzed disaggregated conflict data by point location have reached a number of important conclusions regarding the ebb-and-flow of civil wars. O'Loughlin and Witmer (2009) analyzed over 14,000 conflict events in the North Caucasus of Russia (Chechnya and surrounds) showing how conflict centers have shifted as political actors (federal, local and rebel forces) change military strategies in response to local and national developments and shifting support among local populations. Weidmann et al. (2007) employed agent-based modeling of central African conflicts to distinguish between the spatial ranges of rebel and government conflict signatures. When ethnic identities are responsible for increased violence, poverty and economic conditions can often exacerbate conflict. This is especially apparent in post-state collapse situations when governments cannot dispense money for public goods (schools, militaries, food price supports, etc).

Time series and disaggregated analyses have advanced our knowledge of civil war, but have missed significant, though basic, spatial questions such as how does violence vary within and across countries? Which areas of a state are most contested? How do instabilities in neighbors influence localized risks of civil war? Are civil wars

protracted when rebel groups are weak relative to the government (Cunningham et al. 2006)? In short, the extant literature on conflict incorporating a spatial dimension has largely focused on conflict onset and uses relatively simple spatial measures, such as straight-line distance to a significant political target, height (to measure terrain), forest cover and simple contiguity to determine a location's conflict risk. The conclusions garnered from those studies remain somewhat mixed; the most useful among them suggest that unstable neighbors breed regional instability, borders can be conduits for conflict, environmental factors such as water and resource depletion do not directly lead to conflict onset, and terrain is a generally insignificant factor in civil war onset.

### **Qualitative Contributions**

The qualitative literature on conflict has generally emphasized its localized nature, with specific reference to how the correlates of violence and conflict dynamics are often rooted in local-scale relationships. The main insights of the qualitative literature that help to identify predictive variables for quantitative analysis include how variation in violence and war goals differ across scales; how the physical, political, social and economic geographies of a state separately and collectively shape the dynamics of civil wars; and how conflict patterns should be associated with more developed literatures on modernization, development, nationalism and political institutions.

The correlates to violence are often rooted in local relationships, both between neighbors and local/regional/national political elites. Sub-national war patterns are dictated by the variety of local contexts and characteristics, not national attributes, resource endowments or economic performance. Kalyvas (2006) documented local patterns and individual motivations for participation in both the Greek and Vietnamese



civil wars. From his magisterial review of civil war studies, patterns of rebel control and civilian support for governments are often based on individualized local relationships between supporters and opponents rather than with the meta-narrative of civil wars. Boone (2003) also made this point in her discussion of West African conflict and governance patterns, which are shaped by local elites and their relationship to national governments. In his analysis of violence during the Irish Independence and Civil Wars (1919-1923), Hart (1997) compared the pre- and post-civil war dynamics to show that patterns of violence were markedly different as the main center of violence outside Dublin shifted southward. Historians had relied on explanations such as the “structure of rural society”, wealth, class and occupation to explain the dynamics of revolution and nationalism in Ireland. Hart, through detailed maps of locations of violence (newspaper and archival sources) and from the diaries of participants, clearly confirmed that hotbeds of Irish nationalism and revolution were strongly related to education experiences and teacher influences. Further, due to limited national support, rebels relied on local pockets of support.

The spatial patterns of conflict are partially determined by strategic and military capabilities, but also by the relative strategic importance of places. While the character and goals of any movement are rooted in its territorial imperative, McColl (1967:155) emphasized that the dynamics of conflict are based on logic and strategy wherein “locations must have access to political targets....these are the treaty ports for their wealth and large administrative centers for their political and economic significance. This means that bases cannot be simply located where they would be safe due to topography or distance for the enemy”. O’Sullivan (1989:100) supported McColl’s assertions that

“given that power is exerted via the manipulation of force and information, then the centers of transport and communication networks must be held in order to rule. These are the geographic circumstances of revolution”. Various authors provide a hierarchy of control targets for both governments and rebels in developing states. Herbst (2000) highlighted the importance of large population areas and road networks for his African cases. Clapham (1986) stressed that holding military areas, resource zones, economic infrastructure (ports, airports) is the pre-eminent challenge to both government and rebel groups in sub-Saharan Africa where spatially-sporadic jurisdiction can supplement weak political legitimacy.

The emphasis on localized geographic targeting is evident in the contrast to a growing literature (from economists and political scientists) that holds that conflict patterns are dictated by opportunistic resource grabbing and quasi-criminal activity (Kaldor 1999; Le Billon 2001; Collier & Hoeffler 2004a; Buhaug & Lujala 2005). The geographies of revolutions often follow previously-established patterns of government inclusion/exclusion. In short, analysts need to be more aware of the “topography of power and governance” that shape internal conflict dynamics (Boone 2003).

Descriptive accounts of fighting in many civil war case studies intersect with literatures from a broad swath of social science work on development, nationalism, and ethnicity. For example, in reference to the complicated role of ethnicity in fighting, Lyall (2006) found that insurgent strategies and recruitment patterns are dictated by the size of ethno-political groups present in various locales. He developed and tested an argument regarding how ethnic ideologies are resources to be mobilized by rebels in the North Caucasus of Russia, thus providing local support bases for their movements; a deep

knowledge of these place-to-place differences are thus used effectively, similar in Hart's (1997) comparable analysis of IRA activity.

Qualitative analyses employ spatial explanations to discuss the variation in causes, support, and dynamics of civil war patterns. The complexity of local-level findings is difficult to replicate in quantitative studies, but the approaches are complementary. The conclusions regarding how participation in conflict is determined by scale (local, regional and national issues), and how the variation in participation is a function of support across the population and individual characteristics (employment and education, for example) present a richer and more comprehensive picture of internal conflict than is possible with large-*N* quantitative analysis.

### **Spatial Analytical Methods for the Study of Conflict**

The goal of spatially analyzing conflict patterns is to model significant influences, such as those distinguished within the qualitative literature, within a quantitative framework. Most spatial approaches found in the conflict literature commit one of two errors: 1) they “control” for geography or space, which removes a considerable amount of contextual and relevant information from the studies, in effect, omitting a key predictor (see Gould 1970 for a classic exposition and more recently, the text by Ward & Gleditsch 2008); and 2) the underlying assumptions in the typical suite of analytical techniques used for spatial phenomena are not aligned with the data and process models (Anselin, Florax & Ray 2004). Thus, the conflict research community risks committing several errors if it continues to address sub-national heterogeneity and its attendant problems of serial and spatial dependence in a manner similar to what it has done in the past. An important note on terminology is needed. While autocorrelation is a measurement and statistical

issue that can arise from many sources, including a mismatch of spatial unit and process, spatial dependence is a theoretical issue about why spatial autocorrelation exists or is expected. Though distinct, in practice the terms are often interchanged.

### *Context and Spatial Data*

The definitional constraints in typical quantitative studies often do not allow for nuanced understanding of the violence occurring during civil wars. Violence between two strictly defined groups has to result in the deaths of a certain number of people within an established time frame in order to be designated as a war (Gleditsch et al. 2002). For instance, the Uppsala Conflict Data Program (UCDP) and the International Peace Research Institute of Oslo (PRIO) created an Armed Conflict dataset that lists armed conflicts where at least 25 people were killed in battle by country for the years 1946 to 2007 (Gleditsch et al. 2002; Harbom et al. 2008). Using the DR Congo as an example, the UCDP/PRIO dataset records armed conflict in 17 of the 48 years since 1960. These country-year datasets are of little use for regional- and local-scale studies since they only provide a binary indication of whether a country is at war for each year. Other, well-used conflict datasets such as the Correlates of War (COW) (Singer & Small 1972) and the Militarized Interstate Disputes (MID) data (Jones et al. 1996) suffer from a similar paucity of locational data.

The use of sub-state violent event data offers the opportunity to explore the local distribution of violence over time. The Armed Conflict Location and Event Data (ACLED) from PRIO provide exact locations and dates for battle-related events (Raleigh et al. 2009). Data are currently being coded from 1997-2009 for 50 countries and the project continues to backdate conflict information for African states to the year of

independence. Events are derived from a variety of sources, mainly concentrating on reports from war zones, humanitarian agencies, and research publications. The data contain information on the date and location of conflict events, the type of event, the rebel and other groups involved, and changes in territorial control.

The second concern regarding spatial analysis is best summarized through the well-cited critiques developed by Gould (1970), who noted four errors in the typical approach amongst scholars who develop models for spatial data. First, the form and function of data distributions are assumed to be linear, regardless of much evidence to the contrary. Second, conflict studies have usually analyzed a country-year or grid-year dataset, thereby applying statistical analysis to an entire population; analytical alternatives include split calibrations and evaluation samples. This defect is particularly relevant for country-year or grid square-year samples. Third, analysts assume that the error terms are normally distributed with a mean of zero. Fourth and related, researchers assume independence across observations and residuals. Data that are gathered on a geographic grid or on the basis of pre-existing units (like census tracts, provinces or countries) are not typically independent, and neither are observations within variables. Checks for the presence of autocorrelation within spatial data should be a routine feature of analysis. Unfortunately, most conflict studies assume a lack of serial or spatial dependence among the observations in conjunction with ignoring heterogeneity within the sample and population. “All our efforts to understand spatial pattern, structure, and process have indicated that it is precisely the lack of independence, the very interdependence of spatial phenomena, that allows us to substitute pattern, and therefore

predictability and order, for chaos and apparent lack of interdependence of things in time and space” (Gould 1970: 443-444).

Spatial non-randomness presents a problem for traditional correlation and regression analysis since parameter estimates lose precision and are often biased. Since the spatial component of the phenomenon is often of specific interest, this effect can be modeled explicitly using a spatial lag model that adds a spatially-explicit independent variable, such as the mean of the dependent variable for neighboring units. Introducing this spatial lag term to the regression equation introduces a simultaneity problem, which means the model cannot be properly estimated using ordinary least squares (OLS) so maximum likelihood estimation is usually employed instead (Anselin 1988; Anselin 2002). While the spatial lag method is especially well-suited for modeling spatial dependence, spatial regimes (separate models for each sub-region defined a priori) and Casetti’s (1997) spatial expansion method (multiply independent variable values by absolute location or relative distance) can also be used to model spatial heterogeneity. Geographically-weighted regression has recently gained widespread use for insights into non-stationary processes that exhibit both spatial heterogeneity and spatial dependence by estimating spatially-varying parameters for each sub-unit of the entire study area (Fotheringham et al. 2002; O’Loughlin & Witmer 2009).

Another concern when studying spatial phenomena is that inferential tests ( $F$  and  $t$ ) on regression parameters are not valid in the presence of spatial dependence. Since each observation is not independent, the standard errors of parameter estimates are not minimized and their variances might be underestimated. In aggregate data analysis, the usual statistical approaches will yield estimators that are biased, inefficient, inconsistent,

and insufficient (Anselin 1988; Griffith & Layne 1999). To avoid these problems, Bayesian statistical methods that rely on Markov chain Monte Carlo (MCMC) simulation and Gibbs sampling have been used to generate distributions of regression parameters (Ward & Gleditsch 2002). Since many of these methods rely on knowing both locational and topological (i.e. neighbor) information, specialized software has been developed that can read geographic data formats such as shapefiles (Anselin et al. 2006; Rey & Anselin, 2006).

While geographers stress these errors in spatial analysis as potentially serious, other disciplines typically avoid any consideration of the local characteristics and environments in which political (and social-economic) processes takes place. Some political scientists have gone so far as to note that such contexts are a bogus effect that can evaporate with proper statistical analysis (King 1996, 2002). Context relates to how contagion influences relationships between variables, how milieux vary in character, and how places interact to produce a highly varied geographic surface of conflict.

Researchers cannot know how important contextual effects are until they are formally identified and measured -- such checks are rare (O'Loughlin 2003: 33). Application of mixed spatial-structural models (models with the usual predictors of conflict and additional measures of geographic contiguity and spatial autoregressive terms) specifically take geographic considerations into account. Geographers emphasize that analyses should not separate political events and processes from their geo-sociological environments.

### **Spatial Analysis Methods for Conflict Point Data**

For conflict studies that use individual events to track violence over time, additional spatial analytical methods beyond regression techniques are available. These include centrographic statistics and point pattern analyses. Centographic methods describe the distribution of events over a geographic space. The mean center, standard distance, and standard ellipse are the spatial equivalent to the univariate mean and standard deviation measures. The mean center is calculated by averaging the x and y coordinate values separately, and optionally weighting by population (to yield the mean population center) or other variables of interest. The standard distance and ellipse measures are used to describe the spread of the data around the mean center. The standard distance provides a radius that is the standard deviation of the distance of each point from the mean center. The standard ellipse measure extends this concept to include anisotropy (direction bias) by constructing an ellipse around the mean center. For data normally distributed around the mean center, each standard ellipse encompasses approximately 68% of the events. Rose or circular histograms can also detect directional trends between points or mean centers, especially useful for anisotropic phenomena whose spatial dependence varies by direction. Such directional variation may be caused, for example, by an important road that serves as an artery for moving military equipment and personnel and is thus subject to more frequent attacks by rebels. These and other descriptive statistics for spatial distributions are described in Burt et al. (2009).

Tests for spatial randomness in the distribution of violent events have strong parallels with the use of these methods in spatial epidemiology. Methods such as quadrat tests, nearest distances, Ripley's *K*-function, and cluster detection can be used to identify non-randomness in the distribution of events (Bailey & Gatrell 1995). General



measures of spatial autocorrelation that yield a single value for an entire study region such as Moran's  $I$  and Geary's  $c$  have been extended to produce local indicators of spatial association (LISA) such as the local Moran's  $I$  and local  $G_i^*$  (Anselin 1995; Fotheringham et al. 2002). These measures identify "hot spots" such as locations in civil war analysis where more intense fighting is concentrated. One of the earliest implementations of cluster detection was the geographical analysis machine (GAM) by Openshaw et al. (1988). Recently, the cluster detection method has been modified and extended to detect space-time clusters using the SaTScan program (Kulldorff 1997, 2007; Kulldorff et al. 2005). We provide an example of the application of some of these methods to violence in Congo/Zaire (now DR Congo) below.

A key advantage of local spatial analysis methods is the ability to detect local variation in the distribution of events. With detailed locational and temporal event data, space-time clusters can be detected, and the diffusion of events over time can be visualized through cartographic displays. One immediate concern is that many of these methods are sensitive to the definition of the study area extent. Border and edge effects are a concern for many of these local methods, but fortunately, Monte Carlo simulations that compare the observed distribution of events to a randomized set of events over the same study area help to mitigate these problems. (For a further discussion of the challenges facing spatial data analysis, see Chapter 10 in Fotheringham et al. 2000).

For modeling purposes, event data present both prospects and problems. As individual events within a single conflict can reach into the thousands, the rare event issue that plagues country-year studies of conflict is no longer a concern. Furthermore, it is possible to create calibration and evaluation samples, using data from one country to

predict the actions in another of similar qualities. However, data accessibility (complete reporting of violent events in archival or accessible forms) and data bias (selective newspaper accounts of violence) continue to mar event-analysis, and it can be difficult to choose appropriate statistical tests when analyzing spatially- and temporally-dependent data.

Perhaps the closest parallels to geostatistical analysis of violent events are found in the criminality and epidemiology literatures. Like disaggregated violence data, crime and health data typically geocode precise locations and temporal sequences of these phenomena thus allowing the researcher to map, analyze statistically, and predict future trends. Diffusion models are widely debated and used while the large data sets allow comparison of predicted and empirical data distributions. Within the geographic literature, contagious, hierarchical (from larger to smaller places), relocation, and expansion diffusion models have over 50 years of use for examining the spread of social, agriculture, disease and economic occurrences (Gould 1969; Cliff et al. 1981, 2000). Though the application of geostatistical methods to conflict events has thus far been descriptive, future work can emulate similar developments in the study of crime and disease where predictive models are common. Specifically, predictive diffusion models offer a lot of potential if the underlying spatial process can be identified through close examination of spatio-temporal trends. The large suite of methods for such identifications were first presented almost 3 decades ago by Cliff and Ord (1981) and though their regression models have been applied to war study, the diffusion models that they applied in disease distributions and diffusion (e.g. Cliff et al. 2000) have not been widely applied to the study of conflict.

### *DR Congo Case Study*

Sub-country, event-specific data enable researchers to gain insights into the local spatial distribution of violence and its trends over time. As an example, we present a brief analysis of violent events in the Democratic Republic of Congo (DR Congo, formerly Zaire) since independence in 1960. Figure 1 shows the mean centers and standard deviational ellipses for violence in four time periods for the DR Congo. The conflict data are from the ACLED project described above and are also examined in the Rustad et al. (2008) study of the effect of forest cover on the distribution of violence.

DR Congo has been plagued by multiple conflicts since independence in 1960. Early civil wars were revolutionary and secessionist in nature, while later conflicts, with the exception of the Shaba Wars of 1977 and 1978, were outcomes of power vacuums at the center, involving multiple groups with shifting alliances and splinters (Clark 2002; Legum 1978). To identify changes over time in the spatial distribution of violence, we divide the period into four sections based on overall governance structure and conflict trends.

## DR Congo Violent Events over Four Periods, 1960-2008

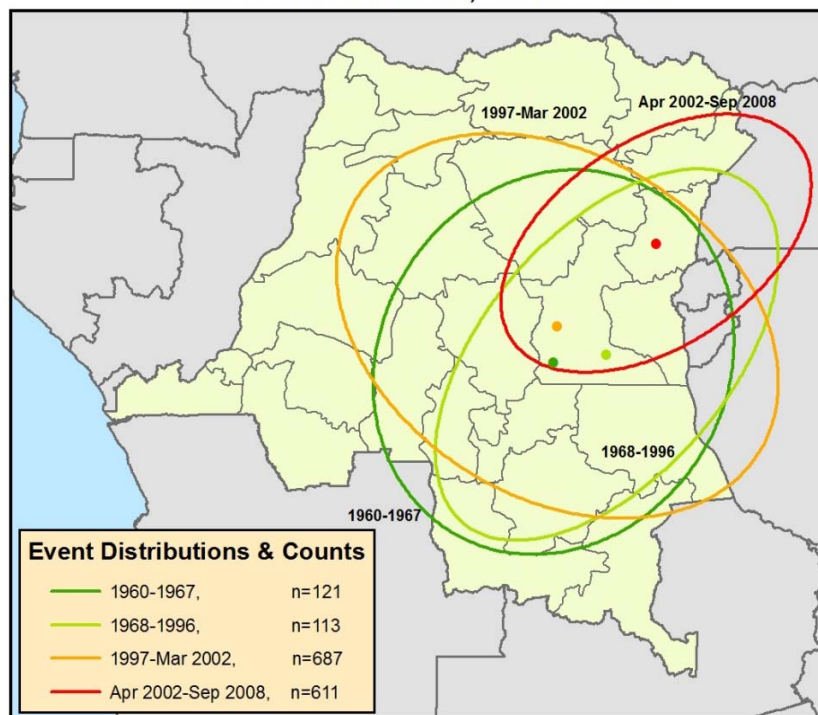


Figure 1: Means centers and standard ellipses of violence in DR Congo since 1960

The first period, 1960-1967, represents the immediate post-independence and state consolidation time frame. The first half of this period was marked by secessionist movements in the central and southern regions of Kasai and Katanga (Shaba). The large geographical dispersion of these rebellions is captured by the dark green mean center and standard ellipse in Figure 1. By the end of this period, Joseph Mobutu rose to power. Remaining President through 1996, his regime was marked by repression and relative peace, with the exception of the Shaba Wars in 1977 and 1978 (light green ellipse for violence in this period in figure 1). In addition to these wars, low-level conflicts and multiple bouts of instability occurred mainly in the east.

International pressures in the 1990s forced Mobutu to decentralize power and the resultant power vacuum incited large-scale conflicts for power, mainly in the unstable eastern region from 1997 to the spring of 2002. The area of eastern DR Congo is characterized by high population densities, natural resource wealth, a low level of development, a diverse ethnic character, and generally limited incursion or control by any governing forces (Cyrus-Reed, 1998). Tensions grew due to instability in neighboring Rwanda, which pushed radicalized Hutu elements (Interahaweme) and the former Rwandan army (FAR) into the territory of eastern DR Congo following the 1994 Rwandan genocide (*Africa Confidential* 1998; Longman 2004). The Banyamulenge (eastern Congolese Tutsis) were long the target of hostilities from other ethnic communities in eastern DR Congo. One particular militia group, the Mayi Mayi, arose to both prey on Banyamulenge and fight the Tutsi Rwandan ‘foreign invaders’ (Uppsala Conflict Data Project /UPCD; Afoaku 2002). In late 1996, the eastern Tutsis joined a number of anti-Mobutu groups who, with considerable Rwandan and Ugandan assistance, created the *Alliance des Forces Democratiques pour la Liberation* (AFDL). The lack of other organized forces allowed for a rapid success for the AFDL, who assumed power by installing Laurent Kabila in the presidency in August 1997 (Cryus-Reed 1998: 148-150).

Fighting resumed in mid-1998 as President Kabila demanded that Rwandan and Ugandan troops leave the eastern region where both were pursuing rebels responsible for violence in their respective countries. In turn, Rwanda and Uganda organized the *Rassemblement Congolaise pour la Democratie* (RCD), a rebel group who attacked Kabila’s regime in August 1998. The original RCD group was composed of anti-government elements, including former AFDL members, Congolese Tutsis, and former

Mobutists (UPCD). Angolan, Zimbabwean and Namibian troops assisted President Kabila's crippled military to regain military positions in the East. The second main rebel group was the *Mouvement de Liberation Congolaise* (MLC) from Equateur province. Created in 1998 with the intent of overthrowing Kabila, this group collected various elements of former Mobutu clients from his native region (*Africa Confidential* 1999: 40-42). The wide geographic range of conflict in the post-Mobutu years is shown by the orange ellipse in Figure 1.

Into 2008, the eastern Kivu region continued to experience high levels of violence and instability. During this time, cross-border rebel groups such as the LRA (Lords Resistance Army) from Uganda were very active. Consistent targeting of civilians by militias and rebel organizations has continued. Over the past six years, the violence has become more concentrated near the Rwandan border with the city of Goma a particular target for rebel and government forces (near the mean center of the red ellipse in Figure 1).

#### *DR Congo Cluster Analysis*

Event-scale data also allow researchers to test the hypothesis of spatial randomness in the distribution of events. Though there are many reasons to expect a non-random distribution of violence (e.g. variation in location of rebels, government installations, resources, and human settlement), we can quantify spatial variation by detecting statistically significant clusters in both space and time dimensions. A scan statistic commonly used in epidemiology (Kulldorff et al. 2005; Conley et al. 2005) can also be applied to conflict data.

## DR Congo Space-Time Clusters, 1960-2008

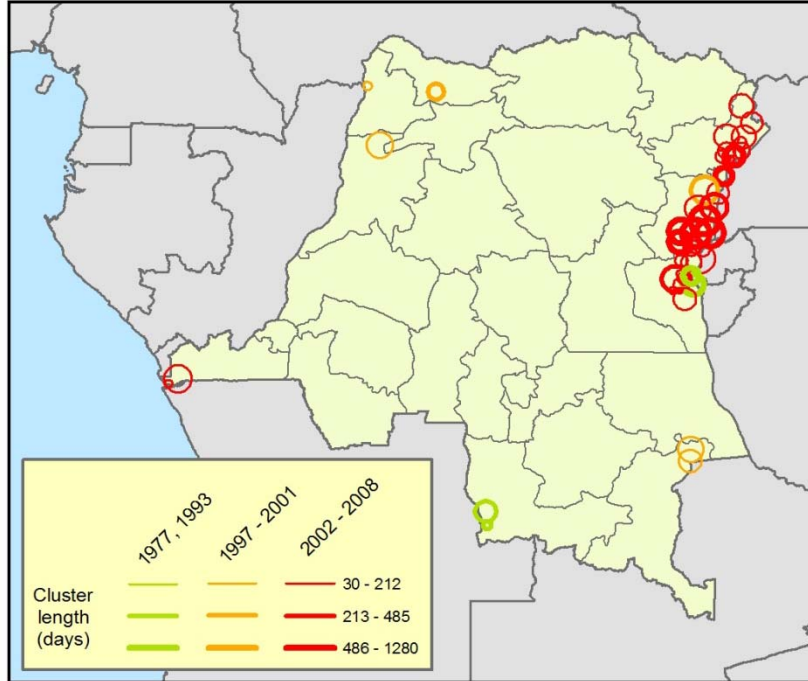


Figure 2. Space-time clusters for the DR Congo generated using SaTScan.

Statistically significant clusters for DR Congo from 1960 to 2008 are shown in Figure 2. These clusters were generated using a maximum radius of 50 km and a maximum time of 5 years. To reduce the number of duplicate clusters, neighboring clusters could not have both their centers within the other's radius. The clusters are mapped within each of the four major time periods and colored to match the centographic measures in Figure 1. No statistically significant space-time clusters exist for the first time period, 1960-1967, and each of the three sets of clusters by time period roughly mirrors the standard ellipses from Figure 1.

Two groups of clusters are evident in the second time period; the first relates to the Shaba Wars and the other reflecting spillover battles within Rwanda and Burundi lasting from May 1993 to November 1996. For the third time period (1997-2001), the

spatial distribution of violence show clusters in northwest and southeast DR Congo. The red space-time clusters highlight the intensity of the conflict along the border region with Uganda and Rwanda since 2002. The cluster analysis is therefore useful for detecting individual hot spots clustered in space and time that might otherwise go undetected as well as highlight patterns over time in unusually intense conflict.

### **New Questions and Directions in Conflict Research**

Civil war analysis can benefit from increased attention to the spatial heterogeneity in its causes and patterns and an acknowledgement of the interdependence of conflictual and peaceful areas. This is not simply a data or methods issue, but demands intra- and interdisciplinary attention. The approaches from quantitative and qualitative research can be complementary. Indeed, with more attention given to local level experiences, quantitative analysis can be guided by qualitative approaches to the study of internal conflict. On the interdisciplinary front, quantitative geographers can produce insights into conflict patterns through spatial analysis and mapping, but if they ignore the rich political science literature on the causes and processes of conflict, these descriptive contributions to conflict discourse will be limited (see Beck et al. 2006 for commentary on this matter).

In the spatial analysis of conflict, detailed information on the political geographies of states can be used to (partially) explain the onset of violence, or at very least, its distribution in both qualitative and quantitative approaches. But political geographers and those who study internal conflict have yet to agree on a consensus that describes how the “geography” of a war is shaped by political contexts. While accepting the strategic role of territories and populations notwithstanding, what does location tell us about the



underlying causes and catalysts for conflict? While we can model spatial heterogeneity and dependence and develop a landscape of conflict risk, this does not substitute for an overarching interpretation of political geography. Once we have modeled the variation in local causes and accounted for spatial autocorrelation, is there evidence remaining that indicates that location matters? At this stage, detailed consideration of the specific contextual factors that govern the ebb and flow of conflict is needed. Factors such as terrain, forest cover, distribution of supportive and opponent populations, influence of bases in adjoining countries, use of the exploitation and export of resources for waging war warrant examination.

In this chapter, we could not address the full range of spatial analytical issues. We have privileged the “local” which requires data that are as disaggregated as possible noting that such data can always be aggregated to larger units (Fotheringham 1997). In addition to sophisticated spatial modeling, researchers of local civil war patterns will increasingly need to address local politics. Within developing states, the practice of politics varies substantially, as do the social and economic consequences of these politics. While this has received attention within qualitative studies, quantitative researchers have been hesitant to address these realities. Yet, it is these very practices of ethnic exclusion, marginalization, cooperation and containment that give rise to the conflict patterns that remain evident in DR Congo, Iraq and Afghanistan. Without a serious engagement with how local realities are mediated by national and global economic relationships, geopolitics, or new environmental realities, we risk omitting significant predictors in future work. Given these new realities, the nature of war is bound to change, as are the

actors and goals of movements. Adding spatial methods to the toolbox currently in use in political science, IR and related fields can assist in understanding these new realities.

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### **Online Resources**

ACLED- Armed Conflict Location and Event Data, Peace Research Institute of Oslo.

<http://www.prio.no/CSCW/Datasets/Armed-Conflict/Armed-Conflict-Location-and-Event-Data/>. The project “codes exact locations, dates, and additional characteristics of individual battle events in states affected with civil war. There is a specific focus on tracking rebel activity and distinguishing between territorial transfers of military control

from governments to rebel groups and vice versa, and the location of rebel group bases, headquarters, strongholds and presence.”

The Dynamics of War Outcomes, University of Colorado

<http://www.colorado.edu/ibs/waroutcomes/>. The site provides maps, presentations, papers and data on civil war violence and ethnic attitudes to violence in Bosnia-Herzegovina and the North Caucasus of Russia.

GeoDa Center for Spatial Data Analysis and Computation, Arizona State University

<http://geodacenter.asu.edu/>. The Center develops state-of-the-art methods for geospatial analysis, including spatial regression models, geovisualization, geosimulation, and spatial process modeling, and distributes free software tools for application in social and environmental sciences

CRAN Task View, Analysis of Spatial Data, Roger Bivand, University of Oslo

<http://cran.r-project.org/web/views/Spatial.html>. This site distributes many functions in R that are used for reading, visualizing, and analyzing spatial data. Observations must be identified by geo-coded specific locations.

Uppsala Conflict Data Program, Department of Peace and Conflict Studies, University of

Uppsala, Sweden <http://www.pcr.uu.se/research/UCDP/> The program collects

information on armed violence since 1946 and since the 1970s has recorded ongoing violent conflicts. It now includes information on the resolution and dynamics of conflict.

### **Keywords**

War and Conflict, Spatial Analysis, Democratic Republic of Congo, Event Data, Political Geography