Climate Change, Environmental Degradation and Armed Conflict

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Abstract

Climate change is expected to bring about major global environmental change, although considerable uncertainties exist with regard to the extent and geographical distribution of these changes. Predicting scenarios for how climate related environmental change may again 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 environment and violent conflict in areas that already experience forms of environmental change that we think will increase with climate change. Previous rigorous studies in the field have mostly focused on national level aggregates. This paper represents a new approach to assess the impact of environment on domestic armed conflict by using geo-referenced (GIS) data and small geographical, rather than political, units of analysis. The paper addresses some of the most important factors assumed to be strongly influenced by global warming: productivity of land, freshwater availability, and population density and change. The preliminary results indicate that the relationships between local level demographic/environmental factors and conflict are not uniform. While population growth and density as well as land degradation appear to be related to less conflict, freshwater scarcity appear to be associated with more conflict, especially when interacting with high population density. Our understanding of the role of physical factors in causing armed conflict is expected to be improved with future inclusion of socioeconomic and political variables to this analysis.

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1. Introduction

Environmental change as a cause of violent conflict has been a contended issue in the security discourse of the 1990s. Although first rising as neo-Malthusian concerns over population growth and over-consumption of renewable natural resources in the late 1960s, scarcities of resources like freshwater and arable land increasingly became security issues after the end of the Cold War. Explanations for this have been twofold. First, a general environmental awareness increased in Western popular opinion in this period, and environmental protagonists succeeded in 'securitizing' central environmental issues, thereby attracting the attention of policymakers (Levy, 1995: 44). In the United States, vice president Al Gore initiated the 'State Failure Task Force' project in 1994 aimed at revealing environmental, political, and social causes of state failure. Second, the end of the Cold War left a void in security policy, and Western national security establishments sought ways to legitimize their continued existence (Barnett 2001: 2; Gleditsch, 2001: 259). According to de Soysa (2002: 396), some of the environmental security literature also argues that ecological and demographic pressures have become more important after the end of the Cold War, representing a 'new age of insecurity'.

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. Renner, 1996; Homer-Dixon & Blitt, 1998; Rahman, 1999; Klare, 2001; Brauch, 2002; Schwartz & Randall, 2003; Pervis & Busby, 2004). To address the issue of whether climate change may pose a traditional security threat, we build on propositions from the environmental security literature, identifying potential links between environmental 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. We argue that our best predictions about the future will necessarily have to be based on how forms of environmental stress that we anticipate will be more widespread under a climate change scenario, have influenced stability and war in the past. Obvious limitations to such approach are the possibilities that environmental 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 environmental scarcity and violent conflict have primarily focused on state level factors (Esty et al., 1998; Hauge & Ellingsen, 1998; Toset et al., 2000; de Soysa, 2002; Urdal, 2005). While there are some strong arguments in favor of comparing sovereign political units, especially related to the opportunity for internal migration, severe forms of environmental change are often confined to smaller areas than entire countries. Sometimes such changes also span across 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 x 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 armed conflict data (Gleditsch et al., 2002) produced by Halvard Buhaug (Buhaug & Gates, 2002). The dataset covers domestic violent 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 availability, productivity of land, and population growth and density.

Based on the results obtained from this study, with the later addition of data on important intervening political, economic and social factors, we aim to predict future risks of violent conflict under different climate change scenarios.

2. Environmental Change and Armed Conflict

While some of the environmental security literature has clearly overstated their case, few scholars would argue that resource scarcities never occur or that they are irrelevant for conflict behavior. Natural resources that are essential to human life and welfare are unevenly distributed between and within states, and scarcities of certain natural resources may arise and persist locally, at least temporarily. The most influential scholar moderating the neo-Malthusian position has been Thomas Homer-Dixon and his ‘Project on Environment, Population, and Security’ at the University of Toronto. Homer-Dixon and associates distinguish between different sources of resource scarcity. *Supply-induced scarcity* results from depletion in quantity or degradation in quality of a renewable resource. *Demand-induced scarcity* is caused by population growth or increased per capita consumption, while *structural scarcity* is aggravated when groups have systematically unequal access to resources (Homer-Dixon, 1999: 48).

Most armed conflicts and wars are over objectives that can broadly be defined as resources (Gleditsch, 2001: 252). Neo-Malthusians are primarily concerned with resources that are essential to food production. Homer-Dixon & Blitt (1998) argue that large populations in many developing countries are highly dependent on four key resources: freshwater, cropland, forests, and fisheries. The availability of these resources determines people's day-to-day well-being, and scarcity of such resources can under certain conditions cause violent conflict (Homer-Dixon & Blitt, 1998: 2). It has been proposed that the resource scarcity and conflict scenario is more pertinent to developing countries due to generally lower capacity to deal with environmental issues and less ability to cope with and adapt to scarcity (Homer-Dixon, 1999: 4–5; Kahl, 2002: 258).

Homer-Dixon argues that increased environmental scarcity is likely to cause social effects that increase the risk of internal violent conflict. Environmental scarcities can lead to constrained agricultural and economic productivity causing migration and widespread poverty. The notion of 'environmental refugees' has received particular attention (El-Hinnawi, 1985; Jacobson, 1988; Lee 1997). However, as Suhrke (1997: 263) notes, migrants fleeing deteriorating environmental conditions rarely have the resources to instigate violent conflict and are more likely to become victims of violence.

Grievances resulting from increased resource competition may cause violent conflict if two conditions are met. First, the aggrieved individuals need to participate in some sort of ethnic, religious, or class-based collective that is capable of violent action against the authorities. Second, the political structure must fail to give these groups the opportunity to peacefully express their grievances at the same time as it offers them the openings for violent action (Homer-Dixon & Blitt, 1998: 11).

Some recent contributions further moderate the neo-Malthusian position. Kahl (2002: 266) refutes the critique that neo-Malthusian models are deterministic, and claims that they are rather underspecified. He criticizes much neo-Malthusian writing for failing to identify clearly which intervening variables are most important. Referring to the assumption of 'state weakness' as a necessary precondition for environmentally induced conflict in the works of Homer-Dixon and of Goldstone (e.g. 2002), he contends that such conflicts can also arise under conditions of 'state exploitation' when powerful elites exploit rising scarcities and corresponding grievances in order to consolidate power. Conflicts in Kenya and Rwanda are claimed to be examples of the latter (Kahl, 2002: 265). Matthew (2002: 243) provides two important critiques of the simple neo-Malthusian thesis. First, it understates the capacity to adapt to scarcities that are manifest in many societies. Second, it does not adequately deal with historical and structural dimensions of violence, like globalization and colonial influence. Matthew's approach shifts the focus to why some states succeed while others fail to adapt to scarcities of renewable resources.

Among the more moderate neo-Malthusian contributions, there are few apocalyptical claims of large-scale warfare over scarce resources. Dalby (2002: 95) concedes that 'the likelihood of large-scale warfare over natural resources is small'. And while claims of future 'water wars' proliferate, Homer-Dixon (1999: 5) concludes that interstate scarcity wars are not very likely. He rather predicts that the most likely forms of violent conflict to erupt from resource scarcities are ethnic clashes and civil strife. In order to address the proposition that scarcity is more likely to produce low-level violence, this study investigates the relationships between different forms of local resource scarcity and low-intensity armed conflict.

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 & Ellingsen (1998) report slightly different results. Esty et al. (1998) found no effects of soil degradation, deforestation and freshwater supply on the risk of state failure. Hauge & Ellingsen (1998) on the contrary concluded that the same factors as well as high population density were indeed positively associated with civil war, but that the magnitudes of the effects were second to political and economic factors. Toset et al. (2000) find that shared rivers increase the likelihood of interstate military disputes, and that water scarcity is also associated with conflict, although not very strongly. Wolf et al. (2005: 81) concludes, on the basis of a major data collection effort that shared freshwater resources is 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) finds a significant effect of population density on domestic armed conflict, while Urdal (2005) reports results indicating that scarcity of potentially arable land may indeed have a pacifying effect domestically. The aim of this study is to reconcile these diverse findings by moving below national aggregates to see if local resource scarcity better predicts conflict behavior.

3. Climate Change as an Environmental Security Issue

> Violence and disruption stemming from the stresses created by abrupt changes in the climate pose a different type of threat to national security than we are accustomed to today. Military confrontation may be triggered by a desperate need for natural resources such as energy, food and water […]' (Schwartz & Randall, 2003: 14)

In recent contributions to the environmental security debate, climate change is frequently argued to constitute a future major threat. Firstly, increasing temperatures, precipitation anomalies and extreme weather will aggravate processes of resource degradation that is already underway, especially with regard to soil, forests, freshwater and fishery resources, potentially leading to increased risks of violent conflict (Renner, 1996: 46; Homer-Dixon & Blitt, 1998: 2–5; Klare, 2001: 20; Pervis & Busby, 2004: 68). 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 and possibly political instability and violent conflict (Renner, 1996: 108; Rahman, 1999: 205; Barnett, 2001: 8). Although climate change is usually regarded as a potential future threat, some argue that climate change has already been a contributing factor to the Darfur conflict (Byers & Dragojlovic, 2004: 2).

Combining the most radical climate change forecasts with a conventional neo-Malthusian perspective on resource wars produce bleak prospects for the future. In a report for the Pentagon, which received global media attention, Schwartz & Randall (2003) speculate about the consequences of a worst case climate change scenario and its implications for US national security. Accepting the neo-Malthusian conflict scenario with little reservation, 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 it's ancient norm of constant battles for diminishing resources (p. 16). But as Barnett (2001: 5) notes, there is every reason to be cautious about the links between climate change and conflict. Existing environment and conflict research has simply not produced sufficient evidence to enable us to make anything but ‘highly speculative claims about the effects of climate change and violent conflict’ (Barnett, 2001: 5).

Although warning against overstating the relationship between climate change and armed conflict, both Barnett (2001:6) as well as Pervis & 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) Whether such changes may result in armed conflict is likely to be highly dependent on social, economic and political contextual factors. Barnett (2001: 9) suggests that climate change may be particularly problematic in a context of weak states, economic transition and high inequality. Furthermore, it appears to be a consensus that climate change, like environmental change generally, represents a greater threat to domestic than international peace, and that the proper focus should be on the sub-state level (Barnett, 2001: 6).

Based on the 2001 impact assessments of climate change from the United Nations Intergovernmental Panel on Climate Change (IPCC), we identify three major forms of climate related environmental change that according to the environmental security literature is likely to have security implications: land productivity, freshwater and population .

3.1 Land Productivity

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 a few degrees of warming are projected to generally increase temperate crop yields, larger amounts of warming may decrease temperate crop yields. In tropical areas, where dryland 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). If such changes should be considered important security threats we would expect that the carrying capacity relative to the population that depends on the land, to be important:

H1: The lower the productive capacity of the land and the higher the population density the greater the risk of armed conflict.

3.2 Freshwater Availability

According to the IPCC (2001: 31), there are currently 1.7 billion people who presently live 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. If climate related water stress should be regarded as a future security threat, we would expect to see that already water scarce areas are more susceptible to armed conflict:

H2: The lower the freshwater availability and the higher the population density the greater the risk of armed conflict.

3.3 Population Crowding

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 acute flooding may cause what we may rightfully term ‘environmental refugees’. However, the most dramatic form of change as it affects human settlements, sea-level rise, is likely to happen gradually. Improved forecasting skills will make adaptation easier and reduce the problem of population displacements (Chimeli et al., 2002: 213). Rather than the massive and sudden influxes of refugees, we are likely to see a gradual migration by people in search for more fertile land. This is analogues to the situation in many marginal areas today, and for population to be a valid security threat under the climate change scenario, we would expect to see population crowding be associated with armed conflict even today:

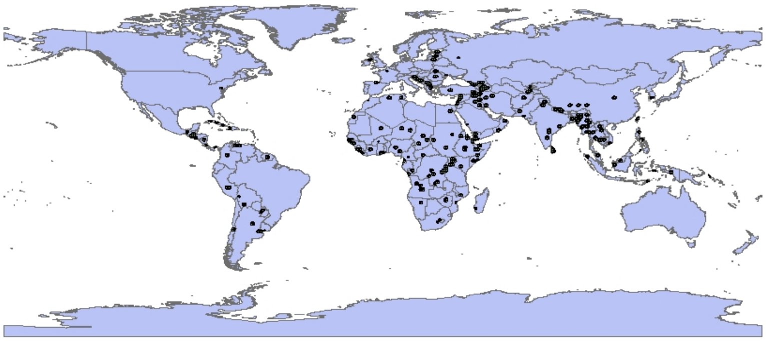
H3: The higher the population density and the greater the population growth, the greater the risk of armed conflict.

4. Geospatial Data and Logistic Methods

For this sub-national study, data were created from geospatial information. The process began with fitting a fishnet across the globe (described in greater detail by Buhaug and Rød, 2005). Fishnets produce a grid whose individual square size is dictated. For the purposes of this study, the square dimensions are 100 km x 100 km. This is a considerably smaller unit of analysis than previous studies of civil war and climate change. The fishnet squares are divided between conflict squares, of which there are 1,583 and random point squares, of which there are 11,817. The number of conflict squares is based on the Uppsala/PRIO conflict location latitude and longitude coordinates (see Map 1 for an illustration of conflict points). All coordinates are automatically assigned a scope of 100 km, which explains how 218 conflicts result in 1,583 conflict squares. 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. Conflicts often do not in reality conform to the circular measure. We choose a scope extent of 100 km as we assumed this would properly denote a ‘conflictual area’. 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 (for more see Gleditsch et al., 2003).

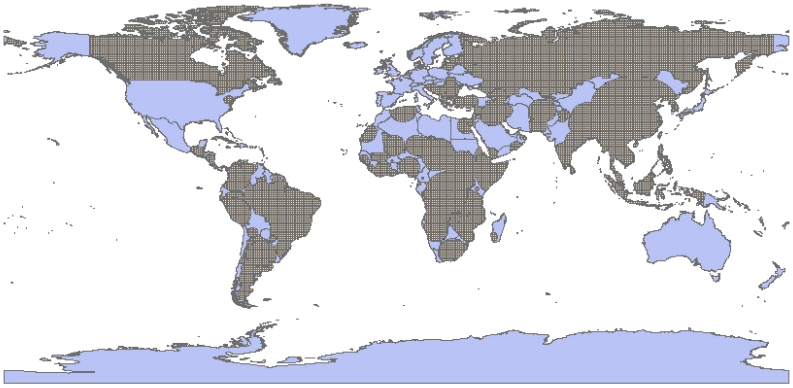
In this paper we include all conflicts for the entire 1946 – 2002 period, although our explanatory variables mostly exist for the 1990s. The analyses are purely cross-sectional, there are no time-series data employed. One implication is that we disregard potentially important processes of change in the explanatory variables over time. Another is that we are not able to distinguish between onset and incidence of conflict. This calls for cautious interpretations of the results. These shortcomings will be addressed in future versions of the paper.

Map 1: PRIO/Uppsala Conflict Locations 1946-2002



Random points were created by choosing a number of countries and areas within countries (see Map 2). We chose a selection of points, rather than the entire globe, to ease data collection; the size of our selection ensured a large random sample. In total, the dataset amounts to 13,401 100 x 100 km squares, of which 11.8% are conflict squares. The entire analysis covers 1,304,100 km2.

Map 2: World Fishnet Coverage



Grid squares are assigned data for their area from both raster and shapefile information. Below is a summary of the variables, along with the data specifics. With rasters, which often come with 1km data resolution, information is aggregated up to the size of the square. Shapefile data were either national or sub national. The sub national data is dependent of the variable—a unit of land cover could be larger or smaller than a grid square. This is explained further with specific variables.

Data can also be time dependent. When possible, all stages or data counts over time are included, or in some cases, the change over time (e.g. mean precipitation).

4.1 Shapefiles

Capacity of Greenness – the NOAA/Global Vegetation Index records eight-year mean maximum data at a global scale, integrated across time (growing seasons and all years) and characterized according to the relative health and quantity of green biomass present. Global Vegetation Index (GVI) values denote a capacity of greenness and are not an indicator of land type. The values can be recorded in a five or ten point scale, with 1 being the highest GVI class and 10 the lowest (or desert like) Both minimum and maximum values found within each square are reported (similar to raster sets, see below). The minimum GVI scale has a mean of 6.22, with a standard deviation of 2.53; the maximum GVI scale has a mean of 6.85 and a standard deviation of 2.40. Using the minimum and maximum values implies an under-representation of the mid level values. Hence, the use of the maximum and minimum variables rest on the assumption that, on average, a square with a low minimum value will indicate a higher degree of greenness than a square with a relatively high minimum value. Similarly, a square with a high maximum value is assumed to have less productive capacity than a square with a relatively lower maximum value. Both the GVI minimum and maximum variables are expected to be positively related to conflict, higher values on both indicate less greenness. The data are available at http://www.grid.unep.ch/data/grid/index.html under Global Vegetation Index.

Natural Renewable Water resources – this variable is coded on a national level and measures the amount of freshwater resources available for domestic use. This is measured as a sum of internal and external renewable water resources. It corresponds to the maximum (theoretical) amount of water available in a country on an average year as a function of cubic meters of groundwater. (The range for the variable is up to 8,233 cubic meters; the mean value is 3,060.51, with a very high standard deviation of 2,315.41. The data and further description are available at http://www.fao.org/ag/agl/aglw/aquastat/dbase/index.htm.

Rural population growth – total non-urban population projections recorded as counts or percentage change. As noted by the UN Population Division, definitions of 'rural' vary across countries but are most commonly based on size of locality. Therefore, population that is not considered urban is considered rural. These data have been measured in five year increments beginning in 1961 and extending to 2030. We created a change over time rural population variable by dividing the latest year of growth by the earliest for each time period. Values at 100 indicate no change, above 100 indicate growth and below 100 correspond to negative growth. For the pre 1990 variable, the range is from 70.8 to 195 with a mean of 119.7, and a standard deviation of 51. The second rural population measure is post 1990 rural growth (1990–2030). This variable's range is from 45 to 330, with a mean of 84 and a standard deviation of 43. Thus, rural growth is estimated to decrease on average about 16% in the post 1990 period. The data are available at http://www.un.org/esa/population/unpop.htm

Urban population growth – average annual rate of change. This variable is measured by the UN Population Division. It is measured from 1950 and projected to 2030 in five year increments. Again, we calculate the change in the pre 1990 and post 1990 period, and use these estimates to compare with rural growth. Although population growth is widely accepted as an urban phenomenon, the UNSED believe most of this growth will be in smaller urban settlements (fewer than 500,000 residents) in developing countries. The data are available at http://www.un.org/esa/population/unpop.htm

4.2 Rasters

Using raster data for statistical analysis is a relatively new practice in social science; for that reason numerous problems abound. First, the creators of raster data often do not expect its use in statistical analysis of the type performed here. Legend values (which simplify the interpretation for viewers) often do not correctly match stored values (which is available for statistical use). Our interpretation on values categories is based on our best reading of the data. Second, the GIS program used to interpret raster data provides four aggregate summary readings per unit (in this case, a grid square) – minimum, maximum, mean and range. For example, in a grid square of locally available freshwater, the minimum value found may be 5 (wetlands) while the maximum may be 255 (dry). In that conversion output, we will receive both values, a range score of 250 and a sum of all values in the square without knowing which values are represented between 5 and 255 and whether e.g. 150 (mid level water) is actually the dominant type of availability. These are serious limitations, but we have managed, in this iteration of the paper, to make general statements about the variables. Information concerning each variable interpretation is noted in its description.

[1]*Dominant type of problem lands*: This FAO (UN Food and Agricultural Organization) classification of types of problem land is categorical. The land types represented are (a) cold; (b) dry – including desert and semi-desert; (c) steep – land areas neither cold or dry; (d) shallow – land areas which are not cold, dry or steep, but which have depth limitations; (e) poor drainage – land areas which are none of the above and waterlogged and/or flooded for a significant part of the year; (f) coarse texture – characterized by none of the above, the coarse texture must be less than 18% clay and more than 65% sand or have gravel, stones, boulders or rock outcroppings in the surface layer; (g) heavy cracking clays – land areas with 30% or more clay to at least 50 cm from the surface after the upper 20 cm of soil are mixed; (h) severe fertility limitation – areas which exhibit deficiencies in major, secondary and minor plant nutrients when cultivated; (i) saline/sodic limitation – land areas comprised of soils with a high salt content or exchangeable sodium saturation within 100 cm of the surface. Due to complications in the translation of raster values into legend values, the following ranges are considered to match the above categories:

a. 0-14: All other land types
b. 14-35: Wetlands
c. 35-57: Saline
d. 57-82: Infertile
e. 82-98: Coarse
f. 98-110: Water
g. 110-130: No Recorded Problems
h. 130-150: Steep
i. 150-173: Poorly Drained
j. 173-197: Shallow
k. 197-216: Alluvial
l. 216-241: Cold
m. 241-225: Dry

These data were altered to create dummy variables for cold (472 observations), dry (7149 observations), saline (16 observations), infertile (360 observations), coarse (583 observations), wetlands (79 observations) and steep (46 observations). Again, it is important to note that due to the method of converting raster data, minimum and maximum values will be overrepresented in this index. For that reason, we hesitate in placing too much influence on these results as only the spectrum of problems is indicated, not the main type of problem. The data are available at http://geodata.grid.unep.ch/page.php under Dominant Type of Problem Lands.

Easily Available Fresh Water – this TERRASTAT measure notes the amount of stored soil moisture easily available to crops. The legend minimum amount is 10, the maximum 99. However, the values within the raster vary from 1 to 255. This problem is rectified by associating ranges of values with legend categories. Zero designates no data available. We categorized data based on best estimates of how values clustered together; estimates are represented in both minimum and maximum categories. The higher the value, the less water is available. As with the GVI measure (above), using the minimum and maximum values implies an under-representation of the mid level values. Hence, the use of the maximum and minimum variables rest on the assumption that, on average, a square with a low minimum value indicates a higher amount of available freshwater than a square with a relatively high minimum value. Similarly, a square with a high maximum value is assumed to have less available freshwater than a square with a relatively lower maximum value. Both the freshwater minimum and maximum variables are expected to be positively related to conflict, as higher values on both indicate less water availability. An interaction measure was created from the minimum amount of freshwater availability and population density at 1990 to capture the relationship between local availability and population pressure. The data and further description are available at http://geodata.grid.unep.ch/ under ‘Easy Available Water’.

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[1] See Appendix for information on land rasters initially used in the analysis.

Population density – CIESIN has two population measures (1990 and 1995) at a 1 km level. Both are used here in creating an index of population growth and density in each square. Population count of people per square kilometer is represented as an increasing density score.

Density Score	Population Count
1	no data/0
2	0-0.1
3	.1-.5
4	.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

Population minimum and maximum counts are converted into a population sum measure in the original data. For this project, population sum was used as it provides a total measure of population within the square, and for that reason, is also a density measure. Data available at http://sedac.ciesin.org/data.html.

After GIS data conversions, the dataset is capable of being used in standard statistical program. Standard logistic regression is used in this stage of the analysis where the dependent variable is conflict; the unit of observation is the grid square. With the inclusion of national level data, a multilevel model can model changes of local level and changes in national characteristics while accounting for dependence among the data and grid squares. For the purposes of this initial project, the multilevel model is not incorporated.

5. Local and National Results

5.1 Bivariate relationships to conflict

A number of variables in this study have not been used before in conflict analysis, for that reason we present a short bivariate relationships in the following chart.

Table 1: Bivariate Relationships to Conflict

Conflict	*Coefficient*	*Significance*
Variables: Land		
NDVI Minimum	-.1425	0.000
NDVI Maximum	-.1262	0.000
Interaction (NDVI Min* Population)	-.00041	0.000
Interaction (NDVI Max* Population)	-.00036	0.000
Wetlands	.86593	0.001
Saline	2.0132	0.000
Infertile	.2369	.120
Steep	.11215	.798
Cold	.16256	.236
Dry	-1.5849	0.000
Coarse	.11637	.92
Variables: Water		
National Water Availability	.000087	0.000
Local Fresh Water Maximum	.00327	0.000
Local Fresh Water Minimum	.00159	0.000
Interaction (Freshwater Min*Population)	-.0000043	0.000
Interaction (Freshwater Max*Population)	-.0000054	0.000
Variables: Population		
Urban Growth pre-1990	.0012	.604
Urban Growth post-1990	.0032	.199
Rural Growth pre-1990	.000011	.821
Rural Growth post-1990	-.00237	.001
Population Density 1990	-.0023602	0.000
Population Density 1995	-.00239	0.000
Population Density Change	-.07113	.118

The bivariate relationships illustrated above present mixed messages about the role of environmental factors in conflict. The land variables seem to point to less fertile land decreasing the risk of conflict, while the particular problems of wetlands and saline soil have positive relationships to conflict, although each make up a relatively small portion of the data (79 and 16 cases respectively). Coarse soil has a positive relationship and a much higher representation in the data (583 cases).

The relationships between water and conflict are uniformly positive, although weakly so. This does not support claims regarding water pressure being related to conflict as the bivariate results point to all levels of water as positively related to conflict. Only with the inclusion of population density per square do the relationships between water and conflict become negative; this is clearly related to the strength of the negative relationship between population density and conflict.

Regarding population, national urban population growth both before and after 1990 is not related to onset. Rural growth before 1990 is also unrelated. However, rural growth after 1990 is negatively related, signaling that high rural population growth is related to less conflict while a decrease in population is associated with increased conflict. This relationship could be a proxy for activities in peripheral areas of a state, or possibly, conflict occurs in less populated areas. This conclusion has been reached in a related analysis (see Hegre & Raleigh, 2005). Population growth, density and change are all negatively related to armed conflict, although the change in density from 1990 to 1995 is not significant.

5.2 Hypothesis Testing

Hypothesis 1 considered the risk of conflict to increase when the productive capacity of the land is low and the population density high. This theory is tested using the NDVI scores with population information on both local and national levels. The results below show that both low NDVI scores and population density (1990) demonstrates a negative relationship with armed domestic conflict. When maximum NDVI is used (over-representing low capacity land) and population density, the results confirm the negative and significant relationship between local land type and local population in affecting conflict behavior locally. An interaction of NDVI and population density on conflict (Model 5), testing the conflict probability of high population and low capacity land, is also negative. It retains a negative relationship with both separate variables in the model also (Model 6). This does suggest that high population and low capacity land are not, as Neo-Malthusians claim, related to a higher instance of conflict onset.

When land types with particular problems are included in regression with population, infertile, saline, coarse and cold soil are positively related to conflict at a local level while population is stable and negative. In a regression with all types of problem soils, all significant problem soils are negatively related to conflict, as is population. Hence, it seems that the problem soils' relationship to conflict is not robust; however it is also clear that hypothesis one is not true on a local level – low capacity land type and higher population densities are not related to increased conflict.

- Table 2 Here -

Hypothesis 2 considers the relationship between national and local levels of fresh water access and conflict. On a local level, freshwater access is positively related to conflict whether minimum or maximum values are used. On a national level, available water is also positively related to conflict. The national availability of water can be considered a proxy for country size, and larger countries are often associated with higher levels of conflict (see Hegre & Raleigh, 2005 for a more complete discussion). However, Models 11-13 are quite weak. Yet the inclusion of population (Model 14) does not change the sign of the relationships between water and conflict- even in low population areas, water availability is positively related to conflict. A per-capita water availability interaction is added (Model 15) and is negatively related to conflict only if the two separate variables (freshwater and population) are not included. Upon inclusion, the interaction term is positive and significant (Model 16) and both freshwater availability (maximum) and population density are negatively related to conflict onset. This result highlights the complex relationship between water and conflict- although weakly related at first, when low water availability and high population density are combined, this situation is more conflict prone than when high population density and freshwater availability are considered separately. It stands to reason that this may be the result of structural and systemic biases against certain communities within a country. Again, if the negative relationship of population and conflict can be taken to proxy depopulated rural areas, then the availability of water can be exacerbated by state level polices.

The third and final hypothesis regarding population growth and armed conflict is divided into multiple separate regressions. Density and conflict (Table 1) is negatively related to conflict in our analysis, with the change over time considered in the model. As shown in the bivariate tables, local significant population measures are all negatively related to conflict. Urban and rural growths, in addition to local population at the square, are insignificant to conflict onset. Interestingly, maximum and minimum population values at the individual square level are positively related to conflict. This relationship may be spurious as population sum (the measure used in regressions) accurately records the number of people in the defined grid zone. Furthermore, as noted in Table 2, when population is added to a number of regressions with land and water variables, population growth is negatively associated with conflict. This is directly opposite of neo-Malthusian predictions concerning population pressure.

6.0 Conclusions

It appears from this analysis of disaggregated data that environmental variables and conflict are either not directly related, or related in ways that is contrary to many neo-Malthusian claims. This analysis is unique in that both the dependent variable and independent variables are disaggregated, allowing for direct testing of hypotheses regarding population, land and water. 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 local and national processes.

We find that overall, land capacity is unrelated to conflict site and secondly, this relationship is also negative when population (and population growth) are added to the models. This contradicts claims of population density as a conflict catalyst when considering land type (see Urdal, 2005 for more on this relationship). Furthermore, population growth is negatively related to conflict. The specifics of urban growth are clearly insignificant as is rural growth in the pre-1990 period. Post 1990 rural growth is negatively related to conflict yet less than replacement rural growth is positively associated. Again this relationship may say more about the location of conflict (in rural areas, far from the center of power) instead of relating to the population factors (see Hegre & Raleigh, 2005). Based on these basic regressions, we can say that drier land is negatively associated with conflict.

The results for water and conflict are less straightforward. All levels of freshwater access, both local and national, are positively related to conflict. This neither proves nor disproves the neo-Malthusian claim of scarce water and conflict. However, an interaction between local freshwater levels and population yields a positive relationship to conflict when both freshwater access and population are negative. The interaction of these two salient local levels factors are important and conflictual, not their independent state. This result does bolster neo-Malthusian scarcity claims. Yet, it seems these results can be only understood in light of structural and systemic biases against particular population clusters within a country. This result will be further examined in the next iteration of this paper.

The explanatory power of the models presented in this paper is generally very low, suggesting that environmental and demographic factors may be second to other drivers of armed conflict. We intend to continue this analysis by including a number of political and socioeconomic variables which may highlight how and why environmental factors are salient to particular regions and particular groups. We believe a clearer link between the physical changes associated with environment variables and the political process of rebellion must be established. For that reason, it does not seem strange that the results from disaggregated analysis here do match previous studies regarding the environmental mechanisms in conflict. It seems that such environmental factors are made important through the policies of the state or through market fluctuations (for an example of how environmental factors are used as instrumental variables see Miguel et al., 2002). This analysis demonstrates that such initial theorization about the interaction of physical and political process may be a more fruitful path, as physical conclusions are indeterminate or considerably different that previously assumed.

7.0 References

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Table 2: Environment, Population and Conflict

	Coefficient	*Significance Level*	*R²*	*Log Likelihood*
Model 1 (n= 10,995):				
Constant	-.116	0.158		
NDVI Minimum	-.1423	0.000		
Population Density 1990	-.00230	0.000	.08	-3532
Model 2 (n=12,950) :				
Constant	-.1379	0.102		
NDVI Maximum	-.1282	0.000		
Population Density 1990	-.0023	0.000	.08	-4269
Model 3 (n=9.810):				
Constant	-.308	0.001		
NDVI Minimum	-.1545	0.000		
Population Density 1990	-.002	0.000		
Local Available Fresh Minimum	.0031	0.000	.10	-3075
Model 4 (n=13,401):				
Constant	-.909	0.000		
NDVI Minimum	-.1483	0.000		
Population Density 1990	-.002	0.000		
Local Available Fresh Maximum	.0037	0.000	.09	-3208
Model 5 (n=10,995)				
Constant	-1.025	0.000		
Interaction (NDVI Min and Population Density)	-.00041	0.000	.09	-3548
Model 6 (n= 10,995)				
Constant	-.440	0.000		
Interaction (NDVI Min and Population Density)	-.00017	0.000		
NDVI Minimum	-.0821	0.000		
Population Density 1990	-.0015	0.000	.10	-3523
Model 7 (n=13,401):				
Constant	-1.006	0.000		
Saline	1.23	0.015		
Population Density 1990	-.002	0.000	.07	-4506
Model 8 (n=13,401) :				
Constant	-1.007	0.000		
Infertile	.4242	0.008		
Population Density 1990	-.002	0.000	.07	-4505
Model 9 (n=13,401) :				
Constant	.0655	0.000		
Dry	-2.322	0.000		
Population Density 1990	-.0028	0.000	.19	-3939

Model 10 (n= 13,401):				
Constant	.1686	0.003		
Coarse	-.557	0.000		
Wetlands	-.477	0.100		
Saline	.110	0.829		
Infertile	-.540	0.001		
Steep	-1.028	0.022		
Cold	-.20	0.157		
Dry	-2.13	0.000		
Population Density 1990	-.002	0.000	.19	-3921
Model 11 (n=11,922) :				
Constant	-2.53	0.000		
National Available Water	.0000947	0.000		
Local Fresh Water Minimum	.0032	0.000	.001	-4323
Model 12 (n= 12,846):				
Constant	-2.75	0.000		
National Available Water	.0000919	0.000		
Local Fresh Water Maximum	.00160	0.001	.001	-4145
Model 13 (n= 11,922):				
Constant	-1.558	0.000		
National Available Water	.00010	0.000		
Local Fresh Water Minimum	.002	0.000		
Population Density 1990	-.0023	0.000	.07	-3899
Model 14 (n= 12,846) :				
Constant	-2.14	0.000		
National Available Water	.00010	0.000		
Local Fresh Water Maximum	.0036	0.000		
Population Density 1990	-.00258	0.000	.07	-4037
Model 15 (n= 10,995)				
Constant	-1.581	0.000		
Interaction (Local Fresh Water Maximum and Population Density)	-.00000548	0.000	0.02	-4244

Model 16 (n=10,995)				
Constant	-.7513	0.000		
Interaction (Local Fresh Water Maximum Population Density 1990)	.0000196	0.000		
Local Fresh Water Maximum	-.00116	0.083		
Population Density 1990	-.0067	0.000	.07	-4041