More mouths and less food -
Climate change, resource scarcity and non-state conflicts

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Abstract

Climate change and the effects it has on livelihoods, resources and human interactions are often stated to be the next coming of global turmoil in the form or organized violence on a mass scale. Actual empirical results supporting these hypotheses on the coming danger of climate change for armed conflicts are, however, mixed at best. This may, in part, be because of a lack of good data in the sphere of organized violence that speaks directly to the causal underpinnings of the proposed theoretical frameworks. This article introduces new data from the Uppsala Conflict Data Program; firstly the UCDP Georeferenced Event Dataset (UCDP GED), a new disaggregated and georeferenced event dataset on organized violence, in order to be able to test some of the assertions of climate change and violent conflict below the state level. The article also makes use of a broader approach to test assertions of climate change and organized violence by way of including in the analysis the form of organized violence labeled as ‘non-state conflict’ so as to track possible effects of climate change on phenomenon other than outright civil war. The authors argue that the introduction of these new data into models of climate change and mass violence speak more directly to the theories proposed by scholars of climate change and conflict. In an analysis of a subset of countries in Sub-Saharan Africa, from 1989-2004, we find that the interaction of extreme levels of population density and extreme levels of soil degradation have a significant and substantial effect on the outbreak of non-state conflicts. Also, unlike in other disaggregated studies, higher levels of democracy do not have a tempering effect on the likelihood of the onset of non-state conflict.

Introduction

Climate change and its implications for social interactions between states and societies has risen to the forefront not only of the political debate of possible effects and mitigations of them, but has also led to a vast expansion of this field of research within the spheres of international relations and peace and conflict research (see for instance Gleditsch 1998; Hendrix and Glaser 2007; Buhaug, Gleditsch et al. 2008; Burke, Miguel et al. 2009). This concern dates back to far before the rise of awareness in the world of the phenomenon of global warming, and its roots can be found in earlier debates regarding population explosions, resource scarcity and the degradation of livelihoods.

It was not until recently, however, that the possible linkages between environmental/climate change and large-scale violence begun to be tested in quantitative analyses beyond the single case studies (see for instance Hauge and Ellingsen 1998; Hendrix and Glaser 2007; Meier, Bond et al. 2007; Raleigh and Urdal 2007; Theisen 2008). Most of these studies have their theoretical underpinnings firmly rooted in the *resource scarcity* theorizing of Homer-Dixon (1999), with some also making use of the somewhat more refined theoretical framework of Kahl (2006). Overall, these theoretical approaches hold that the threat towards security stems from the effects climate change has on the scarcity of resources necessary for the sustenance of basic livelihoods. As resource scarcity increases with population increases and climate change, claims the theory, violent conflict may, under some circumstances, lead to violent conflict. In the words of Salehyan (2008): *"The argument about the connection between climate change and conflict boils down to an argument about resource scarcity and competition over the means to sustain livelihood"*.

Studies testing the hypotheses from this overarching theoretical framework have focused mostly on state-level factors (Esty, Goldstone et al. 1998; de Soysa 2002; Urdal 2005; Theisen 2008; Burke, Miguel et al. 2009) and only to a small degree on analyses of sub-state factors (Raleigh and Urdal 2007; Urdal 2008; Østby, Nordås et al. 2009). The latter category of studies is now growing in importance as the perspective that both climate change and armed conflict are localized phenomena below the state-level has gained in prominence, and new and better data have become available.

Despite the fact that much manpower has been put into the study of these hypotheses on climate change, and despite (or, perhaps, because of) the refinement of methodological tools in later years there exist as of now no consensus on the effect of climate change on the incidence of large-scale violence (Buhaug, Gleditsch et al. 2008). In his critique of both the empirical and theoretical field of climate change Salehyan (2008) states that *"…direct links are few and weak; causal pathways are complex and contingent on a host of additional factors"*. Currently there appears to be consensus only on the empirical evidence that institutional factors such as regime types and governance strongly temper or magnify the effects of climate-induced scarcity on organized violence (Salehyan 2008).

Whilst Salehyan with the above quote criticizes the theoretical framework in general we hold that most of the abovementioned studies also suffer from problems with the dependent variable; armed conflict. As was pointed out by Buhaug, Gleditsch and Theisen (2008) nearly all studies of the phenomenon under scrutiny here focus on the incidence of interstate and intrastate armed conflicts. In line with the abovementioned scholars we argue that the theoretical frameworks of Homer-Dixon and Kahl speak more directly to the occurrence of other forms of organized violence, such as so-called 'non-state conflicts'. In other words, violence that carries a much lower cost of initiation than interstate and intrastate wars and that is known to be much more localized in its geographic scope and thus more sensitive to local scarcity.

Secondly, Buhaug, Gleditsch and Theisen (2008) also point out, in their overview of the empirical findings of the climate-conflict nexus, that the overly aggregated approach of most large-N studies induces problems of ecological fallacies, for instance regarding a state's reach across its territory and the actual locations of armed conflicts. In general, many have tried to deduce local-level causes and effects with country-level data.

These are serious problems for the scholarly community and future research. In this article we therefore introduce a more broad use of data for studies of climate change and organized violence in that we study not only armed conflicts but also non-state conflict[1] and how these types of conflict relate to climate-induced factors.

On the sub-state level we introduce new data from the UCDP, namely a sub-Saharan Africa subset of the UCDP Georeferenced Event Dataset (UCDP GED) (Sundberg, Lindgren et al. 2010). The UCDP GED maps, to the extent possible, the exact locations and dates of all events of state-based, non-state and one-sided violence from 1989-2009 globally.

This is done so as to test the propositions these studies have focused upon with data that speaks more firmly to the theoretical framework underlying the debate on climate change, resource scarcity and organized violence. We also introduce some new tests and hypotheses on the intensity of organized violence to complement the work on onsets by Raleigh and Urdal.

Raleigh and Urdal's study test five hypotheses, (1) that in areas of higher population growth areas with high levels of land degradation are more likely to experience armed conflict, (2) that areas with high freshwater scarcity are more likely to experience armed conflict the higher the population growth, (3) that areas with high population density are more likely to experience armed conflict the greater the population growth, (4) that the effect of demographic and environmental factors is stronger in areas in poor countries than in areas in rich countries, and (5) that areas with demographic and environmental pressures are more likely to experience armed conflict during periods of regime collapse and transitions. Raleigh and Urdal find only very small effects of land degradation and water scarcity on the onset of state-based armed conflict, whilst population growth and density are found to be associated with an increased risk of onset. Their final conclusion is that political and economical factors far outweigh the effects of local demographic and environmental factors on armed conflict.

Climate change, resource scarcity and mass violence; general pathways

[1] All data on organised violence on the state-level used here comes from the Uppsala Conflict Data Program (UCDP). The data used are the latest versions of the UCDP Non-state Conflict Dataset Eck, K., J. Kreutz and R. Sundberg (forthcoming). "Fighting Without the State: Introducing the UCDP Non-State Conflict Dataset."

The chain of factors through which climate change is said to affect the outbreak of organized violence is a long and complex one, in which an array of external factors are thought to play a role either as triggers or ameliorates of violence.

In brief, this theoretical line of reasoning holds that climate change affects violence primarily through a range of consequences brought on by the so-called resource scarcity that climate change is believed to bring about. The main proponent of the resource scarcity school has so far been Thomas Homer-Dixon, perhaps especially through his 1999 book *Environment, Scarcity and Conflict*. Homer-Dixon's widely cited theoretical approach deals with resource scarcity through three different pathways: *demand induced, supply induced* and *structural scarcity* (Homer-Dixon 1999).

Demand-induced scarcity occurs when the demands for, for example arable land, are higher than what a specific piece of land or a state can supply, for instance through an increase in demographic pressure. Supply-induced scarcity occurs when the availability of an existing resource wanes, with scarcity of, for instance, fishing waters occurring as result of an oil spill (such as the possible effects of the demise of Deepwater Horizon off the coast of Louisiana) or as arable land is overused and loses its potential to carry crops. Structural scarcity has much more of a political overtone, dealing with the way in which political and economic structures may increase or reduce the availability of resources for some. An example of this may be the privatization of freshwater resources, leading to the unavailability of water for small-scale cattle-herders or farmers who cannot afford to buy water. The link to climate change in these instances is quite simple; climate change is thought to, through a number of ways, influence resource scarcity negatively in that the availability of resources will become lower.[2] These different types of scarcity are then thought to interact with a number of political, economic and social factors that serve to increase or decrease the likelihood of climate-induced violent conflict.

Kahl, in his 2006 volume *States, Scarcity, and Civil Strife in the Developing World*, compiles Homer-Dixon's three types of scarcity into the DES concept; demographic and environmental stress, which more or less contains the same types of demand, supply and structure factors as in Homer-Dixon's approach. The additional value of Kahl's approach instead stems from a more fine-grained analysis of the state's role in disputes over resources, serving to dampen the somewhat deterministic claims of Homer-Dixon. Kahl theorizes that DES may influence the state in two different ways, leading (under certain circumstances) to either state failure or state exploitation and subsequent violent crises.

Conflicts follow from state failure when DES causes a state's authority to weaken, increasing groups' incentives and opportunities for organized violence (Kahl 2006). State exploitation occurs when elites utilize resource scarcities to instigate intergroup conflict for their own interests (Kahl 2006). Kahl then goes on to condition the outbreak of such

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[2] It is reasonable here to take the side of Gleditsch, who has argued that one cannot use the future as evidence Gleditsch, N. P. (1998). "Armed Conflict and the Environment." Journal of Peace Research **35**(3): 381-400.

. In other words, since we do not know exactly what effects climate change will have on resources it is somewhat dishonest to claim that the effects will be negative.

conflicts on a state's propensity for 'groupness' (the ratio of which a state's inhabitants experience group cleavages) and 'institutional inclusivity' (a state's political system). In short, societies with high levels of DES, deep ethno-cultural cleavages and repressive and unequal political structures have a high risk of experiencing climate-induced organized violence.

What both these main theoretical approaches in the debate share is the expectation that coming climate changes will affect resource scarcity and in the end possibly cause organized violence where certain institutional and social settings are present.

Creating sound measurements of resource scarcity is, however, no easy task. Raleigh and Urdal (2007) stipulate that the most important forms of scarcity should be those that affect basic livelihoods, in other words the availability of water and land that can carry crops. To measure if these are then scarce (a resource is not scarce if no one is there to try and drink the small amounts of available water) they interact these measurements with population density. For the purposes of this study these appear to be sound measurements as they speak directly to the underlying necessities of human life and society.

These measurements also make sense in the light of the many predictions that have been made regarding the effects of climate change on the environment. Floods and rising sea levels will destroy places of residence, changing population densities and pressures on land and water resources in the areas where people will (might) move. A warmer climate will (might) reduce the available amounts of water and destroy arable lands, further increasing scarcity. If we can see these effects historically this may tell us something of the possible effects of climate change in the future.

Climate change, resource scarcity and mass violence; refining the dependent variable

Both Kahl and Homer-Dixon make clear in their theoretical frameworks that resource scarcity is more likely to cause intrastate rather than interstate conflict. Kahl, in the 2006 volume, is, however, relatively imprecise in his definitions, claiming broadly that DES may cause 'civil strife', defined as "large-scale, sustained and organized violent conflict within a country". This broad outlook can clearly contain a wide array of forms of organized violence, well beyond the narrow scope of armed insurgency against a government.

Kahl identifies that state-centric approaches to how climate-induced scarcity causes armed conflict often fail to take into the equation the fact that armed rebellion carries with it severe collective action problems as well as high opportunity costs. Even under his conditions of state failure and state exploitation high opportunity costs in confronting a government continue to exist. Lower opportunity costs for armed combat exist only in relation to other rebels, other ethnic/communal groups, and against unarmed civilians.

Homer-Dixon, in his 1999 volume, also addresses violence with a broad view, with his 'core model' displaying the causal links from scarcity to group-identity conflicts, coups d'etat and insurgency (Homer-Dixon 1999). In general, Homer-Dixon applies the same logic of opportunity costs for the likelihood of violence as does Kahl, but with a somewhat stronger focus on relative deprivation as a causal factor. In his overview of types of violence caused by resource scarcity Homer-Dixon lands in the conclusion that group-identity conflicts (conflicts between groups defined by identity) and insurgencies are the conflicts most likely to erupt. Refining his specification further Homer-Dixon finally lands in the conclusion that sub-state group-identity conflicts should be the most pronounced ones, since scarcity affects dwellers in rural areas to the greatest degree (Homer-Dixon 1999), and presumably because opportunity costs are lower (this is not clearly spelled out).

The unavailability of good data on forms of violence beyond armed insurgencies has, however, seen Kahl's and Homer-Dixon's statements transformed by scholars into models testing hypotheses regarding the relationship between climate change, resource scarcity, population pressure and the dependent variable of 'armed conflict' only. Commonly, the dependent variable has been the outbreak of armed conflict as defined by the UCDP/PRIO Armed Conflict Dataset (Gleditsch, Wallensteen et al. 2002); in other words the existence in a country in one calendar year of more than 25 battle-related deaths in battles between a government and a rebel movement concerning an incompatibility regarding either government or territorial control. This variable captures only parts of what Kahl refers to as 'civil strife' and only the 'insurgency' concept presented by Homer-Dixon. In other words, the type of strife identified by both as being the most likely to occur is ignored.

This dependent variable is used both in Raleigh and Urdal (2007), in that study in the form of the geographical disaggregation by Buhaug and Gates (2002). Whilst this definition might intuitively appear to speak to the frameworks of Kahl and Homer-Dixon there are other forms of mass violence that have a much clearer link to the theoretical explanations proposed.

There is wide agreement in the literature on scarcity –as has been shown above- and also within the works that have tested the scarcity hypotheses, that the main influences of climate-induced scarcity should not affect mainly armed insurgencies against the state but low-level intergroup clashes.[3]

From the above follows that previous studies have not yet tapped completely the dependent variable of which the literature speaks. So-called non-state conflicts and one-sided violence have not been included in studies, almost solely because of a lack of good data and long time series that allow for quantitative tests.

We argue, in line with Klare (2001), that the opportunity costs of instigating non-state

[3] The authors admit, however, that Kahl's more refined theoretical framework at times speaks more directly to armed insurgency against the government (mainly in the form of state exploitation) than does Homer-Dixon's, which is more directly focused on sub-state intergroup violence.

conflict and one-sided violence against rival sub-state entities are much lower than for initiating armed rebellion against a state, which naturally (in the vast majority of cases) has a higher destructive capacity than a neighboring rival. It is much less costly, and likely carries with it a much larger degree of possible success, for Karamojong groups in Kenya to attack rivaling sub-clans or groups of Toposa herders, than to engage the Kenyan state in combat. Empirically, Kenya has also experienced several non-state conflicts since the Cold War, but no state-based armed conflicts.

The same can be said for much of the one-sided violence (violence against civilians) perpetrated by ethno-nationalist outfits around the globe. Whilst many of these, such as in Northeast India, do fight armed insurgencies against the government they also engage in high levels of one-sided violence against civilians, often with the stated or implicit goal of expelling 'immigrants' that have settled on land they claim to belong to a certain, often 'indigenous' ethnic group. In fact, the levels of one-sided violence in low-level insurgencies often match, or even surpass, the intensity of battles with the government. Just as we theorize regarding non-state conflicts, the opportunity costs for attacking civilians are much lower than engaging a government head on. One-sided violence also carries many traits of what is commonly referred to as 'communal violence', i.e. violence between groups of differing ethnic/religious/communal identities; something which has a clear place in the theoretical frameworks of scarcity debate.

What follows from this reasoning is that studying also the occurrence of these two types of organized violence fits more neatly into the theoretical framework proposed for climate-induced conflict.[4]

Taking this view of the theoretical frameworks to some degree mitigates Salehyan's statement regarding the weak theoretical and causal links between resource scarcity and organized violence. It also goes one step further in addressing the shortcomings in empirical studies of this phenomenon that have been pointed out by Buhaug, Gleditsch and Theisen (2008).

In terms of hypotheses we propose that the possible effects of climate-induced scarcity should have the strongest effects on the occurrence of non-state conflicts, secondly on one-sided violence and lastly on so-called state-based armed conflicts. Further, we also propose that this effect should be pronounced not only in regard to the onset of organized violence (as was studied by Raleigh and Urdal), but also in the form of its intensity. In other words, the more climate-induced scarcity we see, the more intense should the violence be, in the same ranking order of organized violence phenomenon.

We thus include into the hypotheses tested by Raleigh & Urdal the non-state conflict category, testing their five hypotheses (see pageX) with this new dependent variable.

Climate change, resource scarcity and mass violence; the need for a disaggregated approach

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[4] One-sided violence is, however, not analyzed in this version of the paper.

The call for a more disaggregated approach to studying armed conflicts and civil war has become a strong one, and has been echoed in several influential studies as of late (Buhaug and Rød 2006; Raleigh and Hegre 2009; Østby, Nordås et al. 2009). Commonly, the main argument in favor of disaggregating both dependent and independent variables below the country level comes in the form of claiming that an ecological fallacy may be at play when one attempts to explain local variations from national data. One can exemplify this is many different ways. For example, armed insurgencies do not always take place across the entirety of a country's territory.

In Thailand, to take one of many examples, the Muslim Pattani insurgents fighting the government of Thailand conduct their operations (and the government conducts counter-operations) solely in the South region where the Muslim minority lives. Drawing conclusions based on any aggregated national scores may then be faulty, since the political, economical and social contexts in the South and the East, North and Central are radically different on a lower level of analysis.

In some cases civil wars are not even fought on the soil of the country over which the incompatibility stands. The Rwandan FDLR rebels, for instance, have not conducted any large-scale attacks in Rwanda proper for several years, instead being involved in fighting against the Rwandan and Congolese armies in Eastern Democratic Republic of Congo (DRC). It is relevant to ask if the continuation of this rebellion is not due to the dense jungles of the Eastern DRC and other local attributes more than the ethno-linguistic fractionalization score of Rwanda itself.

Finally, using country level aggregates runs the risk of effectively masking regional differences within a country (Østby, Nordås et al. 2009). Östby, Nordås and Röd explain this possible effect in clear terms in the form of regional income and development differences, but the problem is existent also in the form of environmental variables that can cause scarcity. A country may be to 70% made up off soils that yield a high level of crops and contain rich amounts of water. The other 30% may have poor soil quality and scarce amounts of water. A national aggregate would conceal these differences and an analysis of organized violence in that country as a whole would not be able to capture a possible association since we would not be able to see that 100% of the fighting took place in the 30% of the country without any resources.

In order to touch upon explanatory variables that can be applied to lower levels of analysis we must thus continue to study organized violence - and independent variables that can explain organized violence - on a level of analysis below the state.

Method and design

In order to test our propositions on the affects of climate-induced scarcity on non-state violence we set out to introduce new data that speaks more directly to the theoretical frameworks outlined above into the analytical models of the highly influential disaggregated study by Raleigh and Urdal (2007). This exercise should be viewed as having a three-fold aim; (1) introducing new data that can serve to enhance our knowledge within this scholarly sphere, (2) testing propositions that are somewhat more in line with the theoretical debate in the field, and (3) to see if the results described in the abovementioned study hold under new and more fine-grained specifications.

The disaggregated method of analysis means that we have to go below the state level in terms of the level of analysis. In approaching this we follow the specifications given by Raleigh and Urdal in their study's section on geospatial data (p.681-685), creating a fishnet of 100 km x 100 km grid squares (at the equator) over sub-Saharan Africa as the unit of analysis. This creates roughly 2400 units of analysis per year, where each country (depending on size) thus has a set number of 100 x 100 km squares that make up its' landmass. These grid squares are then assigned values from shape and raster files that contain information on the variables used to measure possible resource scarcity.

Following Raleigh and Urdal we use four variables in interaction to capture resource scarcity. First of all we use measurements of UN-adjusted *population density and population change* from CIESIN ((CIESIN) and (CIAT) 2004), secondly measurements of *human induced soil degradation* from the International Soil Reference and Information Centre ((ISRIC) 1990) and thirdly *Easily Available Freshwater* from TERRASTAT of the Poverty and Food Insecurity Project. These data are available in raster and polygon formats that have to be aggregated up to the 100x100km grid squares.

The soil degradation and easily available water measurements are ordinal variables, with the former ranging from 0 to 4 and the latter having been transformed into a scale from 0-7. The population density score comes as an interval variable.

In aggregating data to the units of analysis we follow the majority aggregation rule. This means that if a 100 x 100 km grid square is occupied to more than 50% of a certain value that value will be assigned to the entirety of the grid square.

To test our hypotheses on the intensity of violence we also make use of annual GDP (Gleditsch 2002) and Polity IV scores (Marshall and Jaggers 2005) as per Raleigh and Urdal's specifications (logged and lagged where necessary). [5] This country-level data is also assigned to the 100 x 100 km grid squares, following the same majority rule (meaning that a grid square that is occupied to 51% by the Democratic Republic of Congo and to 49% by Burundi is viewed as being part of the former, receiving that country's GDP and Polity scores).

We also calculate population density increases and decreases on a yearly basis from 1990-2005.[6] This creates, in addition to Raleigh's and Urdal's static dataset, a time-

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[5] For a more detailed description of how this data is utilized to create datasets for quantitative analysis, and information on the data itself, please refer to the study by Raleigh and Urdal (2007) and their replication notes at PRIO/CSCW's webpage (http://www.prio.no/CSCW/Research-and-Publications/Publication/?oid=63254)

[6] Population density scores are available from 1990 with a five-year interval. We thus impute values for intervening years.

varying dataset on geographic and political contexts from 1990-2004[7] that can be utilized for the study of the intensity of organized violence.

The geographic variables have been chosen by Raleigh and Urdal to capture scarcity of crop lands and water, and population pressure on the same lands. The highest levels of scarcity should thus be where high soil degradation, low levels of available water and high levels of population density interact. The political variables also included in the analysis are stipulated to be relatively sound measurements of some of the political and institutional factors thought to affect scarcity's social consequences.

Lastly, we plot onto these grid squares so-called 'events' of organized violence – non-state conflicts in this study – perpetrated by all dyads/actors that have at one time surpassed the 25 death threshold for inclusion that is applied across the UCDP's data on organized violence. The time period under study is limited to 1990-2004 due to data limitations on the geospatial data. This grid square data is, after being applied in GIS (Geographic Information Systems) software, exported into datasets that can be used in standard programs for quantitative analysis. The unit of analysis thus becomes the single grid square year, and the dependent variables the onset, incidence and severity of events of non-state conflict.

The events of organized violence stem from a subset of the UCDP Georeferenced Event Data (UCDP GED), which records all instances of organized violence (state-based armed conflict, non-state conflict and one-sided violence) in the 1989-2009 time period. Each instance of organized violence is coded as a single event, complete with the exact date, place, number of fatalities and perpetrator/perpetrators (where possible) (Sundberg, Lindgren et al. 2010). Each event thus carries with it a pair of coordinates (point data), which can be plotted onto the fishnet grid squares and then conjoined to the other disaggregated variables on environmental and political factors.

The coordinates in the dataset come with precision variables that denote the preciseness with which the place of the event is known. Since the grid squares used in the analysis are relatively large we include in the analysis any event with a precision score up to and including 5, which signifies an estimated coordinate that is based on contextual information in the source given. We also run an alternate specification using all events with a precision score of 3 or lower, which includes the centroid points of the second order of administrative divisions of a country (not done in this version of the paper).

The UCDP GED dataset used in this study is a trimmed sub-Saharan Africa subset, making use of all the data that has been completed and checked. [8]

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[7] The soil degradation index and the freshwater availability measures are not time-variant however. The interactions that we run, however, induce variety into the analyses.

[8] This study is limited to sub-Saharan Africa only, due to constraints brought on by the data available for the dependent variable (organized violence). Coding of the UCDP GED is not yet completed. We have full data series in sub-Saharan Africa for all countries except Somalia, Ethiopia, Eritrea, Sudan and the Democratic Republic of Congo. For the DRC and Sudan random samples of completed data are used, whilst Ethiopia, Eritrea and Somalia are removed from the analysis.

The non-state conflict category is a novelty in this disaggregated analysis. The non-state conflict data comes from the latest version of the UCDP Non-state Conflict Dataset (a conflict-year dataset) and has been disaggregated and georeferenced into the UCDP GED for the disaggregated analysis. The UCDP defines a non-state conflict as: "*the use of armed force between two organized armed groups, neither of which is the government of a state, which results in at least 25 battle-related deaths in a year.*" 'Organized groups' here denotes both rebel movements that engage each others in combat, ethnic groups in conflict as well as large communal groups. Refer to the codebook (Eck, Kreutz et al. forthcoming) for more detailed information. The non-state conflict category, we argue, effectively captures the sub-state dimension of intergroup clashes that are highlighted in both Homer-Dixon's and Kahl's work.

The onset variable is calculated as a dummy attaining the value of 1 if there is an initiation of non-state activity in one calendar year in a grid square. We make use of both conflict onsets and dyadic onsets, counting as a new onset any activity above the 25 deaths threshold after a full calendar year of no activity in a conflict or dyad.

In order to account for spatial dependence we also enter a spatial lag variable into the dataset. This variable has been automatically generated in GIS software and assigns a value of 1 to a grid square and all its directly neighboring squares if that square experienced any form of organized violence in the preceding year.

Results

Table 1 below shows that there is a bivariate relationship between soil degradation and the frequency of onset of non-state conflict in Sub-Saharan Africa (excluding Ethiopia and Somalia). In the data we use the extent of soil degradation is represented by an ordinal scale with five values. The value 0 denotes stable soil conditions, either because the land is not used for agriculture, because agriculture is well-managed, or because the terrain comprises naturally occurring wastelands, such as deserts. Table 1 shows that there were 30 onsets of non-state conflict in areas with no soil degradation, out of a total of 12,592 observations of this terrain type. This corresponds to an onset rate of 0.24%. The four values 1, 2, 3, and 4, represent light, moderate, strong and extreme soil degradation, respectively. The rate of onsets given extreme soil degradation is 1.44%, or six times higher. The rate of onset for Sub-Saharan Africa as a whole is 0.65% (228 onsets out of a total of 34,968 observations).

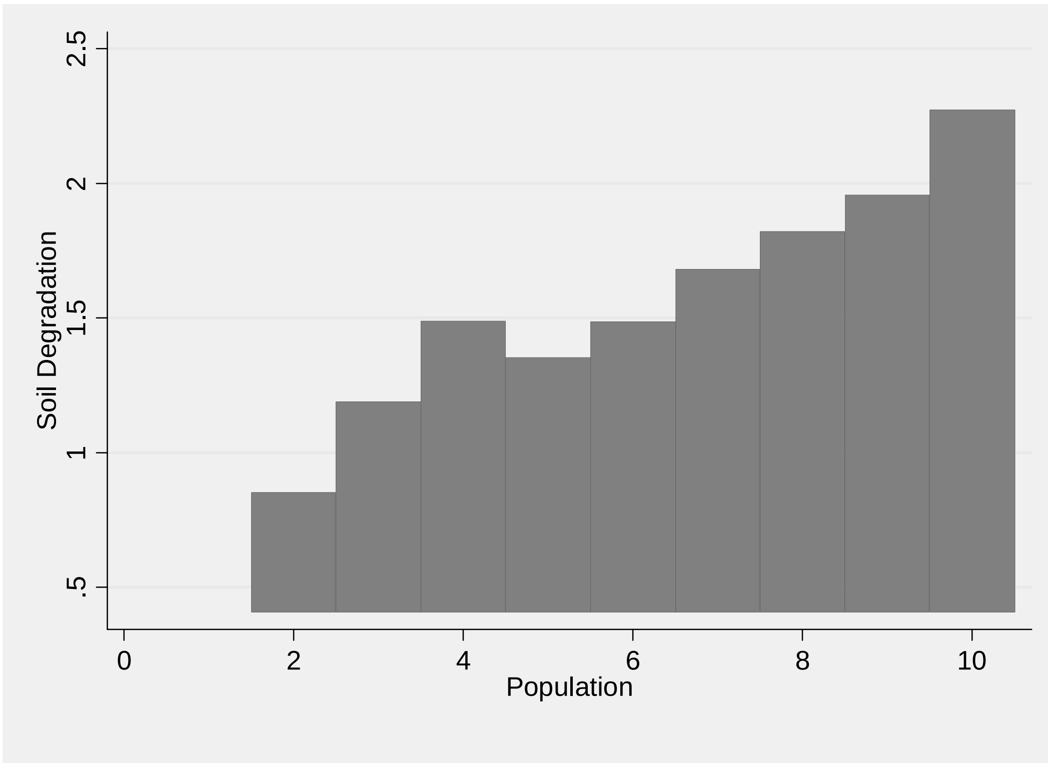
Table 1. The Effect of Soil Degradation on the Risk of Onset of Non-State Conflict

	Soil Degradation	

	0	1	2	3	4	
No onset	12,562	8,281	4,059	6,155	3,911	34,968
	99.76%	*99.39%*	99.10%	*99.15%*	*98.56%*	*99.35*
Onset	30	51	37	53	57	228
	0.24%	*0.61%*	*0.90%*	*0.85%*	*1.44%*	*0.65%*
	12,592	8,332	4,096	6,208	3,968	34,968
	100%	*100%*	*100%*	*100%*	*100%*	*100%*

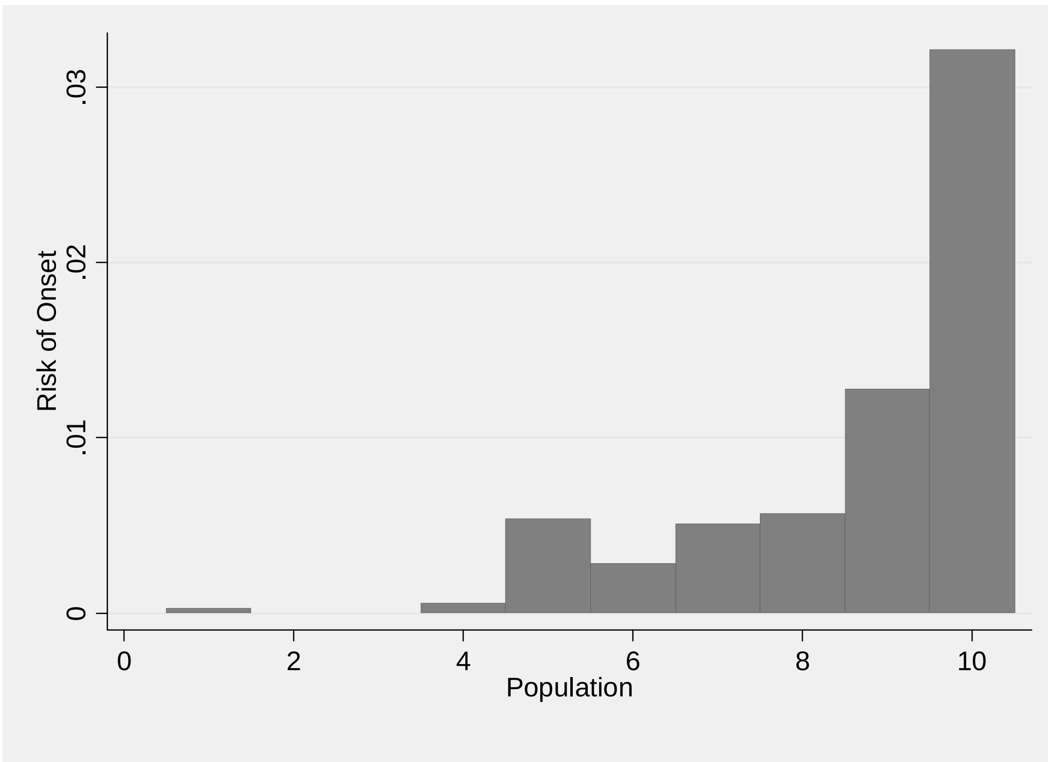
However, soil degradation is partially a result of population density (see, e.g., Dreschel et al., 2001). At the same time, previous research and theoretical arguments give us reason to expect that population density is an important driver of non-state conflict. There is thus a strong possibility that the bivariate relationship between soil degradation and the risk of onset in Table 1 is spurious. Figure 1 below illustrates the average level of soil degradation for different intervals of population density. The x-axis of Figure 1 represents deciles created by sorting the observations from lowest population density to highest, and then dividing the sorted observations into ten parts with equal numbers of observations. There is a clear linear relationship between average soil degradation and population density in the data we use.

Figure 1. Average Soil Degradation by Population Density



Also the x-axis of Figure 2 denote population density deciles. Figure 2 shows a strong association between the risk of onset of non-state conflict and population density in the data we use. The relationship is curvilinear so that more densely populated areas are increasingly much more likely to see the outbreak of non-state conflict.

Figure 2. Rate of Onset of Non-state Conflict by Population Density



Non-state conflicts are extremely rare in the most sparsely populated areas of Sub-Saharan Africa; there are only four onsets in the 1st to the 4th deciles. This means that the 40% of the grids with the sparsest population only generate less than 1% of the total number of 228 onsets. The risk of onset is raised for the 5th to the 8th deciles, higher again for the 9th decile, and much higher for the very most densely populated areas in the 10th decile; fully 3.3% of the observations in the 10th decile had onsets (109 onsets out of 3,305 observations). The rate of onset is thus more than five times higher in the most densely populated areas compared to the rate of onset for Sub-Saharan Africa as a whole.

We now turn to a series of multiple regression models with the onset of non-state conflict as dependent variable. Because of the relative rarity of non-state conflict we use rare events logit (Zeng and King 2001), clustering over countries. Model 1 in Table 2 includes four dummy variables that denote light, moderate, strong and extreme soil degradation, respectively, with no soil degradation (i.e., stable soil and wasteland) as the excluded base category. All the following models also include a spatial lag indicating if any violence took place in the grid or in a neighboring grid in the previous year. In line with the cross-tabulation in Table 1, Model 1 suggests that there are significant effects of higher levels of soil degradation. In Model 2 three dummy variables representing population density are introduced so as to account for the curvilinear relationship between population and onset in Figure 2. When population density thus is controlled for only extreme soil degradation remains statistically significant.

Next we will test for interaction between the conflict-inducing effect of extreme soil degradation and higher population density. Does extreme soil degradation have this effect for all levels of population density, or could it be that extreme soil degradation matters most in the most densely populated areas? The cross-tabulation in Table 1 was repeated separately for each of the population density deciles. Only one of these cross-tabulations revealed a conflict-inducing effect of soil degradation, namely when the sample was limited to the tenth decile with the highest population density. This suggests that there is indeed an interaction between degradation and population, so that the conflict-inducing effect of extreme soil degradation kicks-in only for extreme levels of population density. Model 3 tests for this possibility by introducing an interaction term that takes the value 1 when a grid is characterized by both extreme soil degradation and extreme population density.

Table 2.

	1	*2*	*3*	*4*
Spatial lag	2.105** (0.252)	1.640** (0.253)	1.636** (0.260)	1.611** (0.264)
Light Degradation	0.773 (0.447)	0.054 (0.378)	-	-
Moderate Degradation	1.056* (0.436)	0.160 (0.453)	-	-
Strong Degradation	1.187** (0.333)	0.179 (0.365)	-	-
Extreme Degradation	1.647** (0.379)	0.584* (0.254)	0.054 (0.402)	0.043 (0.403)
Population Deciles 5-8	-	2.511** (0.340)	2.536** (0.330)	2.515** (0.330)
Population Decile 9	-	3.342** (0.537)	3.397** (0.498)	3.395** (0.502)
Population Decile 10	-	4.086** (0.564)	4.005** (0.518)	4.002** (0.525)
Degradation x Population	-	-	0.652 (0.338)	0.677* (0.342)
Population Growth	-	-	-	1.273 (0.733)
Constant	-6.637** (0.407)	-8.471** (0.406)	-8.365** (0.407)	-9.803** (0.952)
Observations	35196	35196	35196	35196

Rare events logit regression with robust standard errors clustered on country in parentheses
* significant at 5%; ** significant at 1%

In order to determine the statistical significance and the magnitudes of the conditional effects of extreme soil degradation given population density we used the software Clarify (King et al., 2000; Tomz et al., 2003). The results are reported in Table 3 below.

Table 3. Changes in Predicted Risk of Onset of Non-State Conflict

Values of Changing Variable	*Value of Constant Variable*	*Effect*	*Low Confidence Band*	*High Confidence Band*
Non-Extreme to Extreme Soil Degradation	Population Density Deciles 1-4	Not significant	-	-
Non-Extreme to Extreme Soil Degradation	Population Density Decile 10	.0131	.00357	.0284
Population Density Deciles 1-4 to Decile 10	Non-Extreme Soil Degradation	.0130	.00601	.0244
Population Density Deciles 1-4 to Decile 10	Extreme Soil Degradation	.0259	.0118	.0500

The predicted probabilities and confidence bands are calculated on the basis of model 3 and with the spatial lag set at zero. The effects in rows 2-4 are much stronger if the spatial lag is set at one.

The first row of Table 3 shows that the change in the predicted risk of onset does not differ significantly between observations with and without extreme soil degradation when the population density in both cases is low. The second row reports that the risk is 1.31 percentage points higher with extreme soil degradation than without extreme soil degradation, given that the context is extreme population density. This effect of extreme soil degradation in areas with extreme population density is statistically significant. The magnitude of the effect of extreme soil degradation is also very substantial since the average rate of non-state conflict for all observations together was .65 percent. The effect is almost exactly the same comparing areas with the tenth decile of population density with the first through fourth deciles in a context of non-extreme soil degradation (row 3). The effect is even stronger in row 4 which represents how much more likely onset is if population density is decile 10 compared to deciles one through four when the level of soil degradation is extreme. In other words, extreme population density is associated with more non-state conflict in areas with extreme soil degradation as well as in areas without extreme soil-degradation, but the effect is much stronger (2.59 percentage points) when soils are extremely degraded.

Thus, in combination with extreme population density does extreme soil degradation predict a statistically significant and substantially important increase in the risk of non-state conflict. Outside a context of extreme population density is soil degradation immaterial to the conflict risk. The effect of extreme population density is more pronounced when soils are extremely degraded but pertains also to land with non-extreme soil degradation.

Model 4 (in Table 2) adds another control variable, namely population growth, but this control fails to reach the conventional .05 level of statistical significance. Other variables are added in later models but first we will examine also the effect of water availability in the same way that we have so far examined soil degradation.

Table 4.

	5	*6*	*7*	*8*
Spatial lag	2.147** (0.258)	1.766** (0.273)	1.504** (0.286)	1.470** (0.271)
Water 2	1.202* (0.527)	1.033 (0.609)	-	1.326* (0.596)
Water 3	0.881* (0.375)	0.667 (0.372)	-	0.625 (0.372)
Water 4	0.414 (0.288)	0.255 (0.293)	-	0.248 (0.291)
Water 5	0.507** (0.195)	0.303 (0.210)	-	0.305 (0.213)
Water 78	0.376* (0.173)	0.261 (0.173)	-	0.265 (0.176)
Population Deciles 5-8	-	2.353** (0.364)	2.505** (0.335)	2.461** (0.368)
Population Decile 9	-	3.205** (0.518)	3.390** (0.511)	3.352** (0.501)
Population Decile 10	-	4.048** (0.549)	3.982** (0.522)	3.962** (0.492)
Extreme Degradation	-	-	0.068 (0.409)	0.051 (0.412)
Degradation x Population	-	-	0.685 (0.351)	0.717* (0.349)
Population Growth	-	-	1.323 (0.799)	1.460* (0.634)
Democracy	-	-	0.002 (0.026)	0.006 (0.026)
Democracy Squared	-	-	-0.010 (0.006)	-0.009 (0.006)
Log of GDP per capita	-	-	0.146 (0.136)	0.130 (0.126)
Constant	-8.124** (0.935)	-9.796** (1.243)	-10.571** (1.445)	-12.050** (1.672)
Observations	37916	37916	35062	34918

Rare events logit regression with robust standard errors clustered on country in parentheses
* significant at 5%; ** significant at 1%

Model 5 tests for the effect of the availability of fresh water. A number of dummy variables are created from the original ordinal scale variable. There are no observations with the value 6 of the water availability variable and hence no dummy is created for this value. Level 1 of the water availability variable is the excluded base category and denotes areas with the least fresh water. The dummy variable "Water 78" combines areas with the most fresh water (level 7) with the original level which stands for wetlands. There are no onsets in wetlands, which means that a dummy variable for wetlands cannot enter the regression (since it would perfectly predict the binary response variable onset). Since wetlands contain lots of water it makes sense to combine the wetlands observations with level 7 into one dummy.

Model 5 shows some statistically significant but inconsistent results for the set of dummies representing fresh water availability. The areas with the least water are the least prone to non-state conflict. Although areas with more water are generally more conflict prone there is no logical pattern in the magnitude of the coefficients. However, areas with more fresh water tend to be more densely populated, and when the controls for population density are added in model 6 all significant effects of water availability disappear. We also tested for various forms of interactions between water availability and population density. Furthermore, we tested for interactions between soil degradation and population growth, and between water availability and population growth. Finally, we tested for tree-way interactions between soil degradation, water availability and population density, but in all regressions only the interaction between extreme soil degradation and extreme population density produced statistically significant conditional effects.

In model 7 we add control variables intended to capture the national-level context that may drive non-state conflict. However, neither level of democracy (together with a squared term so as to capture a curvilinear relationship) nor the natural log of the gross domestic product were statistically significant. Model 7 includes all controls as well as the significant explanatory variables reflecting population density and extreme soil degradation, whereas model 8 includes all controls, the significant explanatory variables, plus the water availability variables. Population growth is statistically significant in model 8, but this control variable loses its significance if the water availability variables, which clearly do not belong in the model, are dropped. We thus conclude that there is no robust support for any effect of population growth.

Discussion

We have found that population density is the most important driver of the onset of non-state conflict. Also extreme levels of soil degradation increase the risk of onset significantly, but only in interaction with the very highest levels of population density. The effects found are substantially quite strong and robust to the inclusion of many combinations of control variables.

In Sub-Saharan Africa (excluding Somalia and Ethiopia, as always in this paper) less than 3% of the observed territorial grids exhibit the combustive combination of extreme soil degradation and extreme population density that according to the results presented above is the most prone to onsets of non-state conflict. Thus, the problem of soil degradation driving non-state conflict in areas with very dense population is a limited one in Sub-Saharan Africa. At the same time, in the relatively rare instances where the soil becomes extremely degraded in the most densely populated areas of Africa this represents a grave increase in the risk of non-state conflict. Areas that show this deadly combination are luckily few. However, if the predictions of the future regarding a radical increase in population density, with its associated soil degradation, are true an increase in such dangerous territories is a very real possibility. Policy implications that follow from this are that preventive actors should identify these risk areas, both in the present and in the future, so as to address both the ecological problems and establish conflict prevention mechanisms where necessary.

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