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Climate change, environmental degradation and armed conflict

Clionadh Raleigh [a,b,*], Henrik Urdal [b]

[a] Department of Government, University of Essex, Wivenhoe Park, Colchester CO4 3SQ, United Kingdom

[b] Centre for the Study of Civil War (CSCW), The International Peace Research Institute, Oslo (PRIO), Norway

Abstract

Climate change is expected to bring about major change in freshwater availability, the productive capacity of soils, and in patterns of human settlement. However, considerable uncertainties exist with regard to the extent and geographical distribution of these changes. Predicting scenarios for how climate-related environmental change may influence human societies and political systems necessarily involves an even higher degree of uncertainty. The direst predictions about the impacts of global warming warn about greatly increased risks of violent conflict over increasingly scarce resources such as freshwater and arable land. We argue that our best guess about the future has to be based on our knowledge about the relationship between demography, environment and violent conflict in the past. Previous rigorous studies in the field have mostly focused on national-level aggregates. This article represents a new approach to assess the impact of environment on internal armed conflict by using georeferenced (GIS) data and small geographical, rather than political, units of analysis. It addresses some of the most important factors assumed to be strongly influenced by global warming: land degradation, freshwater availability, and population density and change. While population growth and density are associated with increased risks, the effects of land degradation and water scarcity are weak, negligible or insignificant. The results indicate that the effects of political and economic factors far outweigh those between local level demographic/environmental factors and conflict.

Keywords: Climate change; Population pressure; Resource scarcity; Armed conflict

* Corresponding author. Department of Government, University of Essex, Wivenhoe Park, Colchester CO4 3SQ, United Kingdom.

E-mail address: clionadh@prio.no (C. Raleigh).

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Introduction

Environmental change as a cause of violent conflict has been a contentious issue in the security discourse of the 1990s. While the concerns over the security implications of population growth and resource scarcity goes back to the late 1960s, the issue has featured more prominently in the security debate after the end of the Cold War. This emerging 'securitizing' of environmental issues followed from an increased environmental awareness (Levy, 1995: 44) combined with an interest among Western national security establishments to identify potential threats that could legitimize their continued existence (Barnett, 2001: 2; Gleditsch, 1998). Despite the attention given to environmental factors as potential security threats, there appears to be a consensus that economic, political and social factors determine how countries handle resource scarcity. Wealthy and democratic countries are likely to be more capable both to adapt to resource scarcity and to mitigate conflict.

With an increasing focus on environmental consequences of climate change, speculations about how global warming may eventually influence patterns of war and peace have arisen (e.g. Brauch, 2002; Homer-Dixon & Blitt, 1998; Klare, 2001; Pervis & Busby, 2004; Rahman, 1999; Renner, 1996; Schwartz & Randall, 2003). To address the issue of whether climate change poses a traditional security threat, we build on propositions from the environmental security literature, identifying potential links between natural resource scarcity and violent conflict. We combine these propositions with environmental change scenarios from the Intergovernmental Panel on Climate Change (IPCC), and develop testable hypotheses about the expected relationships. These hypotheses are tested in a statistical model with a global coverage. If soil degradation, freshwater scarcity and population pressure have influenced the risk of conflict in the past, we assume that this may also inform us about likely security implications of climate change. Obvious limitations to such approach are the possibilities that climate change will bring about more severe and more abrupt forms of environmental change than we have experienced in the past. On the other hand, we are also unable to capture the possibility of an enhanced adaptability to environmental change due to increased technological and institutional capacity.

Previous quantitative studies of resource scarcity and violent conflict have primarily focused on state-level factors (Esty et al., 1998; Gleditsch, Furlong, Hegre, Lacina, & Owen, 2006; Hauge & Ellingsen, 1998; de Soysa, 2002; Theisen, 2006; Urdal, 2005). While there are some strong arguments in favor of comparing sovereign political units, especially related to the opportunity for internal migration and the relevance of international borders for conflict behavior, severe forms of environmental change are often confined to smaller areas than entire countries (for a forceful argument for disaggregating studies of environmental factors and armed conflict see Buhaug & Lujala, 2005). Sometimes such changes also span international borders. Similarly, violent political conflicts seldom affect all parts of a country equally. In this study, the units of analysis are geographical squares of 100 km $\times$ 100 km, allowing us to study the relationship between environment and conflict in a small-scale geographical, rather than political, context. We are utilizing a georeferenced version of the Uppsala/PRIO armed conflict data (Gleditsch, Wallensteen, Eriksson, Sollenberg, & Strand, 2002) produced by Halvard Buhaug (Buhaug & Gates, 2002). Our data set covers internal armed conflicts with at least 25 battle deaths annually, between two or more organized parties, of which at least one is the government of a state. The environmental data stem from several sources, and include indicators of freshwater scarcity, land degradation, and population growth and density. The results obtained from this study will contribute to inform us about the possible security implications of climate change.

Climate change, resource scarcity and armed conflict

One of the major criticisms of the early environmental security literature was that it tended to neglect important political and economic contextual factors (Gleditsch, 1998: 389). Environmental and demographic stress is not likely to be an equally important risk factor under all economic, political or social conditions, both because these factors determine a country's ability to adapt to environmental change, and because they largely determine the general opportunities for rebel groups to succeed. The significance of economic and political variables is well described in recent civil war literature. Fearon and Laitin (2003) argue that poverty increases the likelihood of war since poor states have a much weaker financial and bureaucratic basis, providing opportunity for insurgency. When controlling for income, they find that ethnic and religious diversity does not increase the risk of conflict. Collier and Hoeffler (2004) find that poverty, low economic growth and high dependence on primary commodity exports were important predictors of civil war, while ethnic and religious diversity as well as democracy did not affect the risk of war. Hegre, Ellingsen, Gates, and Gleditsch (2001), on the contrary, found that regime type and ethnic heterogeneity matter even after controlling for level of development. In the first quantitative study of environmental conflict, Hauge and Ellingsen (1998) found that economic and political factors were the strongest predictors of conflict, but that environmental and demographic factors did have some impact. The critique of the lack of contextual theorizing in the field has eventually led to much more specified models of the causal patterns between demography, environment and conflict (e.g. Kahl, 2006). In the following, we show how the resources of concern feature prominently in the emerging literature on climate change and security, before addressing more specifically the prospects from the UN climate projections. Gleditsch (1998: 393) has argued that much of the environmental security literature is 'using the future as evidence', and this is certainly relevant to the literature on climate change and conflict. We argue that for climate change to be a valid security concern, we would expect to see that environmental factors have been related to conflict behavior in the past. In the following, we build on a broad literature, including the most recent developments in the field, to outline the theoretical framework for a relationship between resource scarcity and armed conflict. While the forms of resource scarcity described here may be consistent with a climate change scenario, such forms of scarcity are likely to be a result of multiple processes and not exclusively of climate change.

The impact of climate change on resource scarcity

Scholars concerned with resource scarcity and conflict, often termed 'neo-Malthusians', focus on renewable resources that under conditions of sustainable use regenerate; the most important of these resources are cropland and freshwater (Homer-Dixon, 1999; Kahl, 2006).[1] The literature on climate change and security focuses on two interrelated processes expected to produce resource scarcity. Firstly, increasing temperatures, precipitation anomalies and extreme weather is expected to aggravate processes of resource degradation that is already underway (Homer-Dixon & Blitt, 1998: 2–5; Klare, 2001: 20; Pervis & Busby, 2004: 68; Renner, 1996: 46). Hendrix and Glaser (2007) find that climates that are more suitable for agriculture are associated with a lower risk of conflict in Sub-Saharan Africa, while Meier, Bond,

[1] Other frequently mentioned resources are fisheries and forests.

and Bond (2007) find that increased vegetation is associated with an escalation of pastoral conflict in the Horn of Africa, while precipitation and forage are unrelated to conflict behavior. Secondly, significantly increasing sea levels as well as more extreme weather conditions will force millions of people to migrate, potentially leading to higher pressures on resources in areas of destination and subsequently to resource competition (Barnett, 2001: 8; Rahman, 1999: 205; Renner, 1996: 108). Reuveny (2007) argues that past effects of environmental problems on migration suggest that climate change lead to environmentally induced migration that can increase the risk of conflict, particularly in less developed countries with limited mitigation capabilities. Ware (2005) found that high population pressure and limited migration opportunities led to increased intercommunal tension in the Melanesian countries. Although climate change is usually regarded as a potential future threat, some argue that global climate change has already been a contributing factor in current conflicts such as Darfur (Byers & Dragojlovic, 2004: 2).

In a report for the Pentagon, Schwartz and Randall (2003) speculate about the consequences of a worst-case climate change scenario and its implications for US national security. They argue that ‘as abrupt climate change lowers the world’s carrying capacity aggressive wars are likely to be fought over food, water and energy’ (Schwartz & Randall, 2003: 15) and further that a collapse in carrying capacity could make humanity revert to its ancient norm of constant battles for diminishing resources (p. 16). Although warning against overstating the relationship between climate change and armed conflict, both Barnett (2001: 6) as well as Pervis and Busby (2004: 68) accept that the depletion and altered distribution of natural resources likely to result from climate change could under certain circumstances increase the risk of some forms of violent conflict. It is not likely to be a major or sufficient cause of conflict, but may contribute to a mounting environmental challenge (Brauch, 2002: 23; Tänzler & Carius, 2002: 8).

Based on the 2007 impact assessments of climate change from the United Nations Intergovernmental Panel on Climate Change (IPCC), we identify three major processes expected to follow from climate change that according to the environmental security literature is likely to have security implications: degradation of cropland, increasing freshwater scarcity and population displacement.

Climate change is likely to influence the food-producing capacity in many areas. While some areas may experience a reduction in crop yields, others are likely to benefit. One important factor is temperature. While an increase in temperature of a few degrees is projected to generally increase crop yields in temperate areas, greater warming may reduce agricultural output. In tropical areas, where dry land agriculture dominates, even minimal increases in temperature may be detrimental to food production (IPCC, 2001: 32). Degradation of soil and water resources is likely to be intensified by adverse changes in temperature and precipitation, although adaptation behavior has a potential to mitigate these impacts as land use and management have been shown to have a greater impact on soil conditions than the indirect effect of climate change (IPCC, 2001: 32).

According to the IPCC (2001: 31), there are currently 1.7 billion people living in countries that are water stressed, meaning that they use more than 20% of their renewable water supply. This number is projected to increase as a result of population and industrial growth, and climate change may aggravate this trend in many water-stressed countries as a result of decreases in streamflow and groundwater recharge (IPCC, 2001: 31), although freshwater supply may increase in other countries. Higher water temperatures are likely to lead to a degradation of water quality. Non-climatic factors may influence freshwater availability and quality to a larger degree than climate change, and water management may thus significantly reduce vulnerability

(IPCC, 2001: 31). However, in areas where vulnerability increases and water management fails, increased freshwater scarcity is a likely outcome.

Because of rising sea levels and increased risks of flooding, climate change is expected to contribute to migration from coastal and riverine settlements (IPCC, 2001: 36). Some forms of environmental change associated with climate change like extreme weather and flooding may cause substantial and acute displacement of people. However, the most dramatic form of change expected to affect human settlements, sea-level rise, is likely to happen gradually, as is the process of soil and freshwater degradation. Improved forecasting skills will make adaptation easier and reduce the problem of population displacements (Chimeli, Mutter, & Ropelewski, 2002: 213). So while abrupt displacements may happen, we primarily expect to see climate change resulting in a gradual migration by people in search for more fertile land.

The links between population, resources and conflict

While it is generally agreed in the environmental security literature that the effects of resource scarcity are modified through political, economic and social structures, the resource scarcity and conflict scenario have been theoretically underspecified. Attempting to rectify this problem, Kahl (2006) has identified two alternative causal pathways from demography and environment to violent conflict.[2] Like other leading students of the environment–conflict nexus (Baechler, 1999; Homer-Dixon, 1999), Kahl (2006) argues that demographic and environmental pressures are more likely to cause internal, rather than international, violence. There is also an emerging acknowledgment in the literature that conflicts of interest over shared resources may be a vehicle for increased cooperation (e.g. Wolf, Kramer, Carius, & Dabelko, 2005).

Resource scarcity is seen as a product of three different factors interacting: population growth, resource degradation, and the distribution of resources between individuals and groups. Homer-Dixon has called this *demand induced*, *supply induced* and *structural scarcity*, respectively (Homer-Dixon, 1999; Homer-Dixon & Blitt, 1998). The distributional aspect is central in all the major works focusing on resource scarcity and political violence (Baechler, 1999; Homer-Dixon, 1999; Kahl, 2006).[3] The three sources of scarcity may exert different impacts from case to case, and frequently interact. Homer-Dixon (1999) argues that two types of interactions are particularly common. *Resource capture* occurs in a situation of resource degradation and population growth, providing incentives for powerful groups to take control over scarce resources on the expense of weaker and poorer groups. *Ecological marginalization* denotes a situation where great land inequality and population growth leads people to move into more ecologically fragile areas. While many countries have the ability to adapt to environmental change, some countries, particularly poor and underdeveloped states, are likely to be more vulnerable to environmentally related violence (Baechler, 1999: xvi; Homer-Dixon, 1999: 181).

Kahl (2006) identifies two distinct 'state-centric' causal pathways from resource scarcity to internal violent conflict; the *state failure* and the *state exploitation* hypotheses. Both start from the premise that resource scarcity, or what he terms *demographic and environmental stress*

[2] Kahl (2006) defines 'civil strife' as 'large-scale, sustained, and organized conflict within a country', which includes 'revolution, rebellion, insurgency, civil and ethnic war, and sustained campaigns of terrorism', but excludes low-scale violence such as riots and crime, as well as international conflict.

[3] Despite its theoretical importance, we do not attempt to empirically capture resource distribution, as such data are currently not available on the local level.

(DES), may put severe pressure on both society at large and on state institutions. When the interaction between resource degradation, population growth and unequal resource distribution leads to lower per capita availability of land resources and expansions into more marginal land, this is assumed to put a greater pressure on agricultural wages and contribute to economic marginalization as a first-order effect. Such hardship can, as a second-order effect, lead both to rural-to-rural migration, potentially causing inter-ethnic conflicts over land, and to rural-to-urban migration. While urban populations generally enjoy material standards above those in rural areas, urbanization often puts a pressure on a state's ability to provide vital services such as housing, clean water and health services. Further, the social consequences of DES may produce absolute deprivation, meaning that people do not get what they need in order to survive, as well as relative deprivation, a situation in which they do not get what they feel they are entitled to. Both forms of deprivation may produce grievances among rural and urban populations.

The novelty in Kahl's (2006) approach lies in the way he differentiates between the potential roles of the state. Like Homer-Dixon (1999), he sees DES as a factor that can produce severe strains on a state. DES is argued to potentially weaken a state's *functional capacity* by placing costly demands on the state for development projects in the agricultural sector or social improvements for burgeoning urban populations, but also by generally undermining overall economic productivity and potentially also the ability to finance a coercive capacity (Kahl, 2006: 40–42). The other aspect of state strength, *social cohesion*, may also be weakened by DES. Alternative elites within the state may compete over how to use strained resources either geographical or sectoral, and they may disagree over the best way to respond to the challenges posed by DES (Kahl, 2006: 43).

The weakening of the state is seen as an intermediate factor between resource scarcity and violent conflict. While the resource scarcity literature is often seen as belonging to the 'motive' tradition, the state-centric perspective identifies important opportunity factors in both the possible causal trajectories. The state weakness hypothesis posits that the impact of resource scarcity will weaken state institutions and provide opportunities for potential rebels to challenge the state authority. Conflict may arise when the potential gains from a rebellion are higher than the costs that a state can inflict on the rebels. Waning state authority produces a 'security dilemma' where social groups are 'left to fend for themselves' (Kahl, 2006: 47). Episodes of regime collapse and regime transitions may thus provide particularly great opportunities for DES-generated violent conflict. However, even when demographic and environmental factors are *not* the primary drivers of state failure, relatively weaker states are presumably more likely to experience resource scarcity conflicts firstly because they are less capable of mitigating the effects of resource scarcity, and secondly because they are generally more likely to be militarily challenged by opposition groups. If the state failure hypothesis is an important pathway to armed conflict, we should expect to see that statistical controls for low state capacity and state failure should capture some of the explanatory power of the demographic and environmental variables.

The state exploitation hypothesis suggests another important opportunity aspect, namely the opportunity for weakened states to bolster their support base through mobilizing ethnic groups to capture scarce resources. When regimes experience increased grievances and opposition due to resource scarcity, they may be likely to instigate inter-ethnic violence as a means to divert attention from their inability to meet these demands at the same time as they consolidate support among groups that may capture resources on the expense of contending groups. While theoretically appealing, the state exploitation hypothesis is difficult to empirically test in a statistical model. Kahl (2006: 50) posits that state exploitation 'can occur at levels of state weakness far short of total collapse', but he does not offer suggestions for what characteristics we may expect to see among regimes that would engage in state exploitation. So while we may be able to test whether domestic armed conflicts are overrepresented in resource scarce areas of poor countries, we will not be able to conclude whether a possible statistical relationship between resource scarcity and conflict that is not well captured by the context of failed or very weak states may be due to a 'state exploitation' explanation.

In the environmental security literature, as in the broader civil war literature, it is common to address two structural features that are generally assumed to be important determinants of armed conflict: social or cultural segmentation and regime type. It is generally assumed that the existence of strong social or cultural identity provide greater opportunities to mobilize along group lines and hence overcome the collective action problem of rebellion. While it has been argued that scarcity may aggravate social segmentation (Homer-Dixon, 1999: 96), we do not regard ethnic heterogeneity as such as an intermediate variable, and do not control for it in our models. As for regime type, semi-democratic forms of governance are regarded as providing greater opportunities for violent conflict than autocracies and greater motives than democracies (e.g. Hegre et al., 2001). Governance is capturing aspects of state capacity, so we have included controls for regime type in our models.

Previous quantitative studies have found mixed evidence for the resource scarcity and conflict nexus. The two first larger studies in the field, the State Failure Task Force Report (Esty et al., 1998) and Hauge and Ellingsen (1998) reported slightly different results. Esty et al. (1998) found no effects of soil degradation, deforestation and freshwater supply on the risk of state failure. Hauge and Ellingsen (1998) on the contrary concluded that the same factors[4] as well as high population density were indeed positively associated with civil war, but that the magnitude of the effects was secondary to political and economic factors. Theisen (2006) was unable to replicate their results using the same data set, and found very limited support for neo-Malthusian concerns in his own data. Gleditsch et al. (2006) found that shared river basins increase the likelihood of low-intensity interstate conflicts. Wolf et al. (2005: 81) concluded on the basis of a major data collection effort that shared freshwater resources are hardly ever a major cause of conflict, and that cooperative events between riparian states clearly outnumber conflict events. Assessing the issue of land scarcity, de Soysa (2002) found a significant effect of population density on domestic armed conflict, while Urdal (2005) reported results indicating that scarcity of potentially arable land may indeed have a pacifying effect domestically.

In this study we try to reconcile these diverse findings by moving below national aggregates to see if local resource scarcity offers a better prediction of conflict behavior. While rarely stated explicitly in the resource scarcity literature, the link between resources and conflict may not be properly studied by regressing cross-national aggregate data. Environmental problems may arise and persist locally, and armed conflicts rarely affect whole countries equally. A recent study of India (Urdal, 2006) suggests that sub-national disaggregated studies may provide more support for the resource–conflict nexus, and many case studies in the field look at local pressures and responses. This study addresses the relationship between local resource scarcity and conflict for a global sample. The main focus is on areas that experience multiple stressors in the form of scarcity and population dynamics, as well as on important contextual factors, captured in the following set of hypotheses:

[4] Hauge and Ellingsen (1998) did not have time-series data for the environmental indicators.

H1 In areas of greater population growth, areas with high levels of land degradation are more likely to experience armed conflict.
H2 Areas with high freshwater scarcity are more likely to experience armed conflict the greater the population growth.
H3 Areas with high population density are more likely to experience armed conflict the greater the population growth.
H4 The effect of demographic and environmental factors is stronger in areas in poor countries than in areas in rich countries.
H5 Areas with demographic and environmental pressures are more likely to experience armed conflict during periods of regime collapse and transitions.

Our assumption, derived from the state failure hypothesis, is that demographic and environmental pressures are primarily associated with internal armed conflict in very poor settings and in periods of regime collapse and transitions. Giordano, Giordano, and Wolf (2005) argue that scarcity conflicts are most likely to occur where the institutional capacity is ill defined or non-existent, or where existing institutional regimes are destroyed by political change. If income level and regime interruption, on the other hand, do not account for a lot of the variation in the relationship between DES and armed conflict, this could be consistent with the state exploitation hypothesis.

Geospatial data and logistic methods

For this sub-national study, data are created from geospatial information. The data set has three main differences from typical county-year analyses: the unit of observation is considerably smaller; the dependent variable is positioned to have occurred at a particular location and associated with values from that location; and independent variables are derived from a geospatial data set, including shape and raster files. A shapefile stores georeferenced attributes of a point, line or polygon unit. Raster graphics are digital images created or captured (for example, by scanning in a photo) as a set of samples of a given space. A *raster* is a grid of *x* and *y* coordinates on a display space. It contains information that is directly mapped onto a display grid.

Unit of analysis

The process began with fitting a fishnet across the globe (described in greater detail by Buhaug & Rød, 2006). A fishnet is a grid whose individual square size is dictated; for the purposes of this study, the square dimensions are 100 km × 100 km at the equator. The data cover all countries with populations over 100,000, and the full data set comprises 13,199 polygon squares. Grid squares are assigned to the country in which they fall. Squares that straddle borders are assigned to the country in which a larger percentage of the square lies. Also grid squares that fall within oceans, seas, or polar extremes are excluded from the analysis.[5] Squares are assigned data values from both raster and shape files. With rasters, which often come with a 1-km data resolution, information is aggregated up to the size of the square. Shapefile data are either national or sub-national. While we only have one observation

[5] Grid squares that fall within lakes within countries are effectively excluded as null values from other geospatial data are factored out of final models.

per unit, some of our variables also capture important aspects of change, most notably population growth and land degradation. We create a sample of the total data set based on low income to retest models as research has alluded to low-income states being in a particularly susceptible position for conflict due to dependence on natural resources and the adaptability of state infrastructure to deal with scarcity issues.

We limit the conflicts observed to civil conflicts from 1990 to 2004 as the geospatial explanatory variables we use in the analysis were collected during or after 1990. The number of conflict squares is based on the Uppsala/PRIO conflict location latitude and longitude coordinates. Although all conflict points in the Uppsala/PRIO set are assigned a scope denoting the entire extent of the conflict the scope is, by design, a circle around the point. In reality, conflicts often do not conform to this circular measure. We chose a radius of 300 km from the conflict point as we assumed this would properly denote a ‘conflict zone’. This is still problematic as the Uppsala/PRIO location is an aggregate measure of the center of the larger conflict, so the actual location of the fighting is not directly represented (see Buhaug & Gates, 2002; Strand, Wilhelmsen, & Gleditsch, 2004). However, the majority of conflicts had a radius of 300 km or fewer, and therefore we account for the majority of definite fighting locations. All 585 conflict point coordinates are automatically assigned a radius of 300 km, resulting in 1907 conflict squares. If a square within the set 300 km radius falls inside a neighbouring country, it is excluded from the conflict zone. Fig. 1 displays a hypothetical conflict zone set upon grid square.

In applying a radius feature, contiguous grid squares falling within the conflict zone are coded as conflict observations within the data set. Since the purpose of this analysis is to determine the effects of population and environment on conflict, and the unit of analysis is a spatial location, these multiple observations do not breach statistical analysis norms. Typically, a spatial lag variable for neighbouring conflict would be included as an independent variable. Through our radius feature, we account for characteristics of neighbouring squares in the

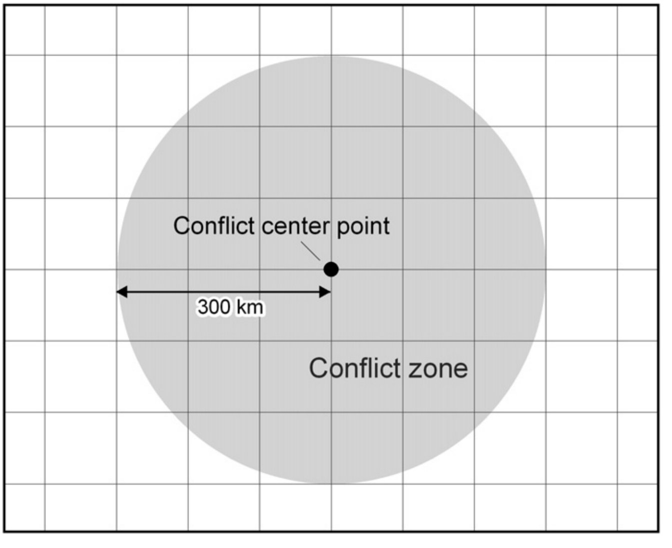

Fig. 1. Conflict zones upon grid squares.

dependent variable. Additional controls for the effects of conflict in neighbouring squares are therefore unnecessary (see Hegre & Raleigh, 2007 for a discussion of spatial autocorrelation in gridded analysis).

Raster data[6]

Geospatial data allow for innovative, in-depth theory testing as data are often collected at a local level; yet these data are infrequently used in political analysis. Using raster data requires translating raster values from an image (JPEG, TIN, or BIL) into a form by which values can be extracted (georeferenced and projected) and, in turn, creating meaningful interpretations for the values (transforming legend categories). Transforming and applying raster data with values recorded at 1 km units to 100 km × 100 km polygon squares involves choosing an aggregation type. The program Spatial Analyst relays information on the minimum, maximum, mean, standard deviation, sum, range, majority and minority values at the kilometer as it is aggregated to the 100 km square. We choose 'majority' as it was the measure which best represented the local conditions– for example, if 5 km of a 100 km square were densely populated (and therefore recorded with a higher number), but the remaining 95 km were quite sparsely populated (and therefore with a lower density score), this majority measure would note that most of the square is actually sparsely populated. Other measures would distort the reality on the ground.

Human induced soil degradation

The measure of soil degradation throughout the world was commissioned by The International Soil Reference and Information Centre (ISRIC) for the United Nations Environment Programme in 1990. The information of soil degradation is based on questionnaire answers from numerous soil experts throughout the world. Each measure combines type, degree, extent, cause and rate of soil degradation. Based on such measures, each kilometer of land was classified by the level of degradation ranging from 1 (no or very low degradation) to 4 (very high). Areas of greatest soil degradation include the tip of South Africa, swaths of the northern Sahel belt, Central America, sections of East and Central Europe and large portions of East and South East Asia.

For the purposes of this statistical analysis, we constructed a set of four dummy variables where land which is categorized as having no or very low levels of degradation is the reference category with 4644 observations, squares with low-level degradation account for 2190 observations, medium to high levels of land degradation are 5560 observations and very high levels of degradation are a separate category containing 805 observations. Areas with no information on degradation were factored out. Interaction terms between medium and high levels of degradation and population growth were created to determine the influence that higher than average population growth in higher than average areas of degradation have on conflict. In additional, interactions between medium and higher levels of degradation and political instability are added to establish whether, in times of political upset, rebels may seize the opportunity to redress land degradation grievances against the government.

[6] All raster data used in this analysis came from UNEP (2005). The GEO Data Portal, as compiled from the United Nations Environment Programme. http://geodata.grid.unep.ch.

Easily available freshwater – this TERRASTAT[7] measure notes the amount of stored soil moisture easily available to crops. To quote the metadata:

> 'This is an indicator for the amount of stored soil moisture readily available to crops. The water retention at two bar suction is used to separate easily available water (EAV) from water which is more tightly held at higher suctions and difficult to abstract, especially from deeper subsoils; and in the use of a conceptual model of effective rooting depth.' (http://geodata.grid.unep.ch/page.php)

The data are collected at the level of 1 km at the equator. The values range from 1 to 255 in the georeferenced raster. The legend clearly notes types of lands and the water variation within those types. The lowest point in the scale is for lands with less than 20 mm of available water; the highest point refers to lands with over 120 mm of available water. There are "wetlands" in each category of land where the maximum amount of expected water is found. Translating these values into a usable measure for statistical analysis results in one scale variable distinguishing water scarcity into five categories; '0' for very high levels of access to available water, '1' for land with high levels of available water, '2' for medium access to available access, '3' for low access to available water and '4' for dry land. To avoid bias based on unclear categorization of raster values, only polygon squares with clear and distinct water level values are used in the final analysis. With 329 null values factored out, the pre-sampled data set includes 1793 squares at '0' level, 1982 squares at level '1', 7063 squares at level '2', 1868 squares at level '3' and 493 squares at level '4'. The raw data and further description are available at http://geodata.grid.unep.ch/ under 'Easy Available Water'.[8] An interaction term with population growth was constructed to test for indirect effects of water scarcity in areas with higher than average population growth. A separate interaction between water scarcity and instability was created to address whether political shocks may enhance the effect of water scarcity in causing conflict.

Population density – CIESIN has two population measures (1990 and 1995) at a 1 km level (CIESIN et al., 2004). Both are used to create an index of population growth and density in each square. Population count of people per square kilometer is represented as an increasing density score (see Appendix 1). All null values are factored out of final models. Differences between 1995 and 1990 estimates determine population growth during this time; approximately 18% of all squares experienced change over this period. An interaction variable between population density and population growth is created to reveal whether areas of high density and high growth are particularly susceptible to conflict.

Country level data

Each polygon square of the fishnet is situated within a country and assigned country level information for GDP and Polity scores dating from 1990 (collected from Fearon & Laitin, 2003). If 1990 information was not available, as is the case with a number of post-Soviet states, 1991 estimates are assigned. A squared Polity term was generated to account for a possible inverted U-shaped relationship between regime type and armed conflict (Hegre et al., 2001). We constructed a dummy variable for political instability for the period of investigation. This

[7] TERRASTAT I Global GIS Databases were created as part of the Poverty and Food Insecurity Mapping Project.

[8] Source: UNEP (2005). The GEO Data Portal. United Nations Environment Programme. http://geodata.grid.unep.ch.

variable takes the value '1' if the original Polity IV data set (Marshall & Jaggers, 2005) codes the country as having experienced a transition (−88) or an interregnum (−77) during the 1990 through 2004 period and '0' otherwise. Finally, we measure the type of political change based on Polity movements in two 5-year intervals from 1990 to 1995 and from 1995 to 2000. We distinguish whether the government of each state has become more democratic or more autocratic. Both of these measures elucidate the political context in which opportunity- or grievance-based violence may occur.

Annual GDP scores are logged for interpretation and less bias at the extremes. GDP scores can be considered an acceptable proxy value for 'state capacity' or 'state adaptability' as in relation to all other states within the model, states with different income levels will vary in the funds directed toward state infrastructure and adaptive capabilities (e.g. sustainability programs), while people in low-income states are more dependent on agriculture.[9]

Method

After GIS data conversion, the data set is capable of being used in a standard statistical program. The analysis method is ordinal logistic regression, where the dependent variable is conflict and the unit of observation is the grid square. Due to the size of the data set significance is often overestimated; all models are bootstrapped to ensure standard errors and coefficient estimates are robust.

Results

All countries

In Model 1, we consider the risk of conflict when land degradation, water scarcity, population pressure and interactions are accounted for in the full sample. For ease of interpretation, results will be presented as logged odds or additional percentage risk from the base risk of conflict, which is estimated by exponentiating the constant term. The base risk for conflict in Model 1 is 2%. The results maintain that in the absence of population growth, increasing levels of land degradation are positively related to conflict; low levels of degradation, albeit not statistically significant, increases the risk of conflict to 2%, medium levels to 3% and high levels to approximately 4%.

The water scarcity variable is positive and significant, at the highest level of water scarcity the added risk of conflict is approximately 6% when population growth is zero. The effect is exacerbated by population growth. Only in areas of extensive water pressure and the highest levels of population growth does the additional risk of conflict strongly increase to 37%.

[9] While we are primarily interested in capturing the national-level effect of income in this paper, disaggregated income data that are now starting to become available may allow for later testing of the impact on conflict by the local interplay of environmental and economic factors. Two sub-national welfare indicators are already available; the CIESIN poverty data based on infant mortality with global coverage at a 770 km × 770 km resolution, and the Geographically Based Economic Data (G-Econ) which calculates a 'Gross Grid Income' where grid cell resolution is 1 degree latitude and longitude at the equator. These sub-national data sets have become available only recently, and there are two main reasons that they are not used in this analysis. First, it has not been feasible to incorporate additional geospatial information at a late stage in the process with the current paper. Second, these data have not been used for analysis purposes previously, and their reliability remains unknown. Details from G-Econ caution that data on developing countries are calculated from less than dependable indicators, resulting in unreliable estimates.

Although the additional conflict risk due to the interaction between very high levels of water scarcity and very high population growth is quite large, it is important to note that the likelihood of an area experiencing both extremes is very low, and that conflict risks at lower levels of both variables are negligible. The interaction terms between degradation and population growth which are assumed to capture the multiple stressors of demographic and environmental factors are highly insignificant.

Population density is positively and significantly related to armed conflict, as in all later models. At lower levels of population density, the additional risk of conflict ranges from 2% to 6%; however at the highest levels of population density, the additional risk reaches 30%. This relationship is a common finding in all civil war studies. While density is frequently used as a proxy for land scarcity in cross-country studies, it cannot serve a similar purpose in sub-national studies of small units like this. Conflicts obviously occur where there are people, and there are several reasons why we should expect that they occur where there is a certain threshold of concentration. Hegre and Raleigh (2007) discuss thoroughly the effect of population concentration in disaggregated armed conflict studies, and point to the fact that population concentrations may help solve coordination problems and ease recruitment to rebel organizations, rebels wish to target areas that can provide supplies and a taxation base, and finally that rebels wish to target areas that are valuable to the government, which often tend to be populous locations. Buhaug and Rød (2006) found that population density was neither a statistically significant predictor of conflicts over government nor of conflicts over territory in a study of Sub-Saharan Africa using a similar design as this study.

As population density is quite clearly the strongest indicator thus far, Model 1 captures the various mechanisms by which population growth may exert influence on the risk of conflict. Although actual population density is a strong indicator, absolute growth is only when interacted with absolute population levels. Areas where the population stresses are high due to high levels of both population growth and density experience an increased risk of civil conflict. The magnitude of the effect is minimal, however, at increased odds of 1.03. Although this basic model does not provide a strong assessment of the factors contributing to civil conflict risk, it is clear that of all demographic and environmental stressors assumed to be correlated with conflict, population density is the strongest and most consistent factor. But, as noted above, population density cannot be automatically assumed to relate to an environmental crisis; it can also proxy multiple other aspects of conflict such as rebel strategy, motive, or economic resources (Hegre & Raleigh, 2007).

Model 2 tests the impact of intervening socio-economic and political variables when considered with degradation and water availability indices. This model displays a substantial degree of improvement in estimation resulting from the inclusion of socio-economic and political variables. As is underscored in many previous studies of civil war, high levels of GDP is strongly related to lower levels of armed conflict. At the lowest income level, the risk of conflict is 5%, which corresponds to the base risk of Model 2. With increasing income levels, the risk of conflict decreases to less than 1%. The impact of political institutions is also pronounced. Complete autocracies or democracies have a slightly lower risk, with a higher risk associated with autocratic governments, a finding in line with the inverse U scenario outlined by Hegre et al. (2001). Yet, the instability of political institutions in the post-Cold War period points to a marked increase in the risk of armed conflict in states that have moved toward autocracy, while the movement toward democracy is insignificant. The risk of conflict in unstable states increases to 11%, and states with movements toward autocracies experience a 12% risk. In addition, the increased possibility of armed conflict due to autocratic changes is one of the strongest findings in this socio-economic model; only population values influence the risk of armed conflict more.

The signs and significance of demographic and environmental variables are similar to Model 1. Medium and high levels of land degradation are both positive and significantly related to conflict, indicating that when all other variables are at their mean, low or no degradation squares experience less than a 5% risk of conflict, while squares with very high risk have an additional 3% risk over very low degradation squares. As low levels of land degradation do not have an increased risk of armed conflict over areas with no degradation, this is evidence for a threshold effect on risk at medium levels of degradation that does not continue to increase steeply at higher levels of degradation.

Decreasing levels of freshwater availability are associated with higher risks of conflict, although similarly to land degradation, this is not mediated by population pressure or instability, as interactions with political instability display results counter to our expectations (Model 2). Instability is interacted with degradation and scarcity to determine whether, in times of institutional upset, rebel groups seize the opportunity to redress ecologically motivated grievances against the government. This does not seem to be the case as all instability interactions are insignificant, with the exception of the negative relationship between instability and water scarcity. This means that in areas with great water scarcity, the impact on conflict from the highly significant political instability variable is slightly weakened.[10]

Model 2 allows us to reiterate the importance and strength of GDP, population density and the instability and direction of autocratic political change. With the inclusion of political and economic variables, the fit and strength of these models have increased substantially. The impact of demographic and environmental factors on conflict is not removed, but they appear to play a lesser role.

Income and political instability picks up a considerable amount of variance, but does not appear to account for much of the variance explained by demographic and environmental factors as one should expect from the state weakness argument.[11] This may suggest that resource scarcity is not as dependent on the political and economic context as suggested in the literature. To address the issue further, we split the sample in two halves based on per capita income. According to the state weakness hypotheses, we should expect to see that demographic and environmental factors would have a stronger impact on conflict behavior in the low-income sample.

Low- and high-income subsets

The full global models suggest that demographic and environmental factors contribute to the risk of conflict, but we have not been able to statistically identify any intervening political and economic variables. Yet, the demographic and environmental factors we hypothesize to operate on the local level are assumed to be a function of poorer economies, unstable political institutions and population pressures. Generally, poor and developing countries are more dependent on primary production, and may have stronger reactions to resource scarcity as a result. Often, popular accounts of conflicts in developing states are framed in terms of environmental

[10] However, this result is not robust. If all squares comprising Niger are removed, amounting to only 1.6% of the sample, the interaction between water scarcity and instability is clearly statistically insignificant.

[11] While not shown here, if we introduce the economic and political control variables in Model 1, the results for the demographic and environmental variables are largely the same.

pressures or resources, e.g. depictions of the Rwandan genocide as a result of population pressure, Darfur as a land security/water issue or the Democratic Republic of Congo conflicts as a prolonged criminal resource war. These arguments tacitly engage an insecurity argument, and presume violence to be a result.

To further test whether the relationship between politico-economic variables and environmental factors is significantly different in a developing context, the global sample is divided into two income subsets: a lower-income set of the bottom two quartiles based on 1990 GDP scores, and an upper-income set of the top two quartiles. The distribution of variables in this sub-sample is distorted. Conflict observations in the lower-income subset (6901 squares) are considerably higher than the total data set, with 1644 conflict squares out of 1907 observations – 24% of the low-income sub-sample is conflict squares. The higher-income sub-sample includes 6298 squares, of which approximately 5% or 263 are conflict squares. Political instability is generally a phenomenon of low-income states. Less than 1% of the higher-income sub-sample experienced political instability during the 1990s. For that reason, this variable falls out of the higher-income sub-sample, as do any interactions with it.

As Models 3 and 4 demonstrate, the relationships between demographic and environmental variables and conflict risk are certainly mediated by income levels. Contrary to general assumptions, degradation and scarcity variables are uniformly positively and significantly related to conflict in the higher-income sample, while the relationships are of mixed significance and sometimes even contrary to our expectations in the lower-income sample. Only water scarcity, population density and the interaction between population growth and density are associated with armed conflict in poorer states, while in wealthy states, all levels of degradation increase risk, as does water scarcity and population density. These relationships are independent of any mediating influence, as all interactions with population growth are insignificant. The results are generally similar after the inclusion of political and economic variables and interactions (Models 5–8).

We suspected that the unexpected results in the high-income sub-sample were driven by individual conflictual states. That indeed seems to be the case, as the results are extremely sensitive to country omissions. If Russia is omitted from Model 3, low and medium degradation as well as water scarcity become clearly insignificant, and interaction terms retain their insignificance. The positive influence of high degradation is driven by 29 high degradation squares in Iraq, Serbia and Mexico (the latter with only two). Further, if either Spain or Mexico is omitted, the water scarcity variable becomes insignificant. Omitting other countries does not have any significant impact on the results.

With the addition of political and economic variables into both samples (Models 5 and 6), a number of the same relationships uncovered in previous models hold for low-income states: the dominance of political institutions and the importance of population density. Only in the low-income sub-sample does GDP exert a strong influence of conflict risk; this may relate to a threshold effect, with increasing levels of GDP in lower-income states diminishing the risk of armed conflict, but after reaching a mid-level threshold (50% quartile in this case) the effect of increasing GDP is negligible. Both movements toward autocracy and democracy have a more pronounced effect in the wealthy sample. In the lower-income sample, a movement toward more autocratic institutions increases the risk of conflict to 19%, while a movement to democracy is insignificant. Instability retains a strong influence in the lower-income subset, almost doubling the risk of conflict to 21%. This variable does not seem to make demographic and environmental variables more important; however, all interaction terms are clearly insignificant.

In Model 6, showing the low-income sample with political and economic control variables, the medium degradation and high degradation level variables are statistically insignificant and areas with low levels of degradation are less susceptible to conflict. Water scarcity, in the absence of population growth, slightly increases the risk of conflict from 1% at lowest levels to 4% at highest levels. Population density again exerts a skewed influence on risk. At low and medium levels, the risk of conflict due to density varies from 13% to 27%. However, at its highest level, the risk of conflict exceeds 64%.[12] This result speaks to importance of local population concentrations on conflict probability.

It is clear that the impact of population growth is mediated via other variables, most notably population density. At the highest levels of both, the risk of conflict more than doubles. However, less than 20% of the sample is coded as having experienced significant population change from 1990 to 1995, so the likelihood that an area experiences both high density and high growth is very low. The interaction between population growth and high levels of water scarcity also significantly increases the risk of conflict. This result, along with other demographic and environmental results for this model, should be considered with two caveats. Grid squares in Niger are driving the result between water scarcity and population growth; its omission from the model renders this interaction clearly statistically insignificant. Further, although the additional risk from population growth interacting with environmental variables varies from insignificant to pronounced, squares with the combination of high population growth and the highest levels of degradation, scarcity and density are unlikely or rare occurrences, calling for considerable caution when interpreting the results.

In fact, it remains that all low-income sample models (4, 6, and 8) show very consistent results despite the gradual inclusion of interaction terms and control variables. Growth interacted with water availability and population pressures increases the risk of conflict, while the traditional national-level explanations of GDP, political institutions and the sub-national population density account for a considerable amount of conflict across states. The inclusion of economic and political control variables in Models 6 and 8 do not alter the impact of any of the demographic and environmental variables from Table 1. This runs counter to our expectation that state weakness variables would capture some of the variance explained by resource scarcity variables. For all intents and purposes, models on the low-income sub-sample speak to the relative insignificance of demographic and environmental pressures for conflict behavior in those areas that should, according to the resource scarcity perspective, experience the most pronounced effects.

Conclusions

It appears from this disaggregated analysis that demographic and environmental variables only have a very moderate effect on the risk of civil conflict. The analysis is unique in that both the dependent variable and the main independent variables are disaggregated, allowing for direct testing of hypotheses regarding population pressure, land degradation and water availability. Although this analysis is a beginning attempt at using these data, the information from geospatial data at local levels can consistently sharpen our understanding of how local processes and national characteristics shape the context of conflict.

[12] As population density is an intervening variable in this model, these results should be considered as the additional risk percentage of density at levels of zero growth.

Table 1
The impact of demographic and environmental factors on armed conflict

	Model 1 — degradation models	Model 2 — political and economic factors	Model 3 — degradation models	Model 4 — degradation models	Model 5 — political and economic factors	Model 6 — political and economic factors	Model 7 — political and economic interactions	Model 8 — political and economic interactions
	Full sample	Full sample	High income	Low income	High income	Low income	High income	Low income
Low-level degradation	0.108 (0.084)	−0.123 (0.093)	0.127 (0.232)***	−0.217 (0.094)**	1.12 (0.245)***	−0.477 (0.103)***	1.13 (0.245)***	−0.452 (0.103)***
Medium-level degradation	0.217 (0.067)***	0.286 (0.079)***	1.10 (0.202)***	−0.053 (0.076)	1.17 (0.212)***	0.050 (0.081)	1.19 (0.211)***	0.049 (0.090)
Very high-level degradation	0.568 (0.100)***	0.435 (0.126)***	2.16 (0.266)***	0.049 (0.111)	1.74 (0.281)***	−0.060 (0.118)	1.75 (0.281)***	0.048 (0.145)
Local water scarcity	0.274 (0.028)***	0.136 (0.035)***	0.181 (0.066)***	0.118 (0.035)***	0.162 (0.071)**	0.095 (0.038)**	0.160 (0.071)**	0.075 (0.043)*
Population density (1990)	0.273 (0.011)***	0.263 (0.014)***	0.302 (0.026)***	0.188 (0.015)***	0.336 (0.030)***	0.239 (0.017)***	0.334 (0.029)***	0.233 (0.016)***
Population growth	0.016 (0.064)	0.143 (0.025)***	0.136 (0.138)	−0.124 (0.089)	0.167 (0.152)	−0.136 (0.094)	0.154 (0.046)***	0.131 (0.031)***
Logged GDP (1990)		−0.753 (0.039)***			−0.285 (0.250)	−0.723 (0.058)***	−0.283 (0.250)	−0.724 (0.058)***
Polity		0.004 (0.005)			−0.097 (0.012)***	0.025 (0.005)***	−0.097 (0.012)***	0.025 (0.005)***
Polity squared		−0.008 (0.001)***			0.026 (0.004)***	−0.013 (0.001)***	0.026 (0.004)***	−0.013 (0.001)***
Instability 1990s		0.728 (0.192)***			n/a	0.784 (0.084)***	n/a	0.500 (0.202)**
Movement to autocracy		0.857 (0.089)***			3.20 (0.335)***	0.588 (0.104)***	3.17 (0.333) ***	0.574 (0.105)***
Movement to democracy		−0.021 (0.070)			2.80 (0.415)***	0.109 (0.076)	2.77 (0.415) ***	0.096 (0.076)
Population growth × population density	0.019 (0.007)**		0.003 (0.014)	0.030 (0.012)**	0.010 (0.017)	0.031 (0.013)**		
Population growth × water scarcity	0.067 (0.020)***		0.031 (0.034)	0.061 (0.029)**	0.038 (0.038)	0.058 (0.031)*		
Population growth × medium degradation	−0.056 (0.052)		−0.124 (0.096)	0.043 (0.076)	−0.202 (0.117)*	0.033 (0.082)		
Population growth × high degradation	−0.108 (0.109)		−0.194 (0.237)	−0.069 (137)	−0.116 (0.237)	−0.061 (0.146)		
Instability × water scarcity		0.089 (0.077)					n/a	0.126 (0.080)
Instability × medium degradation		−0.111 (0.137)					n/a	0.122(0.144)
Instability × high degradation		−0.518 (0.203)**					n/a	−0.195 (0.213)
Constant	−3.84 (0.099)***	−2.79 (0.143)***	−5.79 (0.254)***	−2.36 (0.132)***	−7.88 (0.762)***	−2.06 (0.168)***	−7.86 (0.761)***	−2.00 (0.171)***
N/−2ll/R^2 (%)	13,199/−5019/8	13,199/−4297/21	6298/−943/14	6901/−3684/3	6239/−832/24	2515/−3335/12	6239/−834/23	6901/−3340/12

*Sign at 0.1, **Sign at 0.05, ***Sign at 0.001.

In the global model, we find that overall, medium to high levels of land degradation are related to increased conflict, as are very high levels of water scarcity. However, the relative increases in risks are quite small. Increasing levels of land degradation increases the risk of conflict from a baseline of 1% to between 2% and 4%. Freshwater scarcity appears to exert a somewhat stronger effect, increasing the risk of conflict to 6% for areas with very high levels of scarcity. The coefficients for land degradation and water scarcity have to be interpreted as the effect when population growth in a square is zero. High population density, measured locally, is a consistently strong predictor of armed conflict. Population density and conflict are presumably correlated because densely populated areas and large cities are attractive conflict locations both because they provide better opportunities for organizing and financing conflict, and because they represent strategic targets (Hegre & Raleigh, 2007). From the resource scarcity literature, we hypothesized that interactions between ‘demand-induced’ scarcity, measured by population growth, and ‘supply-induced’ scarcity represented by land degradation, water scarcity and population density, were likely to produce multiple stressors that could act as triggers of resource scarcity conflicts. In the global model, only the interaction between population growth and water scarcity, as well as that between population growth and density, were statistically significant.

It has been argued that the role played by demographic and environmental variables within conflict scenarios is contingent on economic and political aspects of the state. In this paper, we merged specific environmental data, collected at a local level, with state-level GDP estimates and political attributes. We further split the global sample into two subsets based on income. The analysis reinforced the well established importance of these variables in civil war studies. Lower levels of GDP are the most important predictor of armed conflict, with the exception of wealthier states where it exhibits an insignificant effect. This may speak to a threshold effect of GDP in mitigating the risk of conflict across and within states. We considered that states with low GDPs will depend more on their environment for individual and state income than states with higher GDPs. In addition, a poor state’s inability, due to lower capacity as a result of lower national income, to attenuate tensions over degradation may quickly lead to violent conflict. However, resource scarcity actually seems to matter less for conflict in low-income states than for wealthier states. And while political instability is a strong driver of internal conflict in poor states, it does not seem to interact with demographic and environmental factors to increase the risk of conflict. Such results and assumptions suggest that environmental and demographic factors may be second to other drivers of armed conflict. While the resource scarcity literature posits that state capacity, or state weakness, is an important intermediate factor in the resource scarcity–conflict nexus, the rather crude, economic and political variables used in this study to proxy state capacity do not capture any of the variance explained by demographic and environmental factors. This may suggest that the support we find for the resource scarcity perspective, in particular the positive and significant interactions between population growth and water scarcity and density, is better explained by the state exploitation hypothesis (Kahl, 2006). However, since there is no simple way to measure the form of state characteristics that may lead to state exploitation behavior, we cannot conclude whether our results are indicative of the state exploitation hypothesis.

The explanatory power of the models presented in this paper is generally higher than in previous studies (e.g. Fearon & Laitin, 2003; Hegre et al., 2001). We believe this is partly due to the inclusion of geographically varying measures within the model. Since conflict often does not occur throughout entire countries, more localized attributes need to be incorporated into models for a comprehensive understanding of the conflict process. Moreover, we believe a clearer link between the physical changes associated with environment variables and the political process of rebellion must be established. In particular, we foresee a development in which most of these relationships are measured locally, involving local measures of income, state capacity and ethnic fractionalization. We assume that there is still much leverage in the expectation that environmental factors are made important through the policies of the state or through market fluctuations.[13]

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Appendix 1. Population density scores

Density score	Population count
1	0
2	0–0.1
3	0.1–0.5
4	0.5–1
5	1–5
6	5–10
7	10–50
8	50–100
9	100–250
10	250–500
11	500–1000
12	1000–5000
13	5000–10,000
14	More than 10,000

Data available at http://sedac.ciesin.org/gpw/.

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[13] For an example of how environmental factors are used as instrumental variables see Miguel, Satyanath, and Sergenti (2004).

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