Chapter 3

Mapping border conflicts in North and West Africa

Chapter 3 develops several tools to examine whether borderlands are more violent than other regions, how the intensity of violence has changed over time in such regions, and which borderlands are the most violent in North and West Africa. The spatial and temporal relationships between political violence and borderlands are studied using two complementary approaches to define borderlands: one based on a series of buffer zones extending along all of the land boundaries of the region, and the other based on the distance travelled by local means of transportation from any border crossing of the region. A Spatial Conflict Dynamics indicator (SCDi) developed by the Sahel and West Africa Club (SWAC) is used to identify major clusters of violent activities. This indicator is complemented with a qualitative analysis of violent extremist organisations operating in border regions.

KEY MESSAGES

- **This report develops two definitions of borderlands to determine whether the intensity of violence uniformly decreases with distance to borders throughout North and West Africa.**
- **Borderlands are first defined as the area extending no more than 200 kilometres from an international border.**
- **A novel definition of borderlands is then introduced based on their accessibility to the rest of the country, using local transportation and average speeds determined by topography.**
- **A new geographic indicator of political violence assesses the changing geography of violence, over space and through time.**
- **The Spatial Conflict Dynamics (SCDi) indicator identifies several types of conflict in African borderlands and their life cycle.**

HOW TO ASSESS BORDER-RELATED VIOLENCE

Violent events tend to cluster in space and time as conflicts emerge, spread and disappear. Some regions appear particularly favourable to political violence at a certain period, before becoming peaceful again. Other regions are spared from violence for decades. Understanding how hotspots of violence evolve spatially and temporally is critical to evaluating whether violence is increasing, diffusing to other regions, or receding. This report contributes to mapping this changing geography of violence by focusing on North and West African borderlands, areas where the intensity of violence is currently particularly high.

The report examines whether borderlands are more violent than other regions, how the intensity of violence has changed over time in such regions, and which borderlands are the most violent (Table 3.1). The objective of the first question is to determine whether the number of violent events and fatalities recorded in the region since 1997 decreases with distance and accessibility to land borders. In other words, is political violence more clustered near borders than in the interior of the country? The second question examines whether borderlands have always been more violent than other state spaces. Is the current concentration of violence near

Table 3.1
Questions, approaches and tools to assessing border violence

Questions	Approaches	Tools
(1) Are borderlands more violent than other spaces?	Assess the relative number of violent events and fatalities according to their distance and accessibility to land borders	Distance: 10 km wide buffer zones along land boundaries Accessibility: distance travelled in less than 4 hours from any border crossing
(2) Has the intensity of violence in border regions changed over time?	Assess the changing proportion of violent events and fatalities according to their distance and accessibility to land borders over time	Distance: 10 km wide buffer zones along land boundaries Accessibility: distance travelled in less than 4 hours from any border crossing
(3) Are some borderlands more violent than others?	Contextualise the relationship between borderlands and violence by using local factors that can explain why violence emerges near borders	Spatial Conflict Dynamics indicator (SCDi) and qualitative analysis of violent extremist organisations

borders in North and West Africa a historical exception? The last question contextualises the relationship between borderlands and violence by looking at the roots of armed conflicts. Which local factors explain why certain segments of a border are more violent than others?

Several novel tools are developed to address these questions. The spatial and temporal relationships between political violence and borderlands (questions 1, 2) are studied using two complementary approaches to define borderlands: one based on a series of buffer zones extending along all of the land boundaries of the region (distance), and the other based on the distance travelled by local means of transportation from any border crossing of the region (accessibility). The Spatial Conflict Dynamics indicator (SCDi) is used to identify major clusters of violent activities (question 3). This indicator is complemented with a qualitative analysis of violent extremist organisations and rebel groups operating in border regions, including Boko Haram, the Islamic State West Africa Province (ISWAP), Al Qaeda in the Islamic Maghreb (AQIM), the Islamic State in the Greater Sahara (ISGS) and Chadian rebels.

In a first part, the study examines the spatial and temporal evolution of political violence in the entire region from 2019 to 2021. This analysis is first conducted on 21 countries of the region (Chapter 4, Map 3.1). This regional analysis is followed by a focus on case studies in Central Sahel and Eastern Sahel. As in previous studies (OECD/SWAC, 2020[1]), this study uses the SCDi to map both the intensity and spatial distribution of violence across the region. In a second part, the study focuses on violent activities that have taken place in borderlands from 1997 to 2021 (Chapter 5).

Data

The spatial analysis of violence uses event data from the Armed Conflict Location & Event Data Project (ACLED, 2019[2]) that catalogues politically motivated acts of violence in Africa since the late 1990s (Raleigh et al., 2010[3]). From January 1997 through 30 June 2021, the ACLED dataset provides detailed georeferenced information on 43 182 violent events in the region involving over 6 794 unique organisations and 171 255 fatalities.

The study builds on eight categories of actors based on their goals and structure and, where possible, on their "spatial dimension and relationships to communities" (ACLED, 2019, p. 19[2], see Table 3.2). Actors can either be formal organisations, informal groups of people, or non-combatant categories. Formal organisations include 'state forces', defined as collective actors that exercise de facto state sovereignty over a given territory, such as military and police forces from the region. Another type of formal organisation is 'rebel groups', which are organisations

Map 3.1

Countries and case studies

Table 3.2

Number of actors by category, 1997-2021

Name	Number	Example
State forces	924	Military forces of Niger
Rebels	406	Ansar Dine
Political militias	1 449	Imghad Tuareg Self-Defense Group and Allies (GATIA)
Identity militias	2 675	Benue Communal Militia (Nigeria)
Rioters and protesters	3	Rioters (Senegal)
Civilians	1 069	Civilians (Cameroon)
External forces	257	United Nations Multidimensional Integrated Stabilization Mission in Mali (MINUSMA)
Others and unknown	11	Nigeria Petroleum Development Company
Total	**6 794**	

Source: Authors based on ACLED (2021[4]) data. Data available through 30 June 2021. ACLED data is publicly available.

whose political agenda is to overthrow or secede from a given state. Splinter groups or factions that emerge from a rebel group are recorded as distinct actors.

ACLED distinguishes between two types of militias, those defined by identity and those who pursue political objectives. 'Identity militias' are a heterogeneous group of militants structured around ethnicity, religion, region, community and livelihood. Such militias are often named after the locality or region where they operate, such as the Benue Communal Militia in Nigeria.

Table 3.3
Number of violent events and fatalities by type, 1997-2021

Event type	Sub-event type	Events	Fatalities
Battles		**18 826**	**86 637**
	Armed clash	17 013	77 258
	Government regains territory	971	4,856
	Non-state actor overtakes territory	842	4,523
Explosions/remote violence		**7 007**	**24 234**
	Air/drone strike	2 379	9 119
	Grenade	61	53
	Remote explosive/landmine/IED	2 658	8 425
	Shelling/artillery/missile attack	1 393	1 629
	Suicide bomb	516	5 008
Violence against civilians		**17 349**	**60 384**
	Abduction/forced disappearance	2 734	0
	Attack	14 424	59 464
	Sexual violence	191	920
Grand total		**43 182**	**171 255**

Source: Authors based on ACLED (2021[4]) data. Data available through 30 June 2021. ACLED data is publicly available.

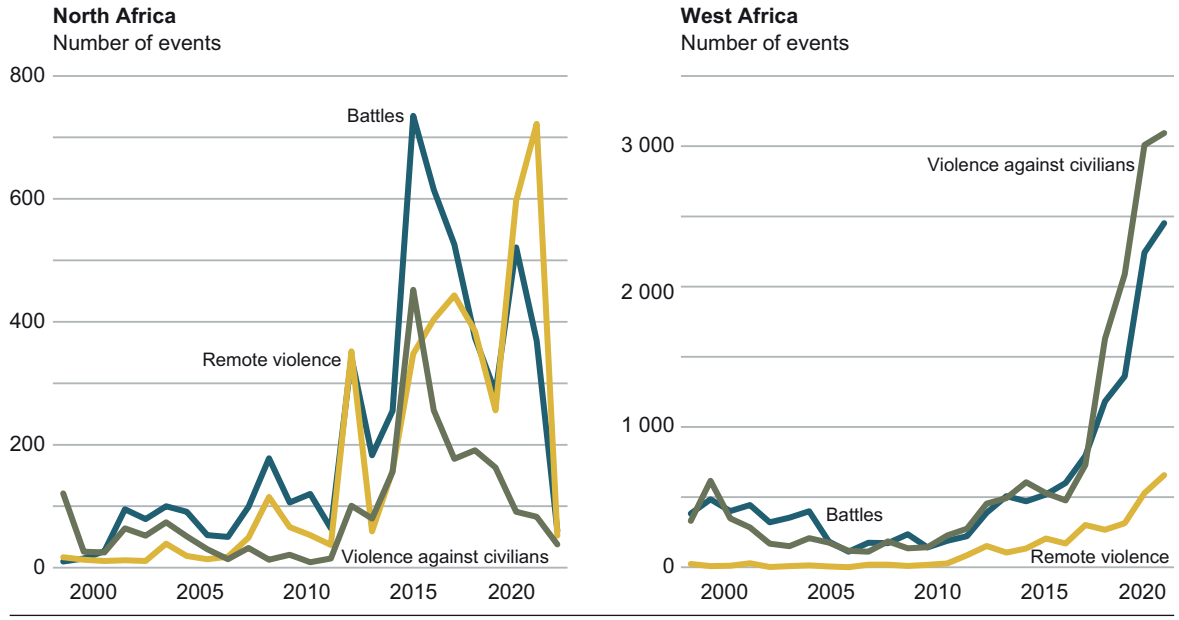
'Political militias' are organisations whose goal is to influence and impact governance, security and policy in a given state through violent means, such as the Imghad Tuareg Self-Defense Group and Allies (GATIA) in Mali. Unlike rebel groups, political militias "are not seeking the removal of a national power, but are typically supported, armed by, or allied with a political elite and act towards a goal defined by these elites or larger political movements" (ACLED, 2019, p. 22[2]).

Several categories of civilian actors are identified by ACLED. 'Rioters' are unarmed individuals or groups engaged in disorganised violence against civilians, government forces or other armed groups during demonstrations, while 'protesters' are unarmed demonstrators who engage in a public event without violence. Finally, 'civilians' refer to the unarmed and unorganised victims of violent events identified by their country of origin. International organisations, foreign military forces, private security firms, and independent mercenaries engaged in violent events are coded as 'external' and 'other forces'. It is important to note that the ACLED database does not indicate the perpetrator and the victim of an attack, with the exception of civilians who are, by definition, unarmed and cannot engage in political violence.

The report focuses on three types of violent events: battles, explosions and remote violence, and violence against civilians (Table 3.3). Non-violent actions such as strategic developments are not taken into account.

- Battles are defined as "violent interactions between two politically organised armed groups at a particular time and location" (ACLED, 2019, p. 7[2]). Battles can occur between any state and non-state actors and involve at least two armed and organised actors. This category is subdivided into three sub-event types, depending on whether non-state actors or government forces overtake territory or whether there is no territorial change. Battles have caused almost 87 000 fatalities in the region since 1997 in a little less than 19 000 events. Almost 90% of these fatalities were caused by armed clashes.
- Explosions and remote violence correspond to "one-sided violent events in which the tool for engaging in conflict creates asymmetry by taking away the ability of the target to respond" (ACLED, 2019, p. 9[2]). These acts

Figure 3.1
Violent events by type and region, 1997-2021



Note: 2021 data are projections based on a doubling of the number of events recorded through 30 June.
Source: Authors based on ACLED (2021[4]) data. ACLED data is publicly available.

of violence can be carried out using bombs, grenades, improvised explosive devices (IEDs), artillery fire or shelling, missile attacks, heavy machine gun fire, air or drone strikes, or chemical weapons. Explosions and remote violence have killed more than 24 000 people since 1997 in 7 000 incidents.

- Violence against civilians includes "violent events where an organised armed group deliberately inflicts violence upon unarmed non-combatants... The perpetrators of such acts include state forces and their affiliates, rebels, militias, and external/other forces" (ACLED, 2019, p. 11[2]). Violence against civilians represents 40% of the events and 35% of the fatalities recorded in North and West Africa since the late 1990s. The vast majority of the 60 000 civilian deaths and more than 17 000 incidents observed in the region were caused by direct attacks against them.

North and West Africa have experienced very low levels of political violence until the early 2010s, followed by a massive increase in violent events and fatalities due to civil wars in Libya and Mali, and armed insurgencies in Burkina Faso, Niger, and Nigeria (Figure 3.1). In recent years, the north of the Sahara has experienced a notable decrease in the number of violent events which contrasts strongly with the degradation of the security situation in West Africa. With more than 135 000 events and 36 000 fatalities recorded so far, the intensity of violence south of the Sahara is three times higher than in North Africa. The number of direct attacks, kidnappings and sexual assaults against civilians now exceeds the number of armed battles between state forces and armed groups in West Africa. In North Africa, the number of events related to explosions, remote violence and battles has reached an historical low after the signature of a permanent ceasefire between the Libyan National Army (LNA) and Government of National Accord (GNA) in October 2020, and the formation of a Government of National Unity in March 2021.

The type of armed conflict adopted by the belligerents explains the contrasting evolution of violence between the two main regions. In North Africa, the vast majority of the incidents and victims were due to a war between regular forces and their militias. Violence emerged when political factions disagreed over the distribution of resources and power, and receded when they

reached an agreement, as after the First and Second Libyan wars. Conflicts in West Africa are of a completely different nature. Instead of mobilising regular forces for conventional military campaigns, armed conflicts south of the Sahara are protracted with asymmetric struggles between central governments and a plethora of non-state actors, including secessionist rebels, religious extremists, communal militias, and self-defence groups. These conflicts tend to kill a larger number of civilians than conventional wars.

MAPPING CHANGING CONFLICT DYNAMICS

The report uses a geographic indicator of political violence that assesses the changing geography of violence, over space and through time (Walther et al., 2021[5]). The SCDi measures two connected but different spatial properties of violence: the intensity of conflict across a region, and the distribution of conflict locations relative to each other. The SCDi has been previously applied to all of North and West Africa (OECD/SWAC, 2021[6]; OECD/SWAC, 2020[1]) using a uniform grid of 50 x 50 kilometres to subdivide the study area. The SCDi is calculated annually for each of these grid cells since 1997. The same approach to defining regions and durations is also utilised in this report.

Measuring the intensity of violence

The first spatial property measured by the SDCi is conflict intensity (CI). The CI metric identifies the total number of events in a given region, such as the 50 x 50-kilometre grid described above, for some duration of time, such as a year. This number of events is then divided by the area of the grid to allow comparisons between regions. The resulting CI metric has a lower bound of 0 if there are no events within a given region during a given year and no upper bound. As the CI metric increases from 0, it reflects an increasing spatial intensity of violence within the footprint of a region (Figure 3.2).

When using a 50 x 50-kilometre grid, most regions have a CI score of 0 in any given year reflecting the absence of violent events. However, there are also many regions that are assigned a CI score greater than 0. In addition to calculating the raw CI score for each region, the SCDi also classifies a region as higher or lower than an expected CI value. The expected CI value for North and West Africa is called the CI 'generational mean' as it is the 20-year average conflict intensity between 1997 and 2016. The CI generational mean is 0.0017 events per square kilometre, or 4 events for a 50 x 50-kilometre region. Therefore, in this report, a region is classified as high intensity if 4 or more events occur in a grid within a given year and as low intensity otherwise.

Measuring the concentration of violence

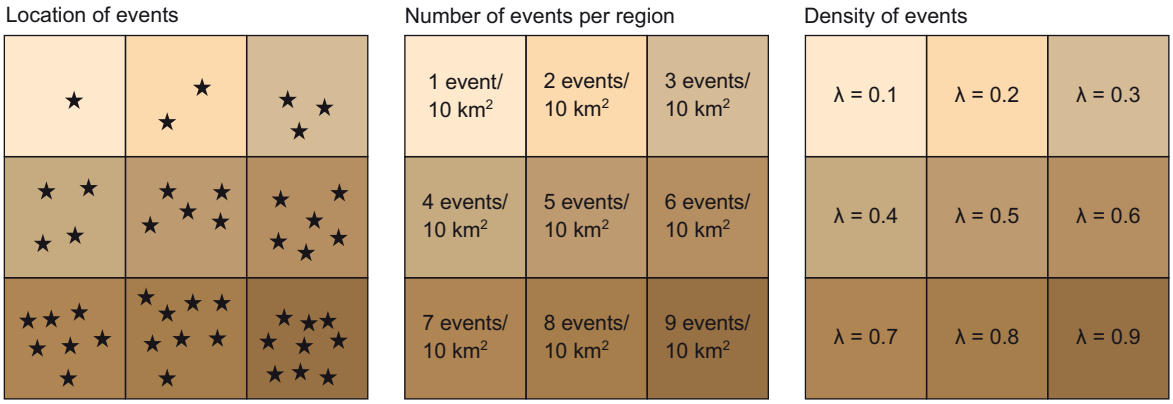
The second property measures the distribution of conflict locations relative to each other within a given region. This is called the conflict concentration (CC) metric. The CC metric calculates observed average distance between events in a given region within a given year divided by the expected average distance if the events were randomly distributed throughout the region. As presented in Figure 3.3, the patterning of events relative to each other is a different concern from conflict intensity and two regions can have a small conflict intensity while resulting in very different locational patterns.

Like CI, the CC metric has a lower bound of 0 with no conceptual upper bound. A CC score of 0 would represent a series of events at the exact same location, an example of extreme geographic clustering of events. A CC score of 1 would represent a random pattern of event, or no detectible locational pattern. A CC score of more than 1 would represent dispersion of events from each other, further apart than would be expected by chance. As shown in Figure 3.4, CC scores lower than 1 in a region are classified as clustered and scores higher than 1 are classified as dispersed.

An average nearest neighbour (ANN) ratio is calculated to determine whether the patterns of violent events exhibit clustering or dispersion. The ANN ratio is calculated as the observed

Figure 3.2

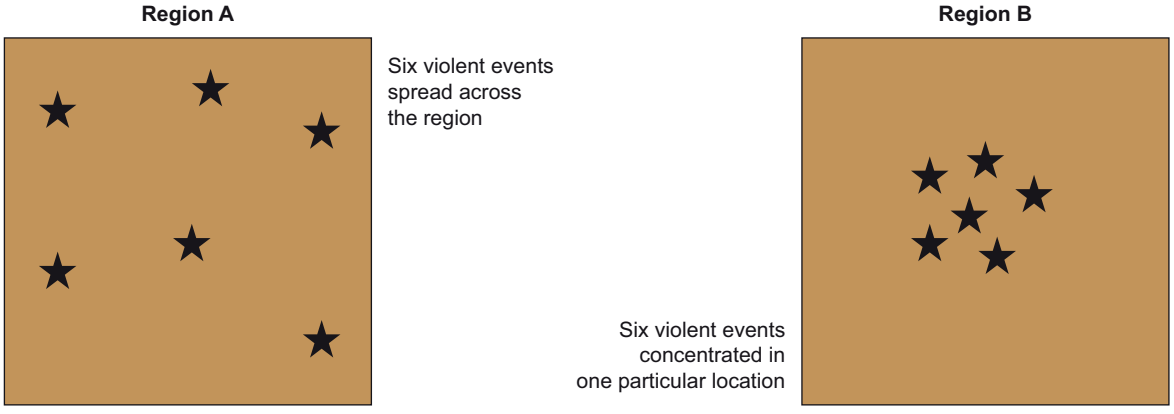
Density of violent events



Source: OECD/SWAC (2020[1]).

Figure 3.3

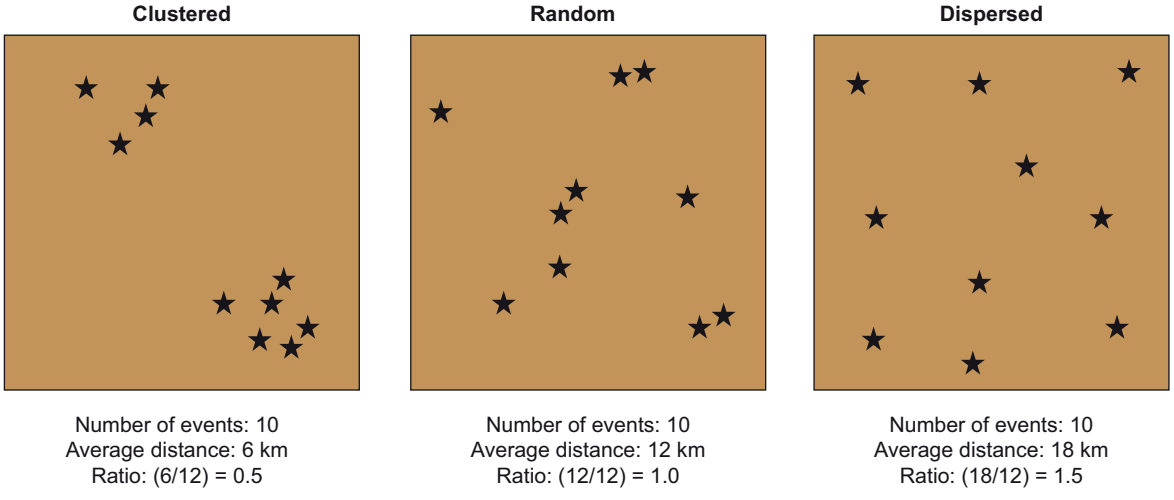
Identical density but different distributions of violent events



Source: OECD/SWAC (2020[1]).

Figure 3.4

Distribution of events as measured by the average nearest neighbour (ANN) ratio



Source: OECD/SWAC (2020[1]).

Table 3.4
The four spatial types of conflict

	High intensity	Low intensity
Clustered	Type 1. More events than mean and closer together than expected	Type 3. Fewer events than mean and closer together than expected
Dispersed	Type 2. More events than mean and further apart than expected	Type 4. Fewer events than mean and further apart than expected

Source: OECD/SWAC (2021[6]).

average distance among violent events in a given region divided by the expected average distance that would have been obtained if the events were distributed randomly (ESRI, 2019[7]). ANN ratios smaller than one indicate clustering while ratios greater than one indicate dispersion. For example, the distribution of events represented on the left-hand side of Figure 3.4 is clustered compared with a random distribution of the same number of events, as shown by its ratio of 0.5, while the distribution on the right-hand side is dispersed, with a ratio of 1.5.

Types and conflict life cycle

The SCDi combines the CI and CC scores of political violence to identify four different spatial types of conflict according to whether violent events are dispersed or clustered, and of high or low intensity (Table 3.4).

- The first type characterises regions that have an above average intensity and a clustered distribution of violent events, suggesting that violence is intensifying locally.
- The second type characterises conflicts with a higher-than-average intensity and a dispersed distribution of events, indicating that the violence is accelerating.
- The third type applies to regions where there are fewer violent activities and most of them take place near each other, possibly indicating a decreasing range of violent groups.
- The fourth type, in which a lower-than-average intensity and a dispersed distribution of events are combined, suggests that a conflict is lingering. This situation may indicate that opponents are highly mobile or are unlikely to face protracted opposition in a given locality.

These four types are indicative of potentially different stages in the overall lifecycle of a conflict (Walther et al., 2021[5]). For example, when violence first emerges in a region, it is usually Type 2 clustered/low-intensity (the majority of cases) or Type 1 clustered/high-intensity (one-third of cases). This indicates that violence is most likely to be concentrated spatially when it first emerges. However, once a conflict is established, it commonly persists over time in its clustered/high-intensity form (Type 2, over 70% of the cases). As conflicts start to end, they tend to move from Type 1 to Type 2 before stopping altogether.

Although violence has been observed to both initiate and end from all of the SCDi typologies, the dispersed categories (Type 3 and 4) are most common either at the beginning or ending of a sequence of violence in a sub-region. Further, dispersed conflicts are quite unlikely to persist over time when compared to clustered conflicts and tend to change quickly to no conflict once they have emerged. This suggests that regions displaying these spatial typologies are either quite near the early stages of a conflict episode or the end. Finally, conflicts most commonly end by transitioning from Type 2 clustered/low-intensity to no conflict in the following year (nearly 60% of observed cases). Violence is often concentrated even just before it ends.

Taken together, the four spatial categories reveal insights about the dynamics of the lifecycle of a typical conflict in North and West Africa. These are the general trends however and not all sub-regions, places, or localities will always exhibit the same lifecycles between the SCDi categories. Nonetheless, there is a predominate pathway reflected in event data across the region since the late 1990s (Walther et al., 2021[5]). Emerging conflicts tend to result in clustering of

either type, dispersed conflicts tend to quickly change, clustered/high intensity are more persistent, and violence most commonly ends from the clustered/low-intensity forms. The typology of the SCDi is first applied to the entire region (Chapter 4) to characterise the recent evolution of violence, before being specifically applied to border regions (Chapter 5).

MAPPING VIOLENCE WITHIN BORDER REGIONS

A borderland region is one in which the influence of a border on daily life and the identities of the people that live near it is detectable. This report uses two different approaches to define borderlands and maps their relationships to political violence: one based on fixed distances from borders and one based on accessibility to border crossings. Both approaches provide a more comprehensive understanding of how borders can influence conflict dynamics than definitions based on existing administrative units, whose size can vary greatly across countries (Figure 3.5).

The first approach conceptualises borderlands as extending no more than 200 kilometres from an international border. Using a cut-off distance allows to empirically assess whether the intensity of violence uniformly decreases with distance to borders through North and West Africa. To allow for meaningful comparisons between large and small states, the study creates a series of 10 km wide buffer zones along all the land borders in the region. Not all states have zones that extend to 200 kilometres, while others, such as Algeria, require that the buffer zones be extended out to 690 kilometres from a border. Violent events are then overlaid on the buffer zones and are assigned to the buffer zone that the fall within.

The second approach acknowledges that there is no consistent distance or threshold where border effects vanish or where the border does not matter. Instead, borderland regions are highly variable constructs. For example, a border city might be consistently impacted by the presence of the border because of cross-border trade and mobility while an adjacent rural area might experience few or no interactions. Further, given that the land areas of the states in the region are of quite different sizes (Algeria is more than 200 times the size of Gambia, for example), borderland regions should be expected to fluctuate from state to state and from border to border. Establishing such a criterion is challenging for such a vast region because border processes are fluid and not always tied to the locations of borders or borderlands themselves (Ptak et al., 2020[8]).

In order to address this issue, the report introduces a novel definition of borderlands based on their accessibility to the rest of the country. Borderlands are formally defined as the area that is accessible by road in less than four hours from any border crossing of the region, using local transportation and average speeds determined by topography. This relational definition helps understand whether violence tends to decrease with accessibility to borders, rather than just with distance. It is theoretically better adapted to capture the diversity of borderlands in the region and the ability of belligerents to travel across borders than a fixed buffer zone.

Travel times from border crossings are estimated using a similar methodology to that used to determine accessibility to urban centres in Europe (van Eupen et al., 2012[9]; Gløersen, 2012[10]), in West Africa (OECD/SWAC, 2017[11]; OECD/SWAC, 2020[1]; OECD, 2019[12]), East Africa (Macharia, Mumo and Okiro, 2021[13]), and at world level (Nelson et al., 2019[14]; Weiss et al., 2018[15]). The logic behind the accessibility model used to define borderlands is similar to the one presented in Box 3.1 to delineate trade hubs' areas of influence in Niger. In both cases, the road infrastructure and urban network used by local populations is modelled to identify new regions that are potentially more influenced by border dynamics than the rest of the country.

The first step to measure travel times is to quantify at which speed people travel across the region by local means of transportation. For this, North and West African countries are divided into cells of the same size and all datasets are converted to raster datasets with

Figure 3.5

Borderlands defined according to buffer zones, travel times and administrative units

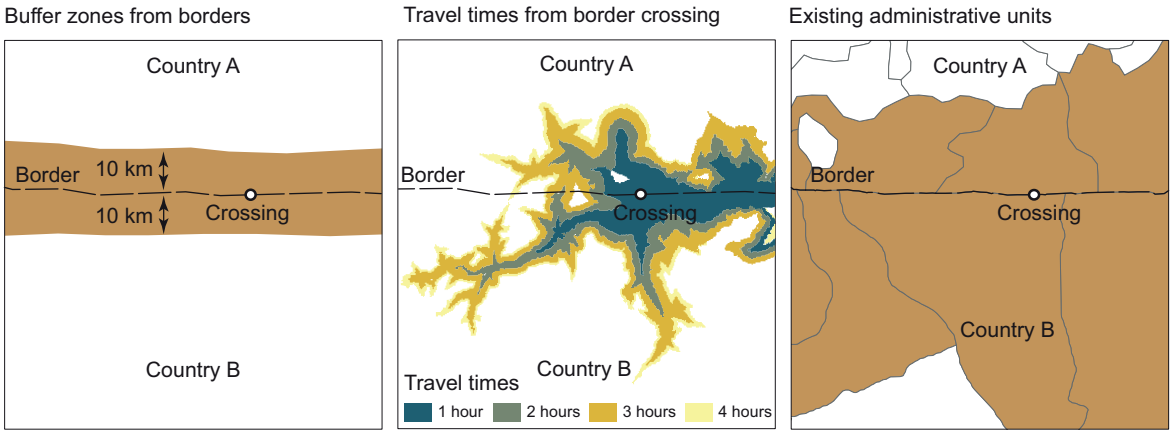
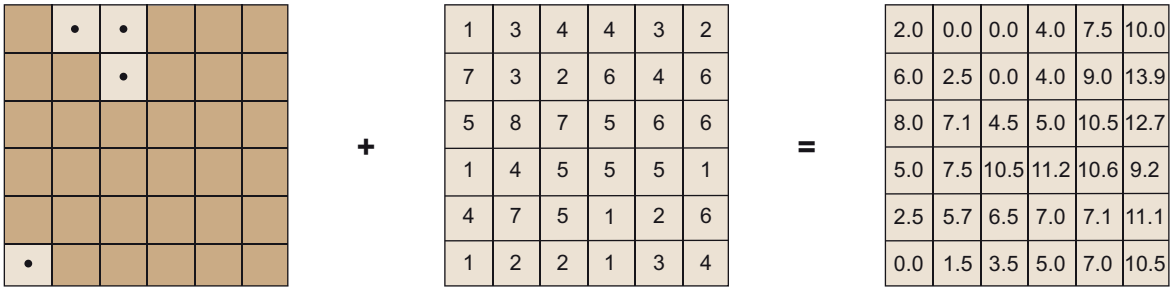


Figure 3.6

Calculation of travel time from each border crossing based on a friction surface grid



Source: Adapted from OECD (2019[12]) by the authors.

Box 3.1

An algorithm to delineate borderlands according to trade

In the Sahel, borderlands are at the core of political and fiscal competition between states and armed groups. The spatial representation of borderlands is a condition for political dialogue and technical co-operation among security actors. Border agencies, the military and experts use either administrative units or buffer zones extending from the border to represent borderlands. However, neither the smugglers nor the armed groups are limited by administrative lines or fixed distance from borders. Moreover, some cities may be economically connected to borderlands but located very far from them, such as Agadez in Niger. This makes fixed buffer zones largely irrelevant to defining borderlands.

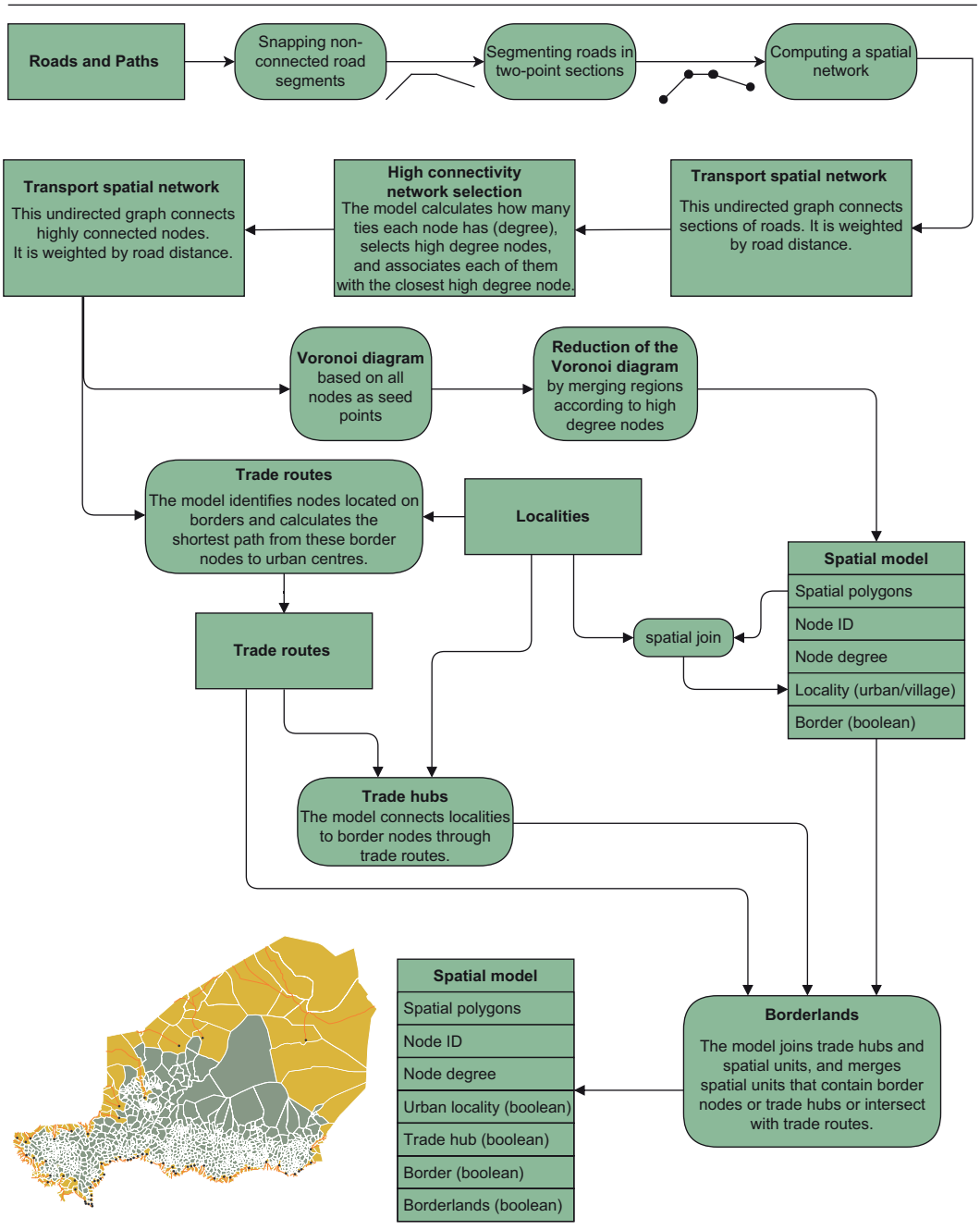
One of the ways to address these issues is to develop a spatial model that defines borderlands according to the road network and local markets used by traders and insurgents to move from one region or country to another. The model uses the sf and tidygraph packages in R to encode spatial vector data (Pebesma, 2018[18]; Pedersen, 2020[19]). The first step of the model is to transform the existing road network into a graph where the nodes represent the extremities of road segments and the weighted ties represent the road distances between nodes (Figure 3.7).

(Continues overleaf)

(Box 3.1 continued)

Figure 3.7

Flowchart of the spatial model algorithm



Source: Thomas Cantens for this publication.

The model then divides the territory into smaller regions organised around the nodes of the network to produce a Voronoi diagram. Each spatial units therefore captures a segment of road and its surrounding space. The model then calculates the number of ties each node is connected to (degree), selects the most highly "connected" nodes and associates each node to the closest high connectivity node. This allows to aggregate each precedent spatial unit of the Voronoi diagram to that of the closest high connectivity node. At this stage, the spatial model is composed of units shaped by highly connected places like cities, big villages, crossroads and the spatial influence of roads and tracks segments.

(Continues overleaf)

(Box 3.1 continued)

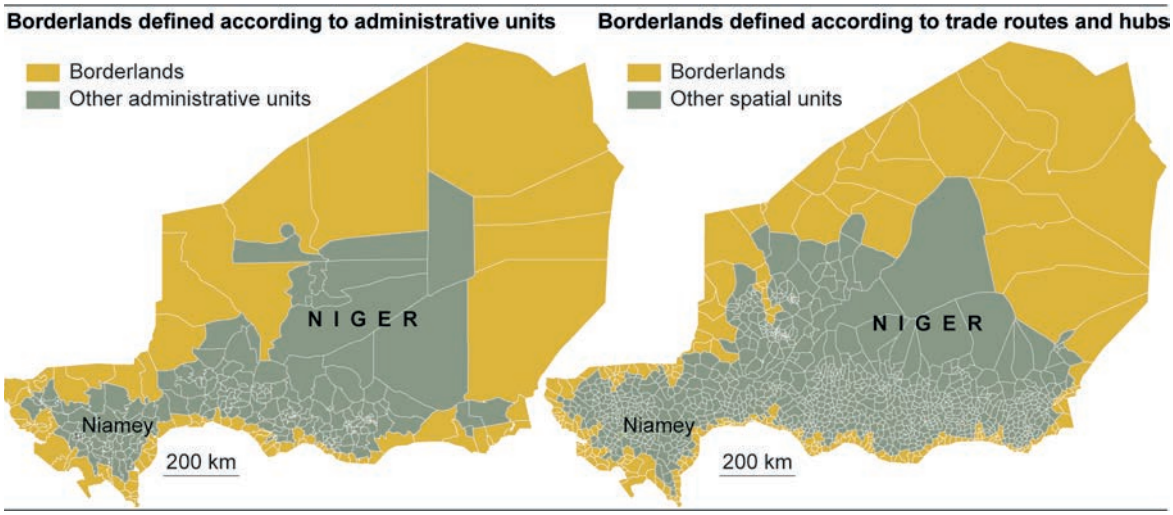
The final step is to delineate borderlands. All border crossings are identified and associated with the closest locality. Localities that are connected to the border are identified as trade hubs. Routes that join the trade hubs and the border crossings are defined as trade roads. By reversing the direction of spatial analysis, the trade hubs' areas of influence are computed as the spatial union of the Voronoi units crossed by a trade road or containing a trade hub. Borderlands are then the union of the trade hubs' areas of influence and the spatial units touching the border.

The use of trade routes and hubs to define borderlands provides a much more realistic view of African borderlands than existing administrative units (Map 3.2). In Niger, for example, where traders and insurgents have used borderlands intensively to conduct their operations, administrative borderlands represent 58% of the national territory (74 units out of 266). However, large portions of some of these regions are poorly connected to borders. When defined according to trade routes and hubs, borderlands only represent 49% of the country (249 units out of 1 259) and more precisely reflect the geographical extent of border dynamics.

Source: Thomas Cantens for this publication.

Map 3.2

Administrative model (left) and spatial model (right) for Niger



Source: Thomas Cantens for this publication. Data is from United Nations Office for the Coordination of Humanitarian Affairs (OCHA).

a spatial resolution of ~1 km (30'' arc seconds). Using this grid, the model then builds a 'friction' surface, in which the value of each cell is the time needed to travel across it depending on local factors, such the existence of roads, land cover, topography, and rivers (Figure 3.6). When following a road, the model follows a least-cost path algorithm and integrates the higher speed of flows along this axis. When travelling off-road, the model uses vegetation density to simulate the slowest speeds. Watercourses and steep slopes are considered potential obstacles that slow travel speed. The model does not impose a penalty when crossing borders, since the source points used to calculate travel times are located precisely on the border line.

The model uses road data from Open Street Map (OSM) and the Global Roads Open Access Data Set (GROADS), both from 2019. OSM provides mean travel speeds associated with four types of roads with average speeds ranging from 60 km/h for asphalted highways to 10 km/h for all unpaved roads not classified as secondary roads. Because the GROADS dataset does not provide

average speeds for West Africa, an average speed of 30 km/h is used as the reference speed for roads that are only included in this dataset. Off-road speeds and on dirt roads not covered by OSM and GROADS are estimated using land cover data from the European Space Agency (2010). Building on earlier studies in the region (OECD/SWAC, 2017[11]; Walther et al., 2020[16]) average speeds are estimated for 32 land cover classes of the region. To take into account the topography of the region, the model uses data produced by NASA's Shuttle Radar Topography Mission (SRTM) digital elevation model and interprets steep slopes and rivers as potential obstacles that reduce speed. A speed multiplication factor of 0.5 is applied to slopes from 15 to 45 degrees and a factor of 0 to slopes higher than 45 degrees. Using OSM and GROADS road data, the model applies a speed multiplication factor of 0.5 to correct for waiting time at ferries and lower speeds at bridges.

A total of 1 480 border crossings were identified where one of the road segments cut an international boundary. The vast majority of these border crossings are located in the densely populated regions of North and West Africa rather than in the Sahara, where population and roads are rare. The unequal distribution of population and roads explains that borderlands cover a much larger extent in the northern and southern parts of the region. However, most movements in the Sahara occur off-road and are not necessarily captured by the accessibility model. This distortion was corrected by adding a series of buffer zones on every segment of border where the absence of permanent roads does not allow to calculate travel times.

The model then uses 2019 population data from the Land Scan Global Population Project (Dobson et al., 2000[17]) to calculate the population basin of each border crossing. This dataset is a global population database compiled on a 30" x 30" latitude/longitude grid. Each grid estimates population counts from sub-national census data in combination with a series of other factors, including land cover, slope, road proximity, and high-resolution imagery. Four travel times ranging from one to four hours were calculated. Travel times of less than one hour correspond to short movements starting from a border crossing. It is estimated that crossing a border to get to another border city takes approximately two hours. Reaching a regional centre located within a given country generally requires three hours of travel. Four hours is the threshold at which day-to-day travel in border areas is no longer significant.

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