2 On Environmental Change and Armed Conflict

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2.1 Introduction

Environmental security (ES) is a complex concept with many connotations. It is a central part of the even broader concept of human security (UNDP 1994) and is inherently linked to sustainable development (Brundtland 1987). All these terms emerged at a time when the threat of large-scale nuclear war was no longer perceived as credible, and policymakers and military actors alike saw the need for a wider application of the security term.

Renner (2006) identifies four broad aspects or categories of research on environmental security. The first is whether and how environmental change impacts conflict formation, violent as well as non-violent. A key component of this approach is environmental scarcity, which may be due to increasing consumption, decreasing supply, inequity in access, or a combination of the three (Homer-Dixon 1999). The second aspect of ES connects resource wealth with conflict. Environmental consequences of extensive, industrialized resource extraction (such as pollution, deforestation, changing upstream-downstream dynamics), and unfair distribution of benefits and income are central here. Third, ES includes environmental impacts of armed conflict (nuclear winter being an extreme-case scenario), while the fourth component discussed by Renner (2006) covers environmental peacemaking. In line with an increasing focus on the social consequences of climate change, a large majority of contemporary scholarly contributions to the ES literature relates to the first category. For this reason, we limit the subsequent assessment of theoretical and empirical work to that focusing on the security implications of environmental scarcity and change.

This chapter starts with a review of the theoretical foundation for the central arguments linking climate change to armed conflict.[1] Next, the quantitative literature on the subject matter is assessed, pointing to notable discrepancies in findings and interpretations. The substantive contribution of the chapter is an empirical assessment of drought and civil war in sub-Saharan Africa since 1960, using a large variety of complementary measures of short-term rainfall deficiency. Almost all specifications return an insignificant result for drought; however, we do find weak signals in some models that drought two years earlier increases the risk of the onset of civil conflict. The chapter concludes by offering a few suggestions for future research.

2.2 Point of Departure

Since its peak in the early 1990s, the global prevalence of armed conflict has undergone a remarkable decline (Harbom/Wallensteen 2009). The reasons for this decline are many, including the collapse of the bipolar world system, successful resolution of the many consolidation conflicts in the former Soviet Union and Yugoslavian republics, increased international community interventions (notably by UN peacekeeping forces), and the spread of liberal norms and values (Gleditsch 2008). Armed conflicts today are overwhelmingly concentrated in poor, developing countries with illiberal and corrupt political regimes. Most of these countries share a border with at least one other conflict-ridden country, epitomizing the transnational character of contemporary conflicts (Gleditsch 2007). As shown in figure 2.1, almost all active armed conflicts are found in central parts of Africa and southern Asia.

1 This study focuses on state-based internal armed conflict and civil wars. Our definition of conflict corresponds to the UCDP/PRIO Armed Conflict Dataset (Gleditsch/Wallensteen/Eriksson et al. 2002), i.e., violent fighting between a state and one or more organized non-state actor(s) resulting in at least 25 fatalities per year. We use the terms conflict and war interchangeably in this chapter. See discussion for alternative forms of violence.

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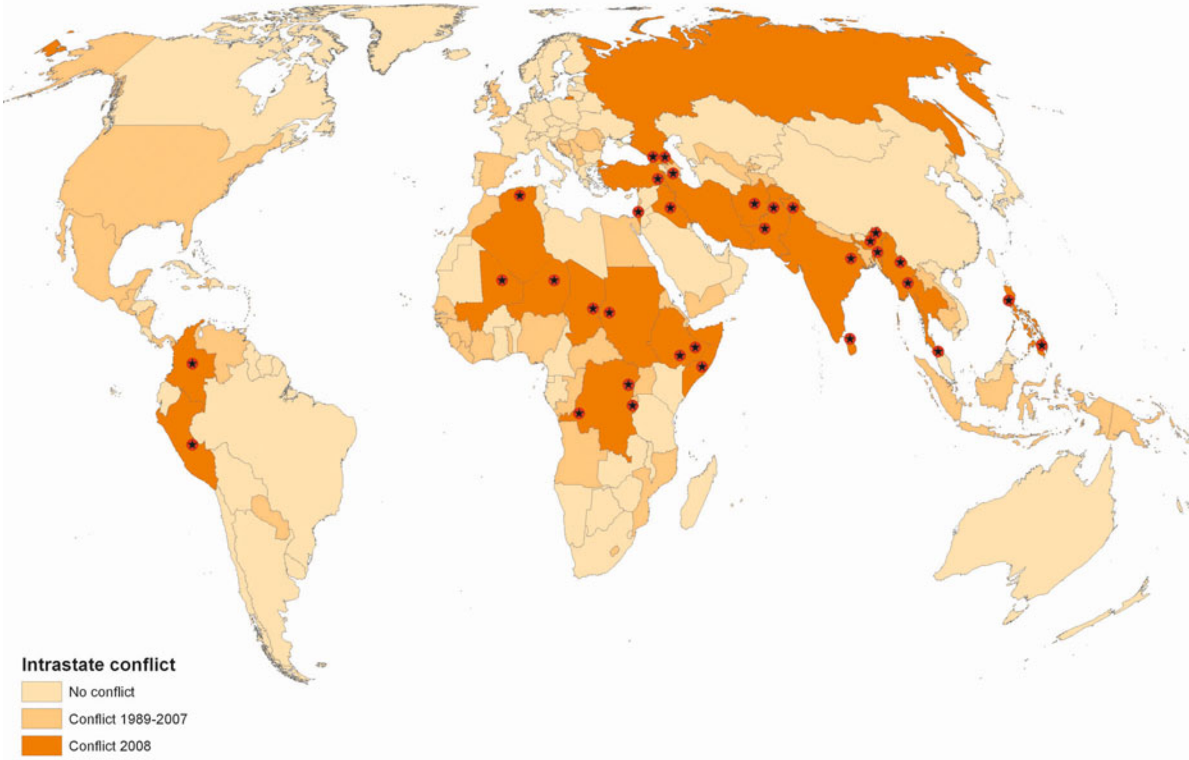
Figure 2.1: Contemporary armed conflicts. **Source:** The map is generated from version v4-2009 of the UCDP/PRIO Armed Conflict Dataset (Gleditsch/Wallensteen/Eriksson et al.). Symbols indicate the geographical midpoint of conflicts active in 2008.



Contemporary armed conflicts are almost exclusively located in developing countries, many of which are experiencing significant environmental stress, be it due to industrialization, pollution, population growth, other anthropogenic effects, or natural processes such as changing weather patterns and high exposure to natural disasters. Future climate change may add to the burden in these societies. Large parts of the globe, including the subtropics of Africa and Asia, are projected to undergo adverse environmental changes (e.g., increasing frequency and severity of drought and extreme weather events) in the coming decades (Christensen/Hewitson/Busuioc et al. 2007).

Experts agree that Africa will be hit first and most extensively by a less hospitable climate (Boko/Niang/Nyong et al. 2007; Stern 2007). This is explained in part by the continent's high economic dependence on rain-fed agriculture, in part by its high environmental vulnerability, and partly by its mostly weak institutional coping capacity. Since only four per cent of arable land in sub-Saharan Africa is irrigated, the continent's predominantly agricultural economies suffer from a low resilience to extreme weather events and increasing climate unpredictability. The result might be loss of agricultural productivity and considerable vegetation die-off in exposed regions, with negative implications for food security (Breshears/ Cobb/Rich et al. 2005). According to recent estimates by the *United Nations Environment Programme* (UNEP 2008), almost all sub-Saharan countries will be in a state of water stress by 2025. Two-thirds of the workforce in sub-Saharan Africa is employed in the rural sector, adding to the particular vulnerability to climate change of this region (Stern 2007).

There is little doubt that the cocktail of high environmental vulnerability and future climate change constitutes a significant threat to human security in a broad sense. Loss of rainfall, more extreme precipitation and wind patterns, and an increase in average and peak temperatures may have devastating impacts on livestock and farming. Among the many plausible consequences are escalating food prices, malnutrition and famine, and increased exposure to diseases, all of which might cause rapid and large-scale human displacement (e.g. Laczko/Aghazaram 2009). Some argue that these challenges also constitute a security threat in a narrow, or classic, sense. In fact, the ES literature includes a number of references to competition over scarce resources that take the form of armed conflict (e.g. Baechler 1999; Homer-Dixon 1991, 1999; Kahl 2006). A common feature in the majority of these cases is the involvement of politically and environmentally marginalized groups in discriminatory regimes. One such example is found in Kahl (2006), who argues that highly politically exclusive institutions and salient ethnic cleavages in combination are crucial contingent factors for whether *demographic and environmental stress* (DES) will produce violent conflict. Similarly, Reardon and Taylor (1996) remark that poor households frequently lack access to non-farming economic activities and are forced to sell livestock and other assets in the face of drought. Discrimination from state authorities adds a further strain on a group's resources. This will affect the group's ability to adapt to a climatic shock (Barnett/Adger 2007). If a group is being denied access to central decision-making processes it is left with few peaceful means of addressing its grievances and concerns (Tilly 2003). Moreover, political exclusion and economic marginalization can generate or reinforce a common identity for the group, which is a key foundation for effective mobilization (Gellner 1983; Gurr 2000; Tilly 1978).

Environmental marginalization might also have more indirect implications for human security and the risk of armed conflict. Forced migration is often considered a key conflict-inducing mechanism in this regard (Christian Aid 2007). While some people may choose to relocate in response to increasing scarcities, distress migration may only transfer the problem elsewhere, if host communities are unable to meet a rapid increase in demand for fresh water, pasture, firewood, etc. This might give rise to resource competition and ethnic tension, as well as land use conflicts between the migrants and the host community (Reuveny 2007). Owing to data limitations and the lack of conceptual clarity, no empirical study has been able to explore the security implications of 'environmental migration' across multiple cases (Raleigh/Jordan 2010).

A somewhat different reasoning for a scarcity-conflict connection is found in the economic literature on civil war. In rain-fed agrarian societies, it is argued, significant deviations from normal precipitation levels reduce income from agriculture and other rain-dependent industries. Such environment-induced economic shocks might heighten the risk of conflict in two ways (Burke/Miguel/Satyanath et al. 2009; Miguel/Satyanath/Sergenti 2004). First, loss of state revenues due to less taxation and fewer exports and other income-generating activities may result in a widening wealth gap between the privileged (i.e. political elites and their supporters) and the discriminated-against segments of society (Albala-Bertrand 1993). Moreover, it can reduce the government's capacity for counter-insurgency (e.g. monitoring, policing, military fighting power) and its ability to deliver public goods. Both outcomes may engender greater opportunities and incentives for dissident organizations to employ violent means to realize their goal. Second, an economic shock may lower the economic opportunity cost to individuals of becoming rebel soldiers by increasing unemployment and lowering wages. This argument can be related to a view of rebellion as individual criminal behaviour, where a potential rebel's decision is based on calculations of expected private economic gain (Collier 2000; Grossman 1991).

The proposed mechanisms that translate a diminishing per capita resource base into violent conflict differ between the literatures; ES-based arguments point to migration, local inter-ethnic competition, and state exploitation as important catalysts, while the economic approach relies on macro-structural explanations of failing state institutions and rationalist individualist behaviour. Yet the theorized outcome is quite similar: riots, rebellion, and civil war.

2.3 Quantitative Research: State of the Art

The first wave of generalizable, large-N research on environmental scarcity and civil war emerged more than a decade ago (e.g. Hauge/Ellingsen 1998; Esty/Goldstone/Gurr et al. 1998). These studies were quite simplistic by today's standards, relying on mostly static measures of environmental features and suffering from considerable missing data. In the interests of space, this pioneering work will not be reviewed here but instead the interested reader is referred to Buhaug, Gleditsch, and Theisen (2010), Salehyan (2008), and Theisen (2008).

Following increasing awareness of global warming and concerns about its possible social effects, research on environmental scarcity and armed conflict has seen a revival in recent years. A notable contribution to the second generation of work is the special issue of *Political Geography* on "Climate Change and Conflict", guest-edited by Nordås and Gleditsch (2007). In many ways, this journal issue embodies the current state of knowledge: the inconclusiveness concerning the impact of the environment on violent conflict. For example, Hendrix and Glaser (2007), studying the association between rainfall patterns and civil war in sub-Saharan Africa, find that drier years increase conflict risk but conclude that future climate changes are unlikely to have a dramatic effect on the incidence of conflict overall. Intriguingly, their analysis also suggests that civil conflict is *positively* associated with freshwater availability per capita. Other studies that report an inverse relationship between rainfall and civil war include Miguel, Satyanath, and Sergenti (2004), and Jensen and Gleditsch (2009). However, as demonstrated by Ciccone (2010), this correlation is an artefact of the particular rainfall growth measure that all of these studies employ (see also Buhaug 2010). Moreover, a disaggregated analysis of local precipitation and civil war outbreak fails to uncover a systematic relationship even with the problematic rainfall growth variable (Theisen/Holtermann/Buhaug 2010).

A second contribution to the special issue looks at a wider set of environmental indicators on a global scale (Raleigh/Urdal 2007). This study finds some support for the population pressure hypothesis in that civil wars are more frequent in densely populated areas and areas with high rates of population growth. The substantive impacts of these factors are low, however, as political and economic factors far outweigh demographic explanations of civil war. In another study, Urdal (2005) finds that high pressure on potential cropland is *negatively* related to civil conflict, but that population growth and density jointly increase the risk of conflict, if only marginally. The comprehensive statistical analysis by Hegre and Sambanis (2006) provides no support for the neo-Malthusian population pressure hypothesis. Similarly, Binningsbø, de Soysa, and Gleditsch (2007) find that countries with a high consumption of renewable resources are *less* at risk of civil conflict, even after controlling for economic development (Theisen 2008).

Recently, a quantitative investigation received much publicity for its finding that higher temperatures are associated with higher civil war frequency in sub-Saharan Africa (Burke/Miguel/Satyanath et al. 2009). In fact, the article concludes that future warming is likely to outweigh any pacifying effect of future economic growth and democratization in the region. This is certainly a worrying projection. Yet, as with the authors' previous study (Miguel/Satyanath/Sergenti 2004), the finding is sensitive to the techniques of model specification and estimation. A follow-up study by Buhaug (2010) shows that small alterations to the unconventionally coded dependent variable (major civil war years) completely dissipate the result, and the conclusion also falls if a standard non-linear model with time-varying covariates (i.e. logistic regression) is chosen, or the temporal domain is expanded to include the most recent years.

A promising avenue for further scrutiny concerns the relationship between communal violence and climatic factors. So far, most evidence runs counter to a simple scarcity-violence connection. For example, Meier, Bond, and Bond (2007) found little evidence of violence being more pronounced in the dry season in the borderlands of Kenya, Uganda, and Ethiopia. Witsenburg and Adano (2009) found that, on average, wet years brought twice as many deaths in intergroup cattle raiding episodes as dry years in Marsabit and Moyale districts in northern Kenya. Likewise, Raleigh (2010) finds some evidence for more violent events during the rainy seasons than during the dry season for Kenya. Still, the consequences of environmental degradation and resource scarcity for low-level violence and communal conflicts remain critically under-researched. As data on non-state conflicts and local violent events are increasingly being collected in a systematic manner (e.g. the UCDP Non-State Conflict dataset), this should have high priority for future research.

In the next section, we offer a new empirical assessment of rainfall variability and civil war for the entire African continent. We draw on an unparalleled selection of precipitation parameters, including not only current and past-year estimates of annual rainfall but also various deviation measures, as well as a direct drought indicator that taps intra-annual deviations from normal precipitation. Moreover, we expand the temporal domain of Miguel, Satyanath, and Sergenti (2004) and subsequent studies to the entire post-colonial period.[2] Finally, we explicitly incorporate sociopolitical structures and investigate a series of plausible interaction effects suggested in the ES literature.

2.4 Rainfall Patterns and Civil War: A Closer Look

As outlined above, the literature is still in disagreement regarding the true relationship between drought and civil conflict. This chapter seeks to offer the most

2 For various reasons, Hendrix and Glaser (2007), Jensen and Gleditsch (2009), Ciccone (2010), and Buhaug (2010) all apply derivatives of the same dataset, containing annual observations of countries in sub-Saharan Africa for the period 1981–2002.

comprehensive empirical assessment of drought and civil war to date. Our general expectation, which is inspired by arguments and narratives presented in the environmental security literature, is articulated in the following deliberately simplistic hypothesis:

Hypothesis: Drier years are associated with a higher risk of civil war.

To test this hypothesis a multivariate regression analysis is conducted on independent African states for the period 1960–2004. The heavy reliance on rainfall for African livelihoods and the distinct seasonality of precipitation patterns in much of the continent make not only the amount but also the timing of the rain crucial. The latter dynamic has been ignored in the empirical literature thus far. Heavy rainfall outside the rainy season(s) may contribute to normal amounts of annual precipitation in otherwise dry years, and yet lead to failed harvests as the rainfall comes too late, too early, or in too concentrated a period. For instance, in 2000 large areas of Ethiopia experienced a drought according to the EM-DAT natural disasters database (CRED 2009). The Wello and Hararge areas in the central east of the country were hit particularly hard. At the same time, annual statistics for the year 2000 show that Ethiopia as a whole saw 12 per cent more precipitation than the annual average for the period 1951–2004. Even though half of Ethiopia experienced rainfall shortage or disrupted rainfall patterns that led to a drought affecting nearly 5 million people, this was masked by the aggregated statistics.

In order to capture intra-annual variation in precipitation the high-resolution *Standardized Precipitation Index* (SPI6) is used, available at 0.5º x 0.5º grid resolution. This index is based on moving rainfall deviation scores from the monthly average during the six preceding months, which are aggregated to the calendar year. The annualized index is dichotomized where drought is defined as three consecutive months with at least 1 standard deviation below normal precipitation or two consecutive months with at least 1.5 standard deviations below normal precipitation (see McKee/Doesken/Kleist 1993 for the idea behind the measure). Two versions of the SPI measure are tested. The first (labelled SPI) is a discrete variable taking the value 1 if a drought was recorded anywhere within the country (i.e. in at least one grid cell) in the year of interest and zero if not. The second (SPI share) captures the geographical share of the country experiencing an SPI6 drought during the year.

The SPI variables capture both intra- and inter-annual rainfall variability and probably constitute the best available indicator of weather anomaly and local acute water scarcity.[3] However, to make our results comparable with earlier studies (notably Burke/Miguel/ Satyanath et al. 2009; Hendrix/Glaser 2007) indicators of inter-annual change in precipitation are also included

$$(\text{Rain } \Delta_{it} = \frac{\textbf{Rain}_{it} - \textbf{Rain}_{it-1}}{\textbf{Rain}_{it-1}})$$

as well as rainfall deviation from the long-term country average

$$(\text{Rain dev}_{it} = \frac{\textbf{Rain}_{it}}{\textbf{Rain}\mu_{it \ldots itn}}).^4$$

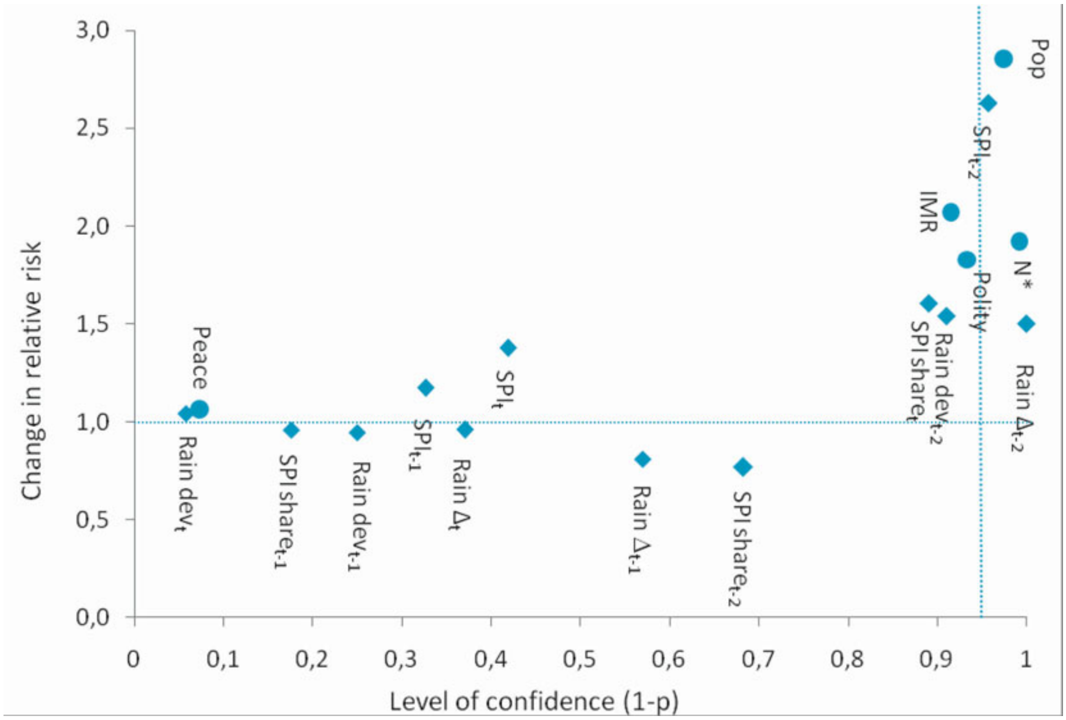
All four measures of drought are tested for the current year (t), the previous year (t-1), and two years earlier (t-2). The precipitation data are based on geo-referenced data from the Global Precipitation Climatology Centre of the UN-sponsored World Meteorological Organization (GPCC; Rudolf/Schneider 2005). Country year precipitation estimates were generated by taking the cell mean value for all 0.5 x 0.5 degree grid cells belonging to the country.

A limited number of control variables are also included. As an indicator of institutional inclusiveness, an updated version of the *N** index of ethno-political exclusion (Cederman/Girardin 2007) is used based on the new *Ethic Power Relations* (EPR) database (Wimmer/Cederman/Min 2009). Put simply, the *N** index gives the proportion of a country's population that belongs to ethnic groups that are excluded from political influence at the national level. A log-transformed variant is used as the initial levels of exclusionary ethnocracy are expected to increase the risk more than further steps down the same ladder. We also include the level of democratic institutions measured by the Polity 2 index of the Polity IV project (Marshall/Jaggers 2002). The *N** measure and the Polity 2 indicators were both lagged one year to reduce the chance of reverse causality. Further, as a proxy for societal vulnerability, we include data on *infant mortal-*

3 Rainfall shortage is of course only one component of water shortage. Yet, given the limited use of irrigation and scarcity of ice-capped mountains in Africa, rainfall is the key determinant of freshwater availability. Besides this, precipitation is exogenous to (short-term) human activities and social processes such as armed conflict, in contrast to irrigation, waterhole development, and desalination and purification industries.

4 Mean annual precipitation was measured based on statistics for the period 1951–2004.

Figure 2.2: Relative risk and significance for explanatory variables. **Source:** The authors.



Note: Drought measures represented by squares, control variables represented by circles. Plots above the horizontal line at Y=1.0 indicate increasing conflict risk with higher values, plots below the line have negative effects. The vertical line marks the threshold value (0.95) for statistical significance.

ity rate (IMR) from the UN's Population Division, supplemented by data from Urdal (2005). The IMR variable is lagged five years to reduce endogeneity. The final control variable is (natural log of) country population size (from Gleditsch 2002). In addition, all models include a non-linear term measuring the time since the previous conflict, based on the UCDP/PRIO dataset (Gleditsch/Wallensteen/ Eriksson et al. 2002), since countries with a violent near past may run a higher risk of experiencing renewed conflict.[5]

Our dependent variable is the onset of civil conflict as defined by the UCDP/PRIO Armed Conflict Dataset (Gleditsch/Wallensteen/Eriksson et al. 2002), which requires at least 25 persons killed each year in fights between organized non-state actors and state forces. We exclude coups, however, as these by definition are intra-government and so are likely to follow a different logic.[6] A period of at least two calendar years of peace is required for recurrence of violence to be coded as a new onset.

The results from the regression analysis on the relationship between various rainfall/drought measures and the outbreak of civil conflict are displayed in figure 2.2 below. Each rainfall/drought parameter (represented by squares) was run in a separate model with all of the control variables (circular dots). The vertical axis gives the estimated change in *relative risk* (RR) of civil war onset when the given drought variable shifts from the 10th to the 90th percentile value, with all other factors kept at their median value.[7] The interpretation is quite straightforward: plots above the horizontal line (RR=1) indicate an increasing risk of conflict onset with higher values on the drought variables while RR<1 implies a negative association. A relative risk of 2 means a doubling of the risk. The horizontal axis gives the statistical level of confidence for the parameter estimate; the dotted vertical line marks the threshold value for the conventional 95 per cent confidence level. Thus, the plots at the upper rightquad-

5 This was realized as a decay function capturing the time since last conflict in the country with a half-life set to two years.

6 The decision as to whether or not to include coups as civil conflicts does not affect the overall conclusion of the analysis.

7 If it is a dummy variable the effects are computed from moving from 0 to 1.

rant of the figure represent variables that increase conflict risk in a statistically significant manner.

As seen in figure 2.2, the factor that has the largest impact on conflict risk is population size, a finding that corresponds well with earlier studies that population size is one of the three most robust correlates of civil war (Hegre/Sambanis 2006). Furthermore, ethnopolitical exclusion is found to have a statistically significant and substantive risk-inducing effect, corroborating Cederman and Girardin (2007), Wimmer, Cederman and Min (2009), and Buhaug (2010). Two other controls, *infant mortality rate* (IMR) and democracy (polity) also are positively correlated with the risk of civil conflict onset, although the effects are not significant at the conventional 5 per cent level of uncertainty. This is probably due to the relative homogeneity of African countries with respect to democratic institutions (most are autocratic or semi-autocracies) and development of societal infrastructure (many are among the world's poorest societies).

Most precipitation parameters hover around the horizontal line (RR=1) and therefore do not have much to say about conflict risk. The most influential climate variables are the dummy for drought in at least one grid cell in the country two years ago [earlier?] (SPI_{t-2}) and inter-annual rainfall change from t-3 to t-2 (Rain $_{t-2}$); both increase conflict risk significantly and positively. Furthermore, above-average rainfall in t-2 is almost significant at the 95 per cent level. The two latter findings run counter to expectations and give hints of an odd characteristic of the rainfall data. [8]Sensitivity analyses (not shown) reveal that both these effects are caused in large part by a single case, Djibouti, which exhibits very large variability around its mean precipitation level. When Djibouti is dropped from the analysis, the effects of these parameters dissipate. The result is also sensitive to other minor adjustments in measurements and model specification, which jointly imply that we do not put much faith in this correlation. Contrary to other studies (Hendrix/Glaser 2007) we do not find any effect of current or previous-year precipitation, though the reader should keep in mind that this analysis covers the entire African continent and twice as many years as earlier research.

We concur with Ciccone (2010) in that using inter-annual change to estimate rainfall shocks is inappropriate as rainfall is mean reverting. This implies that seemingly high positive or negative growth rates frequently represent regression towards the mean trend and not genuine deviations. Deviation from the long-term mean is more reliable, but still misses potentially very important intra-annual variations in precipitation patterns. The fact that different precipitation measures produce different results and any apparent statistically significant relationship disappears once the most extreme outliers are removed forces us to reject the proposed hypothesis; the data do not reveal a robust impact of rainfall variability on civil conflict risk. The results visualized in figure 2.1 do not change substantively if alternative estimation techniques or model specifications are used.[9]

Much of the environmental security literature points (explicitly or implicitly) to interactions between scarcity and distribution, where the political, economic, and cultural contexts come into play (Homer-Dixon 1999; Kahl 2006). In order to test such arguments more properly, the alternative realizations of drought/deviations in rainfall were tested in interaction with three variables that tap some of the potentially conditional effects on civil conflict: political exclusion, the share of a country's population defined as rural, and infant mortality rate. The level of inclusive political institutions in combination with ethnic cleavages is crucial in explaining why some countries experience civil conflict and others do not, and discriminatory political regimes and high ethnic barriers are also argued to be important in making scarce resources more inflammatory. To test this, interaction terms were created between each of the measures of drought with the N^* index of political exclusion. Even though such a connection seems plausible, it did not return a significant coefficient. Next, interactions were investigated with a share of the rural population, as most rural inhabitants in developing countries depend on renewable resources for their livelihood. This interaction added significantly to the model fit in just two specifications. Relatively larger drought-affected areas in the current year (SPI $share_t$) are associated

8 As Ciccone (2010) explains, several African countries affected by civil war experienced unusually wet years at t-2. This led Miguel, Satyanath, and Sergenti (2004) to conclude that drying at t-1 increases the risk of civil war even though the negative 'growth' in rainfall between t-2 and t-1 in effect represented a normalization.

9 We ran models with coups included in the classification of civil conflict and used rare-events logit (relogit) instead of ordinary logit regression (King and Zeng 2000). Results are even less in support of the ES argument if we run models for sub-Saharan Africa only (with or without coups, with logit or relogit), as the drought two years earlier (SPI_{t-2}) loses significance in these specifications.

with higher risk of conflict onset, but this effect is driven by the demographic component, not by drought. A similar but somewhat weaker pattern is found for the SPI $share_{t-1}$. However, the analysis also shows that the cases most prone to conflict are drought-stricken cases with a *low* share of rural population, a finding that is the opposite of what is expected. The only seemingly robust interaction effect uncovered here is the joint occurrence of drought two years ago [earlier?] (SPI_{t-2}) and a high infant mortality rate. While this suggests that there might be a genuine causal link between water scarcity and violent behaviour, the substantial time lag and the failure of other measures of water scarcity to produce similar results imply that this finding should be interpreted with much care.[10]

Earlier quantitative studies of rainfall and conflict have produced mixed conclusions. The results presented here are largely in line with those of Buhaug (2010), Ciccone (2010), and Theisen, Holtermann, and Buhaug (2010), who fail to uncover a systematic relationship between drought or negative rainfall deviation and the risk of civil war. Accordingly, our results counter those of Hendrix and Glaser (2007) and Miguel, Satyanath, and Sergenti (2004), who report that unusually dry years lead to a higher conflict risk in the subsequent year. The source of this incongruence can be found in the way drought is measured. Earlier studies that find support for the general ES proposition apply drought variables that measure the proportional change in precipitation from one year to the next. This is unfortunate as the resulting value is conditional on both the current and the previous-year values. Ciccone (2010) shows that such a trivial misspecification results in findings directly opposite to those produced when rainfall is measured properly (though any statistical association disappears once extreme outliers are left out of the estimation).

Does this mean that there is no linkage between renewable resource shortages and violent conflict? We believe it would be premature to draw such a conclusion at this time. Contemporary statistical research suffers from limitations in data, methodology, and research design that restrict inference, and there are often-ignored disconnections between the case literature and large-N research that need to be addressed. In the next section we discuss some of the many challenges that face future quantitative research in the field.

10 The interactions between our battery of drought measures and the share of a country's revenues that come from agriculture were also tested, without significant results. It should be noted that the agricultural income data suffer from substantial missing observations, which might affect this result.

2.5 Challenges and Opportunities for Future Research

The patchy empirical support for the general ES proposition is indicative, but far from evidential, that resource scarcities are of limited relevance for the general risk of armed conflict. The fact is that the extant quantitative literature suffers from several shortcomings that should be addressed in future research. There are at least four issues that need attention: level of analysis, type of violence, trigger versus underlying causes, and conditional effects.

2.5.1 Geographic Disaggregation

Most quantitative studies of the environment and civil war apply the country as the unit of analysis (e.g. Burke/Miguel/Satyanath et al. 2009; Hendrix/Glaser 2007; Miguel/Satyanath/Sergenti 2004; Theisen 2008; Urdal 2005). Yet, as illustrated by the eastern Ethiopian drought in 2000, resource availability may vary significantly across space – within states – and armed conflicts too tend to be discriminatory in their spatial impact on conflict-ridden countries (Buhaug/Lujala 2005). Conventional country-level research designs are not well suited to tap such nuanced patterns. Acknowledging this deficit, there has been a surge in disaggregated studies of civil war in recent years, focusing on the particulars of the areas where conflicts break out or take place (e.g. Buhaug/Rød 2006; Østby/Tadjoeddin/Urdal et al. (2011); Raleigh/Urdal 2007; Theisen/Holtermann/Buhaug 2010; Urdal 2008). Some of these high-resolution studies do suggest a violence-inducing effect of local resource scarcity under certain conditions, as Østby, Tadjoeddin, Urdal et al. (2011) argued for the case of Indonesia and as in Urdal's (2008) sub-national analysis of India. Time will show whether these associations also apply to other cases.

The disaggregation trend contains great potential for offering additional and more precise insight into the systematic covariation between environmental factors and conditions and violent behaviour. Such spatially focused sub-national studies should not be seen as a replacement for country-level analyses, however. Some theories of political violence and civil war focus on state-wide features that carry little meaning at a local level, including central political institutions, export structure and the national economy, international trade patterns, commodity prices, etc. However, when theory predicts local mechanisms and characteristics conducive to violence, such as political discrimination, economic marginalization, and, crucially, high or increasing environmental degradation, a disaggregated research design should be adopted.

2.5.2 Widening Understanding of Conflict

To date almost every empirical investigation of the drought–conflict nexus deals with large-scale state-based violence, most typically civil war. While larger-scale violence may be less likely to result from short-term resource scarcities caused by organizational and financial factors (Wolf 1998), there are sound reasons to expect that other, less severe forms of violence might be more closely related to environmental factors. Writing on the violence in Darfur in the late 1990s, Suliman (1999) argues that local conflicts between groups competing over scarce renewable resources such as water and land in areas where there are no free eco-zones to migrate to are the most relevant in a scarcity-conflict framework. Suliman further argues that the frequency of this kind of conflict is increasing, notably in the Sahel and Horn of Africa regions. Unlike national conflicts over state power or regional warlord competition, these conflicts take the form of local violent resource competition between marginalized groups. In a similar vein, Raleigh (2010) suggests that if climate variability were to play a role in violent conflicts the lens should be directed towards groups without political leverage at the national level and whose choice of alternative livelihoods outside agriculture or pastoralism is limited. These groups are often regarded as the most vulnerable to climatic shocks, and, particularly in contemporary weak African states, these groups are often left to fend for themselves in areas with little effective state control and/or interest. This can result in violence as a form of mediation of access to resources and economic goods between groups.

A related point refers to conflict dynamics. So far, little attention has been paid to the nature and severity of conflicts within the context of resource scarcity and harsh environmental conditions. What are the immediate implications of drought or climatic shocks for ongoing conflicts? Do increasing scarcities and loss of livelihoods contribute to intensifying prevalent conflicts or do they increase the prospect for peaceful resolution? Are conflicts likely to take on other forms (e.g. a shift from communal violence to riots and government-directed assaults) when environmental conditions deteriorate? These are only three of the many possible research questions related to conflict dynamics that are yet to be addressed in a rigorous, comparative manner.

2.5.3 Trigger vs. Background Effects

The ES literature is generally rather vague as to how scarcities and environmental shocks translate into elevated conflict risk. Much of the recent climate security discourse seems to assume that environmental change primarily contributes to increasing the underlying, or latent, conflict risk. Catchy phrases, such as ‘threat multiplier’ (CNA 2007) and ’consequences of consequences’ (Smith/Vivekananda 2007) point to the indirect, long-term security implications of climate change. A cumulative slow-moving effect is also reflected in the academic literature, most notably in Homer-Dixon’s (1999) concept of *ingenuity*. Resource scarcity, Homer-Dixon argues, is an important prime mover behind much mal-development and resulting violence in developing countries today. Although it interacts with a multitude of social factors, the social outcome is to a substantial extent determined by the resource base. In contrast, Burke, Miguel, Satyanath et al. (2009; see also Miguel/Satyanath/Sergenti 2004) claim a short-term, trigger effect of climatic variability, and speak of temperature or precipitation anomalies as ‘shocks’. While any factor relevant to armed conflict may affect both immediate and longer-term conflict risk, future research should invest more in specifying the temporal dimension of a causal relationship as this has implications both for designing the quantitative analysis and for prediction. Hendrix and Glaser (2007) provide a starting point by empirically assessing both measures of resource shocks and longer trends. However, much is left for future research since many of the claimed long-term effects of resource scarcity are said to be indirect, affecting conflict risk through slow or negative economic progress, increasing socio-economic inequalities, and institutional failure (Homer-Dixon 1999).

The empirical literature contains a wide range of alternative conflict specifications: some study the outbreak of conflict (e.g. Hendrix/Glaser 2007), others study the prevalence of conflict (e.g. Raleigh/Urdal 2007), while some limit their focus to the most severe war years only (Burke/Miguel/Satyanath et al. 2009).

There is little reason to expect these differences to produce similar results (Buhaug 2010). Again, theory must be the guide for designing the most appropriate conflict measure and applying the most appropriate time lag (if any) to the environmental indicators. Moreover, the quality of environmental data is still rather poor; most measures are given as country aggregates only and complete time-series estimates are rare. That said, recent years have seen a rapid increase in high-resolution data, aided by remote sensing and satellite imagery that enable much-needed indicators of environmental conditions at the local level.

2.5.4 Conditional Factors and Context

While environmental security scholars (Homer-Dixon 1999; Kahl 2006; Baechler 1999) claim an interactive effect between resource scarcities and various societal factors, the underlying empirical evidence is based on too few observations to suggest a general relationship. Obtaining generalizable knowledge in this context is challenging as conventional statistical estimation techniques have their limitations when the theoretical framework implies several simultaneous conditional factors. In effect, current empirical large-N studies are limited to testing approximations of ES theory. This has fostered criticism that quantitative analyses are too simplistic to capture key causal processes (Schwartz/Deligiannis/Homer-Dixon 2001; Kahl 2006) while quantitatively oriented researchers have argued that case-based research fails to produce interesting findings (Levy 1995). One alternative method to investigate complex relationships between multiple independent variables is the use of Boolean logic (Ragin 1987, 2008). However, as with any other method it requires good data on environmental and social factors, which up to now are quite limited. In any case, empirical investigations should strive to test the contextual effects suggested in the literature. Factors such as ethno-political exclusion and poverty are obvious candidates for inclusion (Homer-Dixon 1999; Kahl 2006).

An important aspect for human security in a broader sense is the impact of conflict on social vulnerability to climate change. Armed conflicts often inflict considerable environmental and infrastructural damage. Furthermore, conflict can lead to migration, loss of livelihood, and lowered health levels, factors that in turn increase conflict risk (Collier/Hoeffler 2004; Fearon/Laitin 2003; Salehyan/Gleditsch 2006) and potentially destabilize regions for a longer time span by generating a 'conflict trap' (Collier/Reynal-Querol/Hegre et al. 2003). Consequently, a drought or a flood is generally thought to constitute a much greater hazard in a conflict-ridden area than in a peaceful region (Busby/Smith/White et al. 2010). Determinants of human vulnerability to climate change are now gaining academic attention. Much like Sen's (1981) seminal insight that press freedom and institutional openness reduce hunger risk, good governance and empowerment of marginalized sections of society are crucial in reducing vulnerability to climate factors (Busby/Smith/White et al. 2010; Raleigh 2010; Ribot 2010).

Research on environmental vulnerability to date has either been in the form of case studies or cross-national analyses looking at national and static aggregates. Busby, Smith, White et al. (2010) argue that such studies might miss important variations in vulnerability, temporally and spatially, and that this strand of research has much to gain from applying sub-national and dynamic explanatory variables. While we agree with this observation, good data are not enough if the underlying logic and assumptions are wrong. There is a tendency in the literature to take drivers of environmental vulnerability for granted or to present causal models without proper empirical validation. Yet any claim of a causal relationship should be subject to rigorous empirical testing before firm conclusions can be drawn.

2.5.5 Concluding Remarks

The true relationship between environmental change and armed conflict remains unresolved. So far, there is little solid evidence of a systematic connection, and the regression analysis presented above substantiates this non-result. This suggests that other factors, such as poor governance, large heterogeneous populations, societal inequalities, poor economic performance, and a conflict-prone neighbourhood are more important in explaining variations in conflict risk. Yet the relevant empirical literature is still in its infancy and many challenges lie ahead. In this chapter four such challenges have been discussed. Geographical disaggregation, replacing crude country-level aggregates and research designs with sub-national data, is already well under way and promises more nuanced assessments of local-level correlations between the environment and conflict. Applying a more inclusive understanding of conflict will allow the forms of organized violence arguably most plausibly linked to adverse environmental conditions to be studied, namely low-intensive social unrest, communal violence, and urban riots. Moreover, a better specification of facilitating conditions, possible trigger effects, and indirect causal dynamics, theoretically as well as methodologically, should greatly increase the precision of regression estimates and improve our ability to make projections of future insecurity hot spots. It is hoped that future research will be able to address each of these issues in a satisfactory manner.

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