# Using disaggregated grid cells for a study on the onset of African Civil Wars

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Abstract

Empirical studies on the onset or duration of civil armed conflicts tend to be studied using country level measures, like for instance GDP per capita, primary commodities as percentage of GDP, type of regime, percentage of mountainous terrain within the country. Civil armed conflicts, however, do seldom extend the total area of a country but tend rather to take place in smaller regions where government control is hindered and/or where rebel groups have access to contrabands. These are factors that vary geographically. Since both the phenomena being studied and the factors that may explain them are sub-national, any statistical study of civil armed conflicts that applies country-level approximations is potentially flawed. In this paper, we present a disaggregated approach that may be an alternative or supplement to country-level investigations. We disagregate the country into smaller grid cells which we use as the units of observation. For each grid cell, GIS is used to identify whether or not the cell represent a location affected by conflict, and to generate sub-national measures on key explanatory variables. We use grid of three various resolutions (100 x 100, 150 x 150 and 200 x 200 km) in order to control the robustness of regression coefficient on various aggregations. In an analysis were we used an initial 100 km grid, the units show very strong cross-sectional correlation – that is, the likelihood of conflict for any grid is largely conditional on the conflict involvement of contiguous units. To account for spatial autocorrelation, we will therefore include a spatially lagged dependent variable based on first, second and third order neighbourhood.

## *Introduction*

Normally, empirically large N investigation use country measures when attempting to explain conditions that facilitate insurgency. Among the factors commonly associated with insurgency and other forms of domestic unrest are newly established, institutinally inconsistent, poor, resource dependent, corrupt, and discriminatory regimes. Some of these measures relate to the country as a single, political entity as, for instance, type of political system and whether or not the country is a major oil exporter. These factors are necessarily constants within countries and should be treated as such. However, many other factors commonly used in conflict research represent aggregates of phenomena that do vary considerable within the country.

We argue that the empirical study of civil war often suffers from a disturbing mismatch between theory and analysis. While standard statistical investigations are conducted exclusively at the country level, most hypotheses actually pertain to sub-national conditions. Consequently, quite a few commonly held notions about the correlates of civil war are still to be tested in an appropriate manner. Put generally, there is a tendency to neglect the spatial context of social phenomena (Abler et al. 1971; O'Loughlin 2001; Starr 2003). As an alternative or supplement to the traditional aspatial approach, we therefore present a research design where grid cells rather than countries consitute the units of analysis. We emphasise location: location of factors usually found as influencing the onset of civil armed conflicts and location of where those conflicts actually took place. Buhaug and Lujala (2005) argue that researchers have not been able to establish a clear link between the geographic distribution of physical and human factors and civil conflict mainly because most analyses use country aggregates and fail to control for local conditions. We have therefore used geographic information systems (GIS) to generate dissaggregated variables of factors usually accosiated with the risk of civil armed confict onset as well as an improved dataset represent the geographical extensions of internal armed conflicts.

We do not develop new theory or draw on one particular theoretical stand. Rather, our aim is to investigate whether certain geographical factors associated with insurgency are able to explain the onset of domestic conflict on a sub-national scale by using dissaggregated tesselated grids as our unit of analysis. There are at least three difficulties involved with the use of dissaggregated tesselated units: the problem of selecting appropriate form, size and location for the spatial units. Although there are several alternative geometric shapes possible, quadrate shapes are commonly used in empirical disciplines involving fieldwork like geography and biology. We adopted the convention on using regular grids as the form for our spatial units. The size of the grids (or scale) should fit the positional accuracy of our dataset, but for the number of dataset we use, there is a wide range of positional accuracy. While we are able to portray the conflict promoting factors at the resolution 10 km or better, the locational accuracy of the area affected by armed civil conflict are very cource, represented with a locational accuracy somewhere between 50 and 100 km. Until we are able to represent these more accurately, we advocate the use of a 100 x 100 km grid. However, if the spatial unit system in a particular study was specified differently (e.g. 100 km versus 200 km resolution), we might observe different relationships, a problem referred to as the modifiable areal unit problem, MAUP (see Wrigley et al. 1996). ‘The MAUP is unfortunately endemic to all spatially aggregated data and will affect all analysis and modelling methods that are sensitive to spatial data, only those methods which are very insensitive to spatial patterns have any change of being robust!’ (Openshaw & Alvanides, 2001: 282). To improve the robustnes of our methods, , through the use of Geographic Information Systems (GIS), we divide the spatial domain of our analysis – Africa – into grid cells with a resolution of 100x100 km, 150x150 km and 200x200 km (see Figure 1). For the grid cells with 100 km resolution, we have two alternative representations with 52 % overlap (offset of 42 km W and 11 km S).

Figure 1 about here.

In general, the MAUP consist of two subproblems referred to as the scale effect and zoning effect. When the study area is tesselated into units of different spatial configuration schemes from which data variables are compiled, it is referred to as the zoning effect. Hopefully, our two sets of 100 km grids, located with 52% overlap, will allow us to adjust for this influence. When data at different scales or resolution bring about inconsistent results, it is reffered to as the scale effect. Which is the reason why we have therefore generated variables for three different resolutions (100 km, 150 km and 200 km); in order to control for the scaling effect.

As indicated in Figure 1, each grid cell is assigned to one country only. Grid cells that cover international boundaries and thus overlap several countries are defined as belonging to the country that dominates the area of the grid cell. As there are several small countries in Africa we carefully located the 200 km grid to assure that each country became represented with at least one grid cell. Since there are several capitals being close to each other it was impossible to locate the grid without ending up with grids containing two capitals[1]. Since this would make the calculation of distances from capitals difficult, four capitals were slightly relocated[2] as demonstrated in Figure 2 for Conacry.

Figure 2 about here.

[1] Kinshasa and Brazzaville is about 20 km apart, Porto Novo and Lagos about 80 km apart.
[2] Conakry (Guinea) 42 km W, Porto Novo (Benin) 18 km N, Malabo (Eq Guinea) 17 km SW and Maseru (Lesotho) 2 km W.

Three years during our sample period (1970–2001) saw major changes to the outline of the international boundaries: 1990, the separation of Namibia from South Africa; 1993, the separation of Eritrea from Ethiopia; and 1994, the return of the Walvis Bay area to Namibia. Accordingly, we need four grid representations of Africa. Figure 1 illustrates the final period, from 1994 to 2001.

The sample of conflicts is based on a GIS version of the Uppsala/PRIO dataset (Gleditsch et al. 2002), where the conflicts are represented by polygons to reflect the geographical area of the battle zones. Grid cells that overlap with a conflict polygon are thus coded as having a civil war onset in the initial year of the conflict. Each unit is further assigned specific values on a number of space-varying and potentially conflict-promoting variables, including relative location, share of rough terrain, population density, proximity to resource production, level of infrastructure, and language. The results from an initial statistical analysis of African cells, 1970–2001, differ markedly between the territorial and governmental conflict models. In the former case, we find considerable evidence that geography matters. The risk of separatist conflict is highest in regions with low population density, limited rough terrain, distant from the capital city and near the state border. In contrast, the local risk of governmental conflict is highest in urban regions and near the state border.

<u>The geographical extension of internal armed conflicts</u>

The conflict data are based on the armed conflict database (Gleditsch et al. 2002), which includes every contestation between a state government and an organized opposition group that caused at least 25 battle-deaths per year. The Uppsala/PRIO Armed Conflict Dataset is unique in that it characterizes each armed conflict with a pair of co-ordinates (latitude and longitude) indicating the geographical centre of the conflict area and a radius for the extension of the conflict zone (see Buhaug and Gates 2002). The radius of the conflict zone equals half the distance between the two most separated conflict locations, rounded upwards to the nearest 50-km interval to ensure that all significant battle zones were covered. The simplified representation by circular shapes means that some conflict zones will inevitably cover areas not affected by the conflict, thus overestimating the total area of the geographical extension of an internal conflict. We improved the dataset geographically regarding the domestic conflicts that affected Africa during 1970 to 2001. Based on the same descriptive information that were used for determining the radius value (various volumes of Keasing's as well as the conflict data archive at Uppsala University), we replaced the crude circular conflict zones by a collection of polygons covering the areas where the fighting actually took place. We distinguish between conflicts over territory (secession) and conflicts over governance (coups, revolutions) since these types of conflicts are likely to be shaped partly by different conditions. The two dichotomous dependent variables measure the outbreak of territorial/governmental civil war. Any cell that overlaps with a conflict zone is coded as having a conflict in the given year (Figure 3).

Figure 3 about here.

In order to test the proposed hypotheses, we have generated a number of relevant covariates that have values specific (if not necessarily unique) to each particular cell. Below these are introduces under four different headings: poverty, access to natural resources, safe heavens and population/ethnicity.

<u>Poverty</u>

From country level statistics: the most prominent and robust factor associated with the occurrence of civil war is poverty (Collier & Hoeffler 2002, 2004; de Soysa 2002; Fearon & Laitin 2003; Hegre et al. 2001).[3] There is, however, disaggrement on how to interpret these results and the mechanisms through which wealth prevents conflict are less established. Some maintain that per capita income is a proxy for state strength, meaning that richer regimes are better able to monitor the population and conduct effective counterinsurgencies (Fearon & Laitin 2003). Another popular interpretation is that poverty lowers the opportunity costs of rebellion. In poor countries were wages are low and unemployment rates are high, it may be difficult among young males to find better paid work than joining a rebel group. Consequently, income forgone by joining a rebel group is comparably low (Collier & Hoeffler 2004). This interpretation, however, does seem to have some similarities with examples on ecological fallacy. Here is what O'Sullivan and Unwin (2003: 32) uses as example on ecological fallacy:

[3] The relationship between poverty and conflict is most certainly a reciprocal one in that conflict might also lead to poverty (see Alesina & Perotti 1996).

> '… we might observe a strong relationship between income and crime at the county level, with lower-income areas being associated with higher crime rates. If from this we conclude that lower-income persons are more likely to commit crime, we are falling for the ecological fallacy' (O'Sullivan and Unwin, 2003: 32).

Similarly, if we observe a strong relationship between GDP and armed conflict at the country level, with countries with lower GDP being associated with frequent onset and/or long duration of armed conflicts. If we from this conclude that lower-income persons are more likely to join rebell groups, we are falling for the ecological fallacy, ignoring that a strong aggregated relationship does not necessarily explain lower level phenomena. The "opportunity cost" proposition my still be correct, but it's conclusion should be based on individual level data or at least, we would suggest, a dissaggregated level.

Although the ecological fallacy problem has been known for a long time, the effects is not particular well understood but, in general, regression relationships are strengthen by aggregation (O'Sullivan & Unwin 2003). We may therefore expect less strong relationship when using measures at dissaggregated levels (like the grid cell level) than if we continue to use country measures. The country measures represent arbitrary aggregates related to the sub-national phenomena they try to explain. As internal armed conflicts are events taking place usually within small parts of a country, the use of grid cells is a much less arbitrary aggregation than the use of country units, at least for relatively small grid sizes. However, the smaller the grid cells the more severe might the problem of spatial autocorrelation become.

Unfortunately, we do not have good indicators of wealth or social and economic inequalities for our spatio-temporal domain so we cannot test whether or not a dissaggregated measure of wealth has a weak or strong relationship. Rather, we investigate the nexus between another aspect of development and domestic armed conflict. Infrastructure presumably follows the spatial pattern of health and unemployment in that the most inauspicious regions are also the regions with the least developed road network. Moreover, roads are essential to the projection of state authority, and nowhere more so than in Africa. This explains why, according to Herbst (2000), colonial leaders who sought to physically extend their power were obsessed with roads. Roads provide the only form of access to most rural communities. Populated regions with few or no road connections to the capital are likely to be disadvantaged, politically as well as economically. Moreover, remote regions are harder to reach by government forces and are therefore ideal for organizing a rebellion. This compares well to Murshed and Gates (2005), who find that the Maoist insurgency has been particularly severe in the less developed Nepalese districts

Based on road data from ESRI's *Digital Chart of the World*[4], we measured the logged total length (km) of major roads in each cell. Since we found using the initial 100 km grid that road density is positively correlated with population density (r=0.63), we analyze these measures simultaneously in order to discern any effect of infrastructure that is not due to settlement characteristics. Admittedly, this is a suboptimal approximation of local development. When aggregated to the national level, the country average of logged road length per capita nevertheless correlates with logged GDP per capita at a respectable 0.56. Moreover, the lack of temporal variation in the road data is less problematic than initially feared, since Herbst (2000) reports a very strong positive correlation between density of roads at independence and density in 1997 among African states, meaning that the country rank order (as well as absolute length) of roads per square kilometer is largely constant throughout the investigated period.

Access to natural resource

Armed conflict is costly and throughout the 1990s, many armed groups have relied on revenues from natural resources such as oil, diamonds or other gems to substitute for diminishing Cold War sponsorship (LeBillion, 2001). In an attempt to investigate the correlation between natural resources and the presence of armed conflicts, most scholars proxy a country's 'resource wealth' by the ratio of its primary commodity export to its GDP. Collier & Hoeffler (2002) found in their initial results that a country's dependence on primary commodities is strongly correlated with the likelihood of civil war. Efforts by other scholars to replicate the primary commodities – civil war correlation have, however, often failed. Ross (2004) claim that the Collier & Hoeffler (2002) study linking primary commodities to civil war appears to be robust only when scholars use Collier & Hoeffler's own list of civil wars, or something close to it. This unrobustnes may, according to Ross, partly be the result of an overly broad 'primary commodities' variable. The

[4] The Digital Chart of the World (DCW) is a comprehensive 1:1,000,000 scale vector base-map dataset of the world. It consists of spatial and textual data that can be accessed, queried, displayed, and manipulated with GIS software. The database was originally developed by the Environmental Systems Research Institute (ESRI) for military use, and then released for commercial use in the mid-1990s.

‘primary commodities’ variable includes not only those commodities that appear to be strongly linked to conflict (e.g. oil), but also those that do not (e.g. agricultural goods). If only a subset of commodities is associated with conflict, then the broad correlation between the primary commodity variable and conflict may be weak or unstable’ (Ross 2004: 342). Consequently, the ‘primary commodities’ variables should be disaggregated categorically into into variables on oil, timber, gems et cetera. In addition, since the location of natural resources affect the the occurrence of war (Addison et al, 2002) the ‘primary commodities’ variables should also be disaggregated geographically. In the case of Angola, LeBillion argue that oil and diamonds are neither the cause nor the only motivation for the conflict, but their availability and spatial distribution of these resources have been crusial in the course of the conflict (LeBillion 2001). Motivated by these and similar arguments highlighting the importance of location of natural reources, the Centre for the Study of Civil War (CSCW) have initiated data collection projects that so far resulted in global spatio-temporal dataset on diamonds (Gilmore et al 2005) and petroleum (Lujala et al 2006) as well as ongoing work with gemstones. We believe that by using locational data on, for instance, the location of oil and gas installation, we are better able to study how petroleum contributes to the risk of war. Our underlying assumption is that it is the proximity to these installations that increases the risk of separatist rebellion, like in the contemporary conflicts in Southern Sudan and Cabinda, Angola. Unless the rebels control areas of extraction or transport routes, they cannot exploit the lootable commodity for financial gains. Hence, we measured the logged distances (km) from the centroid of each cell to the nearest secondary diamond, petroleum (both onshore and offshore fields) and gemstone deposit. Grid cells in countries without diamonds/petroleum were assigned values similar to the largest recorded resource-centroid distance for the given resource type.

Safe heavens

A recent FAO report claims that several armed conflicts take place in forested regions. Forest can provide refuge, funds and food for combatants and insurgents may use forested regions to hide from government troops. Besides, it is more likely for a government to ignore insurgents as long as they remain in remote forested regions (FAO 2005). In the same manner, also mountainous terrain may represent safe havens for secessionists. Studies that suggest that rebel movements prefer to operate from mountainous or densely forested regions use a variable expressing the average share of mountainous and/or forested terrain in the country (e.g. Collier and Hoeffler (2004), DeRouen and Sobek (2004), and Fearon and Laitin (2003)). Buhaug and Lujala (2005) reviews these studies and find that their results shows disturbing discrepencies, and, consequently, conclude that this terrain measure have so far failed to produce consistent and robust results. Again, Buhaug and Lujala's main argument is that this may be because location is ignored. As proxies for mountains and forests, we measured the logged percentage of each grid cell covered by the given type of terrain. Mountain data were received in raster format from UNEP (2002) and comparable forest data were downloaded from the web site of the Food and Agriculture Organization (FAO) of the UN[5]. The average African grid cell contains 19 % forested terrain and about 14 % mountains.

One of the results from Buhaug and Lujala is that the 'relative location of conflict matters: the further the conflict is from the capital, the longer it last' (Buhaug and Lujala, 2005: 400). In addition to use subnational dataset on mountainous and forested terrein, we also generated measures expressing remoteness by calculating distances from the state capital to the grid centroids assuming that governmental controll is strong in and near the capital but weakens with increased distance. A related argument concerns cross-border sanctuaries. In several recent wars, including the ones in Rwanda, Burundi, DRC, and Liberia, the main rebel groups operate from bases beyond the national boundaries, often with the tacit or spoken support of the neighboring regime. Access to foreign soil not only eases access to important trade markets but also acts as a safeguard against government intrusion. We therefore also calculted distances from the grid

[5] www.fao.org/forestry

centroids to the neareast international boundary assuming that closeness to international borders increases the suceptibility of experience armed conflict.

Roads are essential to the projection of state authority, and nowhere more so than in Africa. This explains why, according to Herbst (2000), colonial leaders who sought to physically extend their power were obsessed with roads. Roads provide the only form of access to most rural communities. Populated regions with few or no road connections to the capital are likely to be disadvantaged, politically as well as economically. Moreover, remote regions are harder to reach by government forces and are therefore ideal for organizing a rebellion. This compares well to Murshed and Gates (2005), who find that the Maoist insurgency has been particularly severe in the less developed Nepalese districts.

Population/Ethnicity

Prevailing theories on insurgency further suggest that the conflicts occur predominantly in the rural countryside; hence, we include a population density indicator. The population data are taken from UNEP-GRID[6], who has generated a raster representation of population counts for Africa at a resolution of 2.5 arc minutes (approximately 5 km at equator). The data are available for every decade since 1960 and give estimates for the number of inhabitants in each cell (see Tobler et al. 1997). We aggregated the population data to the desired grid resolution and applied linear interpolation to fill in data for missing years. Population values for 2001 were extrapolated from 2000. As usual, we take the natural logarithm of the measure (modified to population in 1,000s) to reduce outlier bias. Since all grid cells are equally sized, the population variable is essentially a population density measure. The most populous unit in the sample is the cell that covers Cairo and suburbs with about 15 million people in the year 2000 (corresponding to an average density of 1,500 persons per $km^2$).

Ethnicity is a concept difficult to define and even more to operationalize for systematic studies on a dissagregated level. Ethnicity may be considered as both a way in which individuals define their personal identity and a type of social stratification that emerges when people form groups

[6] United Nations Environmental Programme – Global Resource Information Database, data available from: http://grid2.cr.usgs.gov/datasets/datalist.php3#unep.

(Hiebert 2000). Toft define ethnic groups as 'composed of individuals who share (1) a common trait such as language, race, or religion, (2) a belief in a common heritage and destiny, and (3) an association with a given territory' (Toft, 2003: 19).

A popular belief is that a considereable number of contemporary civil armed conflicts involve fighting between members of different ethnicities. According to Sambanis (2001), roughly two-thirds of all civil wars between 1960 and 1999 are "identity conflicts", i.e. they are rooted in ethnic or religious differences. Sambanis and most other studies trying to link ethnicity to civil war uses an aggragated measure of ethnic diversity referred to as the "ethno-linguistic fractionalization" (ELF) index. The ELF index gives the probability that two randomly chosen individuals will be from the same ethnic group. A major weekness of using an ethnic fractionalization indices such as ELF that summarize a country's ethnic landscape with a single index of fractionalization is that it fail to incorporate potenially relevant information about the spatial distribution of groups within the country (see Posner (2004) for a profound discussion of this and other weakness of the ELF). We agree with Sambanis (2003) in that the regional distribution of ethnic groups may be more important than the extent of ethnic fragmentation in the country as a whole. This corresponds well to Melander (1999), who finds that violent conflict is more likely if an ethnic minority makes up more than 70% of the population in its home region. Toft (2003) goes further when she elaborate that ethnic groups have essential four settlement patterns: concentrated majority[7], concentrated minority, urban groups, and dispersed groups. Toft claims that the concentrated majority and the concentrated minority are the settlement pattern that are most likely to risk violence to gain sovereignty. If this is indeed a general pattern, Africa should be particularly predisposed to identity conflict since African minority groups are more spatially concentrated than minorities in other regions (Herbst 2000).

According to Rokkan and Urwin (1983), the most significant determinant of an individual's identity is language. People with distinctly different native languages are less likely to share a strong feeling of common identity. Language and other cultural distinctions are prone to be amplified by political and rebel leaders in order to rally support and recruit soldiers. Minority language is further likely to be associated with political discrimination.

[7] The operational meaning of majority is equal to or greater than 50 percent.

As a simple measure of cultural identity, we have generated a dummy variable signifying whether the majority of the population in each grid cell belongs to the same language family as the majority of the population in the capital city. Assuming that the language in the capital is the majority language in the country, we define deviating regions as having a minority language. The language variable is based on maps from Ethnologue (Grimes 2000), which were digitalized and converted to the grid structure. This is evidently a crude operationalization of the measured concept for two reasons. First, the largest language group in the capital need not be the most powerful ethnic group. This could be improved by adopting the work done by Posner (2004) and Cederman & Girardin (2005) who have, for a selected number of countries in Africa, identified the ethnic group in power and generated what they call a Political Relevant ELF (PREG). Moreover, it is probable that some groups belonging to the same language family may have very different identity ties. This seems indeed to be true for the case of Madagascar. According to Ethnologue all parts of Madagascar belong to the same language family[8] Malawi-Polynesian (see Figure 4a). The ethnicity map generated by CIA in 1976[9], however, portray a ethnic settlement pattern with much more diversity (see Figure 4b). Madagascar experienced an governmental armed conflict in 1971 when the National Movement for the Independence of Madagascar (Mouvement National pour l'Indépendance de Madagascar – Monima) led a peasant uprising in the southern part of Toliara Province. The conflict had probably nothing to do with "ethnic clashes"[10] but their geographic extension is shown in the maps in Figure 4 to illustrate how the operationalization of an identity variable may affect our results. From our analysis where we have used language families the conflict took place in an area having the same language family as in the capital. However, if we instead had used CIA's definitions on ethnic groups in Madagascar, we would have found that the conflict took place in an areas populated with other ethniv groups than the one in the capital. The discrepancy between these two representations are disturbing and cast doubt on the reliance on using language families as a proxy for ethnic group formations. Returning to the ELF and PREG index values for Madagascar which are 0.00 and 0.06 respectively (Posner 2004) do support the use of Ethnologue's distinction of language families

[8] The same is true for Rwanda and Burundi.
[9] http://www.lib.utexas.edu/maps/madagascar.html
[10] The main issue for the conflict was government pressure for tax collection at a time when local cattle herds were being ravaged by disease.

rather than CIA distinction of ethnic groups. Other arguments in support for the Ethnologue maps are the consistence they have for a large number of countries and that the maps are not 30 years old.

The CIA map, however, do shows another very interesting quality: the combination of ethnic group boundaries combined with population densities. If we are able to draw reliable lines separating ethnic settlements, we could join it spatially with population data. Following the assumptions that territorial distribution of ethnic groups are similar over time, we could do so for the entire period for which we have population data. As a result, we would have a spatio-temporal datasett on a 10 km resolution where we for each grid cell would know both which ethnic group (or at last the language spoken) that populate the area as well as an estimate of the population count for the same area. If we also knew the ethnicity of the group in power, we could have a dissaggregated political relevant, ethno-linguistic dataset.

## *Research design*

The empirical analysis consists of two parts. The first focuses solely on the association between relative location, terrain, resources, and language, and the two types of intrastate conflict. Since nearly all these factors are time invariant, a time-series approach is not desirable. Rather, we test the hypotheses using a collapsed dataset with only one observation for each of the grid cells. The dependent variables (one for each conflict type) then simply distinguish between units that remained at peace from 1970 to 2001 ("0") and units that hosted one or more conflict in the period ("1"). Covariates that do vary temporally, such as population density, are represented by their mean values. The second part of the analysis evaluates the robustness of the initial findings by using a time-series cross-sectional (TSCS) setup with country-level control variables. Here, each of the 3,207 units (for the initial 100 km grid) are observed annually from 1970 (or year of independence) to 2001, giving 101,425 observations, or "grid-years". In these models, the dependent variables denote the outbreak of conflict, i.e. only the first year in conflict is coded "1". Consecutive years of conflict are coded as missing, since units in conflict are not at risk of having a new onset.[9] Grid-years without conflict are coded "0".

The units show very strong cross-sectional correlation – that is, the likelihood of conflict for any grid is largely conditional on the conflict involvement of contiguous units. To account for spatial autocorrelation, we test two types of spatially lagged dependent variables (see Anselin 1988). The most influential spatial lag measures the share of conflict among contiguous grids in the same country. In our initial work (see Buhaug & Rød 2005) we only consided first-order neighbors to the east, west, north, and south as contiguous (a.k.a. rook contiguity). The units in the sample have between zero (islands) and four neighboring cells, and the lagged conflict terms (one for each conflict type) take on values between zero (no neighbor cells in conflict) and one (all neighbors in conflict). Since this measure is highly correlated with the dependent variable, it may potentially 'wash out' or bias even the most powerful independent effects. Hence, we also test a second, less deterministic lag, which simply indicates whether there is a conflict ongoing in any other part of the country at the time of the observation. In the tables below, we only report the results with the latter lag, except in (the few) cases where the choice of lag substantially affects the behavior of other covariates.

In the final, time-series analysis, the data are also likely to suffer from duration dependence, i.e. the conflict status of a unit at any time is related to its status in the previous time period. We reduce this problem by coding onset of conflict rather than incidence (all years in conflict coded as "1") and dropping consecutive years of conflict from the analysis. However, periods of peace will still be correlated over time. Hence, we adopt the procedure of Beck et al. (1998) by adding a peace-years count variable (which gives the number of years since independence or the end of the previous conflict) as well as three natural cubic splines.[11]

In order to better acount for autocorrelation, we have generated variables for the new 100 km, 150 km and 200 km grids were we count the number of neighbour cells as well as the number of these which are conflict cells. We counted the cells separately for 1., 2. and 3. order but only if they are located within the same country as the cell being investigated (see Figure 5).

[11] We tested several alternative specifications where we altered the number and shape of the splines. Although some of these alternative models proved to be marginally superior, they did not affect the reported estimates in any substantial manner.

## *Results*

As we only have run our analysis at the initial 100 km grid, the results below report our finding only for this grid representation.

What separates peaceful areas from those that provided grounds for armed hostilities in the period? Descriptive statistics of sample means (Table 1) show that grid cells with territorial conflict are, on average, closer to the border, further away from the capital, petroleum fields, and diamondiferous areas, they are less populated, less rugged, have less developed road network, and are more likely to contain a minority language than cells without conflict in the period. In addition, these conflict units are generally located in less economically prosperous countries than the random African grid cell. Areas with governmental conflicts differ by being closer to the capital, further away from neighboring countries, more densely populated, contain more rough terrain, are less likely to contain a minority population, and occur in more developed countries than the average unit of observation.

Table 1 about here.

This simple comparison of means reveals two trends. Almost all covariates show a stronger association with one type of conflict than the other and the deviations between the no-conflict and conflict samples for the two types are often in opposite directions. This discovery adds strength to our notion that governmental and territorial conflicts should be studied separately. Additionally, the expected geography of civil war, inspired by theories of insurgency, corresponds best to the territorial conflict type. This suggests, not too surprisingly, that the technology of insurgency is mainly a characteristic of separatist wars.

Next, we evaluate the performance of the independent variables in a multivariate setting. The results from cross-sectional logit analyses of territorial and governmental conflicts are presented in Table 2 and Table 3, respectively. To maintain parsimony we estimate four models for each conflict type. The first model in each case (Models 1 and 5) include only the base variables, i.e. the spatial lag and two indicators of relative location. These variables are present in all models. In addition, Models 2 and 6 include population density, road density, and terrain; Models 3 and 7 explore the effect of proximity to oil fields and secondary diamonds, while Models 4 and 8 include the minority dummy.

Not surprisingly, the spatial lags are very powerful. If some other part of a country experienced a territorial conflict in the period, the risk of conflict is more than ten times higher than if all other grid cells in the country remained at peace. The governmental models indicate an even stronger spatial relationship. Accordingly, the onset of conflict shows clear evidence of clustering – at least at the selected level of analysis.

The models in Table 2 further show that location matters: The risk of a separatist war is positively associated with the distance from the capital. In fact, the marginal effect of capital distance exceeds an order of magnitude: all else being held at the median, cells located approximately 1,500 km from the capital city (95th percentile value) have a predicted risk of separatist conflict of 16.9 %, compared to 0.93 % for cells less than 120 km from the capital (5th percentile value). The distance to the border also shows the expected negative sign, but the estimate is not robust to model specification and the effect is quite weak.

Table 2 about here.

In the second model, we introduce four additional explanatory variables: population density, road density, and mountainous and forested terrain. Popular views on insurgency predict that such conflicts are more probable in sparsely populated and underdeveloped regions and in areas with considerable rough terrain. Model 2 offers scant support to this conjecture. Only one of the variables, forested terrain, produces a significant estimate, and it shows the opposite sign of expected. Road density, too, shows an unexpected positive estimate, but its marginal impact on the model is diminutive. However, these four variables are obviously correlated (e.g. people settle along roads and roads are developed in populated areas). Both population density and road density have negative and significant effects on the likelihood of separatist conflict if they are included individually and without the terrain proxies. The mountain and forest variables, however, always suggest a negative association with territorial conflict. This counters the so-called rough terrain argument and also questions the credibility of country-level studies that claim a hazardous effect of terrain (see Fearon and Laitin 2003). We speculated whether this finding could be a consequence of the negative correlation between extent of rough terrain and country size. Larger African countries, on average, have relatively less rough terrain, and civil wars in larger countries usually cover larger areas (and thus a higher number of cells). Could it be that the negative impact of terrain on the risk of conflict is biased by the overrepresentation of conflict units in a few large countries? Apparently not. When we tested alternative terrain variables that are standardized by the country average of rough terrain, we found similar negative relationships. Accordingly, separatist conflicts are not only associated with less-than-average extent of rough terrain, compared to the random African cell; the conflicts also tend to occur in the least forested and mountainous regions of the conflict-ridden countries. While intuitively surprising, Buhaug and Lujala (2005) report a similar finding. This does not necessarily mean that the rough terrain proposition should be discarded for good. With better data, we might be able to evaluate whether rebel bases tend to be located in high and forested grounds, which is what a stripped version of the proposition would predict.[12] Moreover, the reader should keep in mind that the undertaken study only covers Africa, and the results may not necessarily represent the circumstances in other part of the world very well.

Model 3 tests the opportunity (or "greed") proposition that proximity to valuable commodities raises the motivation for, and hence the risk of, rebellion. Again, the results are mostly unsupportive. The petroleum proxy shows a weak positive effect, suggesting that aggrieved people in oil-rich regions are slightly less likely to seek secession than groups in other parts of the country. This finding does not differ if we consider onshore (or offshore) oil fields only. However, if we add a dummy to mark off countries without oil, the petroleum distance measure assumes the predicted negative effect. This is because the baseline risk of territorial conflicts actually appears to be higher among the non-producing African countries. Proximity to diamonds has a strong, deterrent effect on separatist conflict, and this finding is not biased by the resource-poor countries in the sample. This indicates that aggrieved people in diamond regions generally select another strategy to redress their grievance (see Model 7).

[12] See Raleigh and Hegre (2005) for an assignment along this line.

The deviating performance between petroleum and gemstones should not come as a big surprise, though. In contrast to alluvial diamonds, oil and gas resources are located within a limited area and extraction is only possible with the aid of skilled workers and specialized equipment. Aside from sabotage and blackmailing, only a recognized state can gain revenues from oil. Therefore, groups in oil-rich regions that want to secure the benefits from the natural goods are likely to seek independence. Secondary diamonds, however, can be extracted single-handedly and without advanced technology, and the extremely high value-to-weight ratio make them ideal for smuggling and other quasi-criminal activities typically associated with warlordism (see Le Billon 2001).

Finally, Model 4 indicates that cells with a marginalized language are about twice as likely to host a territorial rebellion in the period as the reference category, though the estimate is not statistically reliable even with a 10 % margin of error. In summary, Table 2 offers modest support to the theory on insurgency. African separatist conflicts occur predominantly in less developed regions at a distance from the center of state power, near neighboring states, adjacent to petroleum fields, but without access to secondary diamonds and with less-than-average mountainous and forested terrain. Table 3 presents a radically different picture. Most strikingly, the relative location indicators contribute little to the overall fit of the governmental models. However, the positive estimate for population density in Model 6 suggests that governmental conflicts are mainly urban events. The risk of a revolution or a coup is four times higher in the most densely populated areas than in the unpopulated parts of a country, all else held constant. Again, our proxy for local development, road density, fails to provide additional explanatory power. The sign of the estimate is now positive, however, as is the case for the terrain measures. Hence, it appears that the rough terrain proposition – at least for the case of Africa – is more in line with characteristics of governmental than separatist conflicts.

Table 3 about here.

Model 7 offers support to the notion of a resource curse, but only for the case of diamonds. Diamond-abundant areas have a significantly higher probability of hosting a governmental war than less affluent parts of the country. This contrasts the findings in Model 3 and suggests that Le

Billon's (2001) theorized link between diamonds and warlordism generally takes the form of (phony) claims to topple the regime. Proximity to petroleum fields does not affect the estimated risk of governmental conflict to any significant extent.

The final model in Table 3 again demonstrates that territorial and governmental conflicts differ substantially. Minority language, which is associated with a slight increase in the risk of secessionist rebellion (Model 4), lowers the probability of governmental conflict by a factor of 2.5. This is not surprising; even if a marginal group were to succeed in toppling the regime and see through political reforms, its numerical inferiority will be a serious impediment to sustained political influence. Realizing this, aggrieved minority groups are more likely to opt for the exit strategy as a means to redress their grievance.

The joint insight from Table 2 and Table 3 supports our assumption that geography differs in its impact on territorial than governmental conflict. Yet, the reported analysis excludes important attributes of the countries involved, such as type of political system and economic level of development, that might potentially affect the estimated relationships. Since these factors often vary considerably over time, they must be represented by time-varying covariates and evaluated in a time-series analysis.

In Table 4, we re-estimate Models 2 and 6 (excluding the irrelevant road measure) with a TSCS dataset, controlling for squared level of democracy and log GDP per capita. Corresponding to the results above, remote regions are more likely to host a separatist rebellion (Model 9) whereas distance from the capital has little impact on the risk of governmental conflict (Model 10). We also see that the distance to the border is now strongly negatively associated with secession. The models further strengthen the finding that populous regions are predisposed to governmental conflicts while separatist movements are most likely to emerge in sparsely inhabited areas. The terrain estimates are generally less robust, but substantiate our impression that the rough terrain argument is not applicable to the broad sample of domestic conflicts.[13]

[13] We also assessed the effect of the resource proxies with the TSCS data. These models reproduced previous findings in that proximity to diamonds is associated with governmental conflict while proximity to petroleum increases the risk of separatist conflict. The size and significance of the latter estimate was sensitive to choice of spatial lag, though.

Table 4 about here.

In line with previous findings, we see that institutionally inconsistent regimes have a higher baseline risk of intrastate conflict than more democratic or autocratic systems. Moreover, the pacific effect of institutional consistency is largest with respect to governmental conflict. The marginal impact of democracy is nonetheless moderate compared to some of the geographic measures, in particular regarding territorial conflict. This may be because Africa is a relatively homogenous continent when it comes to regime type, with a mean polity score of -3.9 (signifying somewhat autocratic) and a standard deviation that is smaller than that of any other continent in the world in the sample period. GDP per capita also differs in its impact on the two models. Wealth apparently is a much better guarantee against a disintegration of the state boundaries than against violent attempts at regime change. This result, too, might well reflect a particular African effect as African countries are on the whole very poor. In fact, the least developed European country (in terms of GDP per capita) in the sample period, Romania in 1970, has a higher development score than the mean value for African countries between 1970 and 2001.

The conversion to a time-series structure with repeated observations and the introduction of regime controls did not cause radical changes but increased the estimated effects of most geographical variables in the direction suggested by the initial analysis.[14] All else being equal, the risk of separatist conflict is highest in remote regions with less-than-average mountainous terrain whereas governmental conflicts are most likely to occur in urban centers (Figure 6). From this follows that rebellions in geographically larger countries tend to take the form of secession, whereas small countries offer better opportunities for capturing the state. These findings imply that Fearon and Laitin (2003) are only half right. Whereas most factors associated with insurgency are well able to explain the local onset of territorial conflict (exactly because most territorial conflicts fit Fearon and Laitin's definition of insurgency), they are either unrelated to the onset of governmental war or show an opposite effect. In fact, since most civil wars are governmental, not territorial, one might argue that "conditions that favor insurgency" only explain a minority subset of all domestic conflicts.[15] Future work will determine if these findings are universal or whether there is some kind of "Africa effect" with respect to the local geography of civil war.

Figure 6 about here.

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[14] These models were also estimated through a multilevel analysis, using MLwiN. This did not lead to dramatically different results. Due to computational limitations, more conventional multilevel applications, such as gllamm for Stata, were unable to handle the large number of observations.

[15] Both the Uppsala/PRIO list of Armed Conflicts and Fearon and Laitin's sample of civil wars include a higher number of governmental wars (65%) than wars over territorial control (35%). For the spatio-temporal domain of this investigation – Africa since 1970 – the dominance of governmental conflicts (48 versus 11) is even more striking.

## *Conclusion*

This study has presented an innovative research design where grid cells rather than countries constitute the cross-sectional units of analysis. We argued that this design is better suited to test theories of civil war that essentially relate to local conditions. Among these are theories on rough terrain, greed/opportunity, ethnic diversity, and center vs. periphery. The analysis, which was conducted separately for territorial and governmental conflicts and included both collapsed and time-series estimations, produced some promising findings. Territorial civil wars – that is, wars over autonomy and secession – are much more likely to occur in remote and sparsely populated regions. In contrast, governmental conflicts occur predominantly in urban and diamond-abundant areas. The analysis also uncovered an unexpected negative association between rough terrain and territorial conflict. Both proximity to oil fields and local dominance of a minority language appear to increase the risk of separatist wars, although these variables were sensitive to choice of spatial lags and other model specifications. Road density, our proxy for local development/government reachability, failed to make an impact on the estimated risk of civil war. Overall, the territorial models correspond best to the broad theory of insurgency. Governmental conflicts are less determined by geographical attributes of the region but presumably more dependent on case-specific political events.

Several factors call for moderation when assessing the importance of the reported findings. First, the sample is limited to Africa since 1970, which calls into question the generalizability of the results. In fact, there are ample reasons to believe that Africa is a special case as it has the highest share of domestic conflict and is culturally more diverse than other continents. Also, since African conflicts more often are contests for state control, the relative scarcity of territorial conflicts might potentially produce biased results. This should not be a huge problem, though, as we separate between these two types of conflict in the analysis. Even so, the reader should be cautious about making too general statements from the reported findings.

Second, there is always a potential for producing misleading findings due to poor operationalizations and omitted variables. In particular, we need to develop better measures of local level of development and ethnic composition in addition to factors that were excluded from this study (most notably economic inequality). While such data may be available on a sufficiently low level for the present time, it is obviously difficult to get good data for previous decades. That said, Miguel et al.'s (2004) procedure to use rainfall deviation as a proxy for economic shocks demonstrates the usefulness of instrument indicators.

Third, the radical research design introduces several complex correlation structures on multiple levels in both space and time that standard statistical packages are not designed to handle. Even so, we believe that the disaggregated approach has great potential and will prove invaluable as a supplement to conventional country-level analyses. When the researcher seeks to explore how attributes of governments and the political system affect the risk of domestic instability, countries constitute the natural units of analysis. If the researcher, however, seeks to understand the role of local conditions, a disaggregated design should be employed. Consequently, a natural next step is to develop better sub-national measures of relevant conflict-promoting factors, as well as geo-referenced data on the location of the conflicts themselves.

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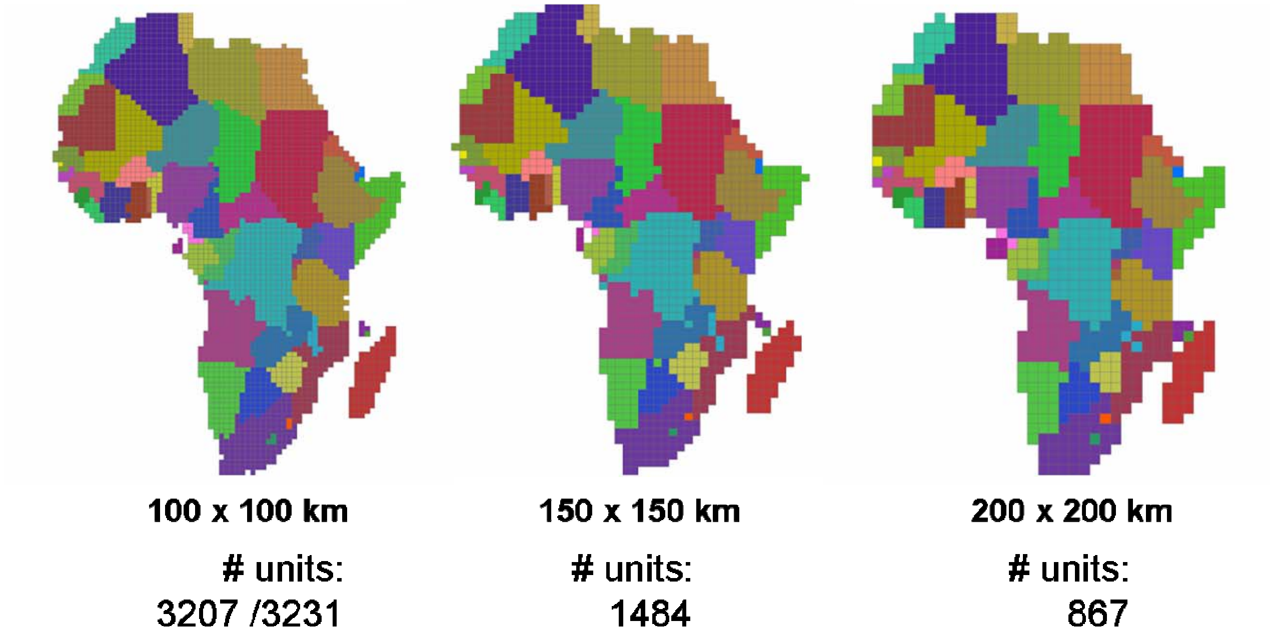
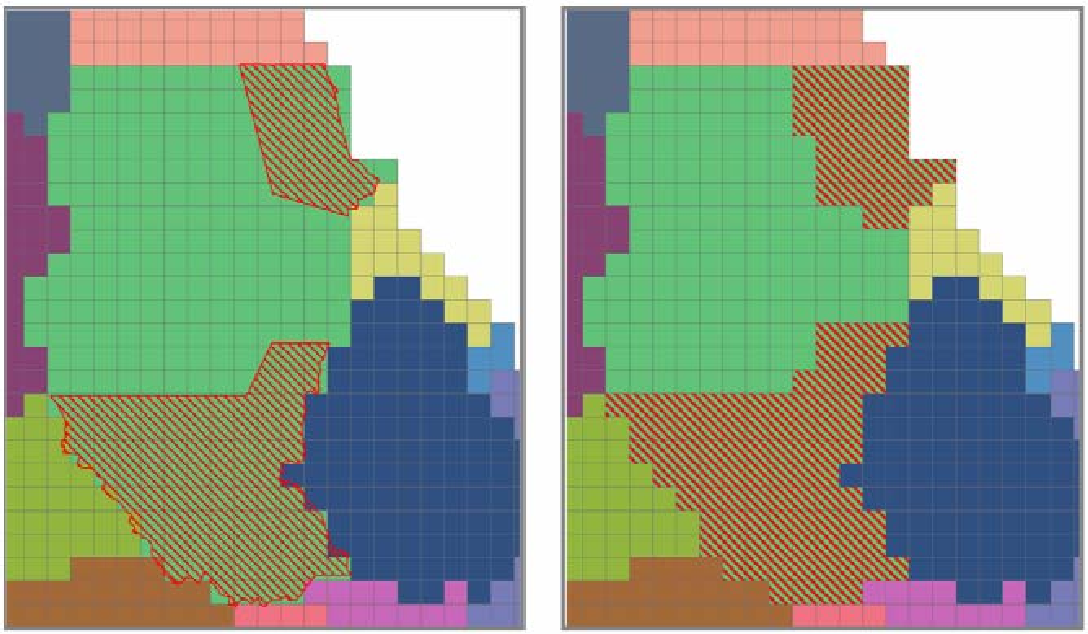
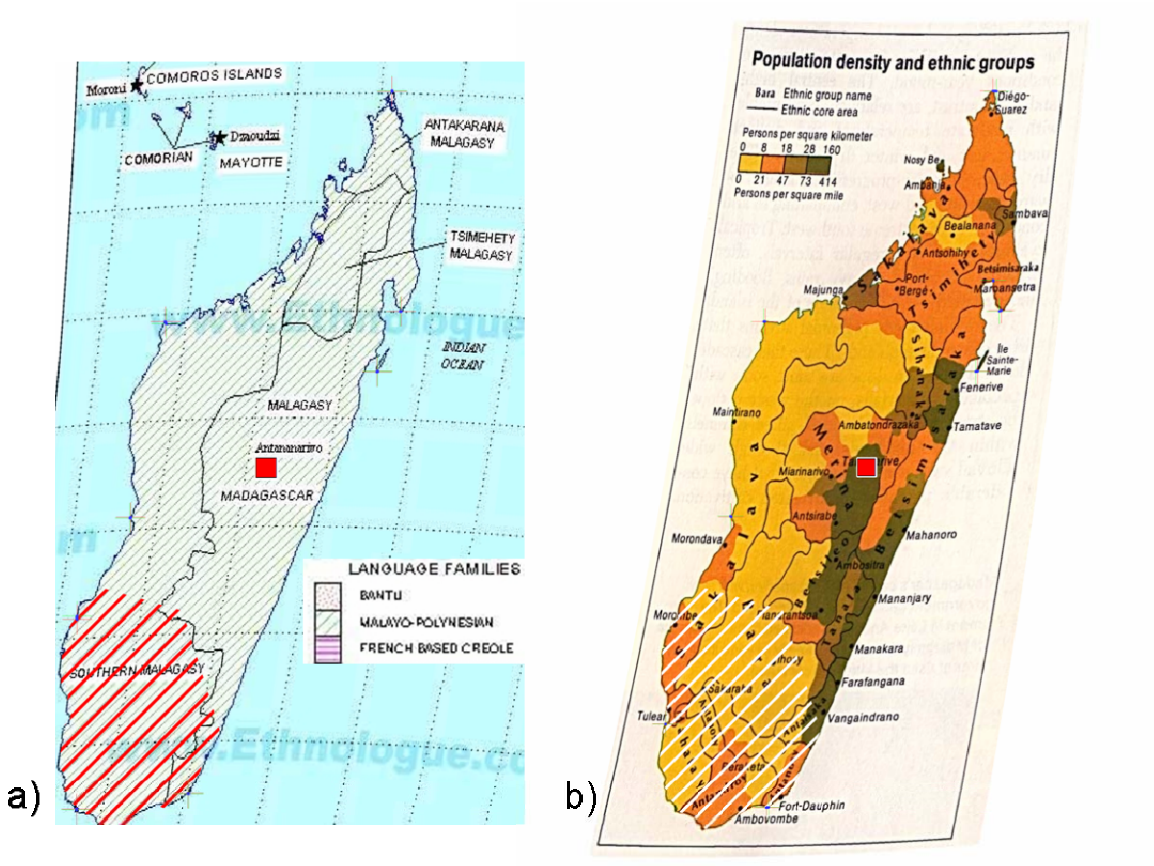



*Figur 1: Grid cell representations with various resolutions and their number of units.*

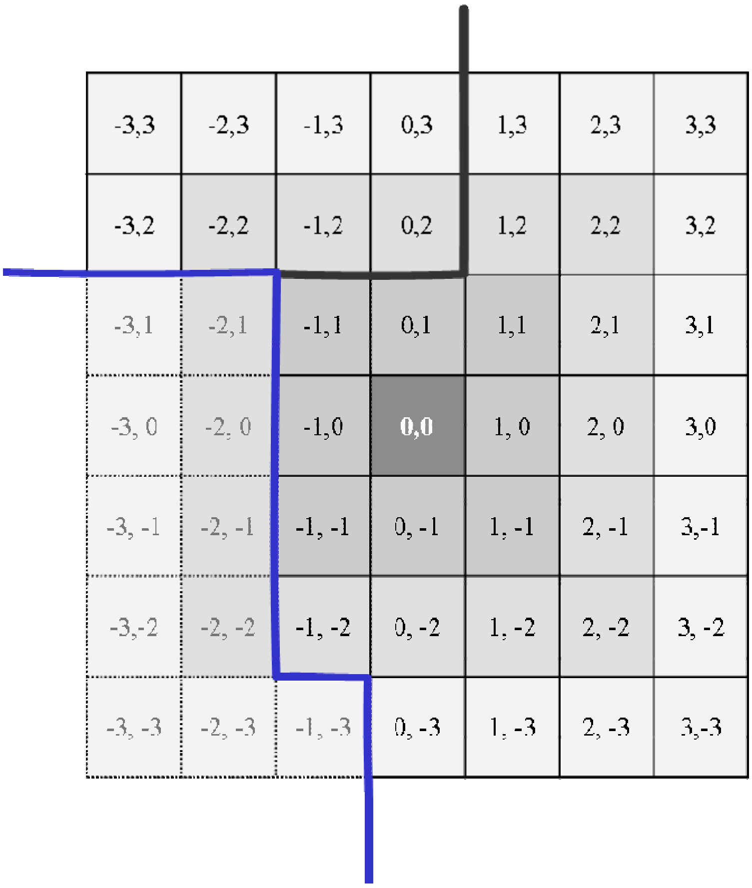


*Figur 2: Conflict polygons and conflict cells in Sudan, 1997 – 2001.*

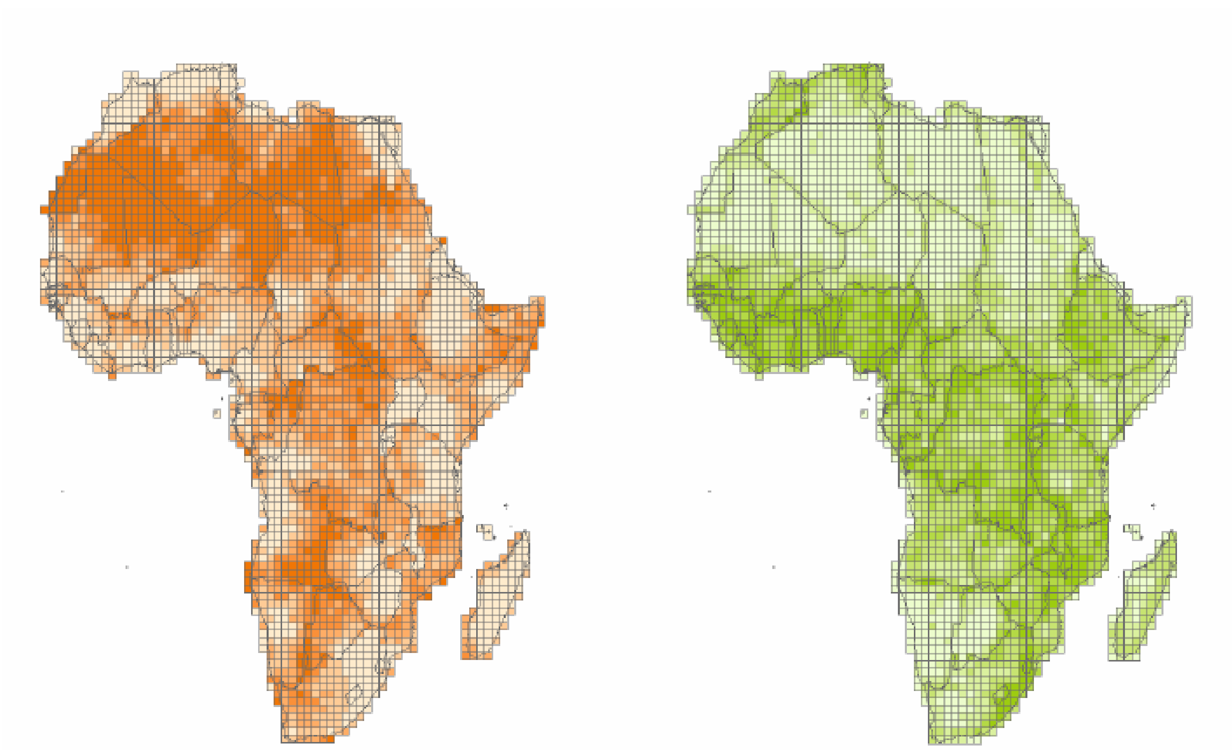

*Figur 3: Relocation of Conacry, 42 km North.*
*The red lines show the 200 km grid.*




*Figur 4: Ethnologue's language families (a) versus CIA's ethnic groups(b). Line-filled area represent the geographical extension of the armed conflict in 1971.*




*Figur 5: First, second and third order neighboors. Blue and black lines represent coast and state boundaries respectively.*



*Figur 6: Zones at risk of territorial and governmental conflict.*

Note: The maps illustrate the relative risk of territorial (left) and governmental conflict as a function of distance to the capital city, distance to the state border, population density, and share of mountainous and forested terrain for the average African unit in 2000. Darker shades signify higher risks. Calculations are based on estimates in Table 4.

**Table 1 Comparison of sample means: conflict and no-conflict cells**

| | Territorial conflict | | Governmental conflict | |
|---|---|---|---|---|
| | Yes | No | Yes | No |
| Distance to border [a] | 155 | 204 | 202 | 194 |
| Distance to capital [a] | 883 | 646 | 645 | 700 |
| Population (1,000s) | 96 | 184 | 217 | 147 |
| Road density [a] | 305 | 404 | 482 | 342 |
| Mountain [b] | 13 | 15 | 20 | 13 |
| Forest [b] | 6 | 23 | 25 | 18 |
| Distance to petroleum [a] | 605 | 514 | 637 | 463 |
| Distance to diamonds [a] | 849 | 366 | 331 | 480 |
| Minority language [b] | 66 | 41 | 31 | 52 |
| Democracy | -3.5 | -4.4 | -3.6 | -4.6 |
| GDP per capita (US $) | 1,748 | 2,316 | 2,350 | 2,170 |
| N | 484 | 2,723 | 1,075 | 2,132 |

Note: The table shows mean values of the covariates for cells that did and did not experience conflict in the period from 1970 to 2001. [a] Km; [b] %.

**Table 2 Logit estimates of onset of territorial conflict**

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Spatial lag | 11.949 | 11.924 | 11.280 | 11.739 |
| | (2.84)*** | (3.08)*** | (3.95)*** | (2.90)*** |
| Distance to border [a] | -0.109 | -0.183 | -0.071 | -0.096 |
| | (1.33) | (2.42)** | (0.72) | (1.06) |
| Distance to capital [a] | 1.258 | 0.877 | 1.275 | 1.176 |
| | (2.59)*** | (1.82)* | (2.94)*** | (2.65)*** |
| Population density [a] | | 0.040 | | |
| | | (0.30) | | |
| Road density [a] | | -0.091 | | |
| | | (0.91) | | |
| Mountain [a] | | -0.236 | | |
| | | (0.98) | | |
| Forest [a] | | -0.409 | | |
| | | (1.95)* | | |
| Distance to petroleum [a] | | | 0.132 | |
| | | | (0.32) | |
| Distance to diamonds [a] | | | 1.404 | |
| | | | (2.76)*** | |
| Minority language | | | | 0.557 |
| | | | | (0.77) |
| Intercept | -10.382 | -6.622 | -21.110 | -10.211 |
| | (3.37)*** | (2.09)** | (2.92)*** | (3.35)*** |
| N | 3,207 | 3,207 | 3,207 | 3,207 |
| Log pseudolikelihood | -738.2 | -679.9 | -652.3 | -730.9 |

Note: Regression estimates with robust z scores in parenthesis (standard errors clustered on countries).

[a] Logged; * p<.10; ** p<.05; *** p<.01.

**Table 3 Logit estimates of onset of governmental conflict**

| | (5) | (6) | (7) | (8) |
|---|---|---|---|---|
| Spatial lag | 19.795 | 19.823 | 18.793 | 19.744 |
| | (5.34)*** | (6.03)*** | (5.59)*** | (5.69)*** |
| Distance to border [a] | -0.068 | 0.019 | 0.023 | -0.094 |
| | (0.42) | (0.13) | (0.14) | (0.64) |
| Distance to capital [a] | -0.406 | -0.160 | -0.461 | -0.306 |
| | (1.54) | (0.67) | (1.85)* | (1.14) |
| Population density [a] | | 0.221 | | |
| | | (2.37)** | | |
| Road density [a] | | 0.089 | | |
| | | (0.90) | | |
| Mountain [a] | | 0.098 | | |
| | | (1.13) | | |
| Forest [a] | | 0.274 | | |
| | | (2.45)** | | |
| Distance to petroleum [a] | | | 0.199 | |
| | | | (1.20) | |
| Distance to diamonds [a] | | | -0.369 | |
| | | | (2.07)** | |
| Minority language | | | | -0.953 |
| | | | | (2.88)*** |
| Intercept | -0.050 | -4.115 | 0.937 | -0.198 |
| | (0.03) | (2.11)** | (0.37) | (0.11) |
| N | 3,207 | 3,207 | 3,207 | 3,207 |
| Log pseudolikelihood | -731.0 | -666.8 | -703.0 | -711.6 |

Note: Regression estimates with robust z scores in parenthesis (standard errors clustered on countries).

[a] Logged; * p<.10; ** p<.05; *** p<.01.

**Table 4 Logit estimates of onset of intrastate conflict, 1970–2001**

| | (9) Territorial | (10) Governmental |
|---|---|---|
| Spatial lag | 9.830 | 8.640 |
| | (12.66)*** | (19.70)*** |
| Distance to border [a] | -0.471 | -0.226 |
| | (5.22)*** | (3.26)*** |
| Distance to capital [a] | 1.624 | 0.171 |
| | (3.30)*** | (1.04) |
| Population density [a] | -0.495 | 0.177 |
| | (5.94)*** | (3.49)*** |
| Mountain [a] | -0.433 | 0.024 |
| | (2.87)*** | (0.56) |
| Forest [a] | 0.067 | 0.163 |
| | (0.68) | (1.62) |
| Democracy squared [a, b] | -0.015 | -0.023 |
| | (1.65)* | (2.70)*** |
| GDP per capita [a, b] | -2.391 | 0.018 |
| | (6.31)*** | (0.05) |
| Intercept | 1.754 | -7.247 |
| | (0.59) | (2.83)*** |
| N | 85,136 | 86,065 |
| Log pseudolikelihood | -652.8 | -1,720.8 |

Note: Regression estimates with robust z scores in parenthesis (standard errors clustered on country years). Estimates for peace-years and three cubic splines not shown. [a] Logged; [b] lagged; * $p<.10$; ** $p<.05$; *** $p<.01$.