**On Exposure, Vulnerability and Violence: Spatial Distribution of Risk Factors for Climate Change and Violent Conflict Across Kenya and Uganda**

**Abstract**

Recent studies discuss the link between climate change and violent conflict, especially for East Africa. While there is extensive literature on the question *whether* climate change increases the risk of violent conflict onset, not much is known about *where* a climate-conflict link is most likely to be found. We address this question by analyzing the spatial distribution of the factors commonly associated with a high exposure and vulnerability to climate change, and a high risk of violent conflict onset in Kenya and Uganda. Drawing on recent literature and quantitative data for the period 1998-2008, we develop various specifications of a composite risk index (CRI) with a spatial resolution of half a degree for Kenya and Uganda in the year 2008. A quantitative comparison with conflict data for the year 2008 provides support for the composite risk index. Finally, the composite risk index is contrasted with the findings of three qualitative case studies, which provide mixed support for the index and help to identify its strengths and weaknesses as well as conceptual needs for further quantitative studies on climate change and violent conflict.

**Keywords**: climate change; violent conflict; risk analysis; Kenya; Uganda; space

## 1 INTRODUCTION

In recent years, possible connections between climate change and violent conflicts have received increased attention by the scientific and policy community (Meierding, 2013). The causal links are yet unclear and the magnitude of the effect of climate change on violent conflict is heavily discussed (Ide & Scheffran, 2014; Scheffran et al., 2012b; Theisen et al., 2013). This is especially the case for East Africa, which is seen as a region highly vulnerable to climate change (World Bank, 2013b). Several recent studies indicate a link between higher temperatures (Hsiang et al., 2011; Maystadt & Ecker, 2014; O´Loughlin et al., 2012) or lower precipitation (Ember et al., 2012; Fjelde & von Uexkull, 2012; Hendrix & Salehyan, 2012; Raleigh & Kniveton, 2012) and violent conflict in this region. They are challenged by other analyses finding no significant impact of temperature increases (Buhaug, 2010) or precipitation decreases (O´Loughlin et al., 2012; Theisen, 2012; Theisen et al., 2012) on violent conflict onset in East Africa.

This debate is not settled yet, and we will not assess in this paper *whether* a link between climate change and violent conflict exists in East Africa. Our study rather addresses the question *where* such a link is most likely to occur. Climate change does not affect all parts of the region in the same way. The magnitude of the warming as well as the trend and degree of precipitation changes show considerable local variations (Hulme et al., 2001; IPCC, 2013). Furthermore, some regions, such as coastal areas (facing flood risk) or arid regions (facing drought risk), are more exposed to extreme weather events. And finally, even if areas with similar geographic characteristics are afflicted by similar climatic changes, their adaptive capacities and resilience to violent conflict are likely to differ considerably (Adger, 2006; Barnett & Adger, 2007).

So if climate change is a cause of violent conflicts, then such a link is most likely to occur in regions which simultaneously suffer from adverse climate change, have few capabilities to cope with these changes, and are characterized by pre-existing tensions and conflict (Gemenne et al., 2014; Raleigh et al., 2014). But until today, few efforts have been made to identify these regions. This paper addresses this gap by using a multi-method approach. It develops a composite risk index (CRI), which consists of exposure, vulnerability, and violent conflict risk variables, has a spatial resolution of 0.5 decimal degrees (°) and focuses on Kenya and Uganda in the year 2008.

We choose to limit our analysis to this reference year and region because the availability, quality and resolution of environmental and socio-economic data up to 2008 is comparatively good for both countries. The other reason for our regional focus is that the debate on environmental or climate change and violent conflict often focuses on Kenya and Uganda (e.g. Adano et al., 2012; Eaton, 2008; Inselman, 2004; Schilling et al., 2012). Therefore, we can also draw on a rich literature to specify our model and contrast it with the findings of other studies as well as with our own case studies.

Our analysis contributes to the existing literature in several ways. It enables qualitative researchers to create most likely-, most unlikely-, most similar systems- or most different systems-research designs, which improves the contribution of case studies to the wider literature on climate change and violent conflict (Ide & Scheffran, 2014). For instance, if a study is unable to detect a relationship between climate change and violence even in highly exposed, vulnerable and conflict prone areas, this would be a strong argument against a supposed climate-conflict-link in East Africa (Gerring & Seawright, 2007). The various maps created on the basis of the risk analysis furthermore facilitate the comparison of commonly used datasets with the results of case studies and field observations (Gleditsch & Weidmann, 2012). Such "ground checking" can help to improve the quality of the respective datasets and is thus likely to benefit future large-N studies. The risk index also provides a valuable tool for policy makers, development workers and security analysts interested in the geographic distribution of the risk factors for climate change and violent conflict. Our study thus contributes to the increasing literature on "climate change hotspot mapping" (de Sherbinin, 2014: 23). Finally, our analysis integrates qualitative and quantitative approaches and thus follows recent calls to integrate various methods in the research on climate change and violent conflict (Meierding, 2013; Scheffran et al., 2012a).

This article proceeds as follows. The theoretical background is introduced in the next section. In section three, we analyze the spatial distribution of the risk factors for climate change and violent conflict in Kenya and Uganda in 2008 and integrate them into a CRI. This analysis is based on a literature review and on quantitative datasets for the years 1998 to 2008. The results are presented in the form of various risk maps with a spatial resolution of 0.5° (equal to 55.5 kilometers at the equator). In section four, we contrast the findings of the risk analysis with conflict data for the year 2008 as well as with three case studies of Loitoktok (Kenya), Southern Turkana-Pokot North (Kenya) and Karamoja (Uganda). While geo-referenced conflict datasets allow a quantitative validation of the CRI, case studies are helpful since they can evaluate the findings of the CRI and its individual components in greater depth. In the final section, we present our conclusions.

## 2 THEORETICAL BACKGROUND

A violent conflict is given when the opposing interests of two or more social groups clash and at least one of the groups uses direct, physical violence in order to enforce or articulate its interests. While most proponents of the climate-conflict thesis agree that environmental violence "tends to be subnational, diffuse, and persistent" (Homer-Dixon & Blitt, 1998: 11), some studies also suggest a link between large-scale intra-state violent conflicts and climate change (e.g. Burke et al., 2009). There are several possible ways to define and operationalize climate change. We focus on short- to medium-term temperature and precipitation changes which are common proxies for adverse climate change (e.g. Fjelde & von Uexkull, 2012; O´Loughlin et al., 2012). The main reason for this is that climate change will increase the number of short- to middle-term extreme events, which are more likely to influence conflict patterns than changing long-term averages (e.g. Meierding, 2013). It is acknowledged in the literature that temperature and precipitation changes are at best one among many other causal factors of violent conflict onset, but have the potential to indirectly act as "threat multipliers" (Gemenne et al., 2014: 3).

Various pathways linking climate change and violent conflict have been considered (Gleditsch, 2012; Scheffran & Battaglini, 2011). For instance, several studies in social psychology indicate that higher temperatures cause an increase in human aggression, which can transform into inter-group conflict and violence (Anderson & DeLisi, 2011). Higher temperatures and reduced precipitation can also cause scarcities of water, food and arable land, which might lead to inter-group competition and grievances (Homer-Dixon & Blitt, 1998; Schilling, 2012). These resource scarcities can furthermore undermine the capability of the state (e.g. if it loses legitimacy) and thus its capacity to prevent inter-group conflicts (Kahl, 2006). Finally, opportunity costs for joining a violent group decrease during times of drought, especially in countries with a population heavily dependent on agriculture, such as Kenya and Uganda (Barnett & Adger, 2007).

In order to assess the distribution of risk factors for climate change and violent conflict, we utilize a theoretical model based on three categories. In accordance with the Intergovernmental Panel on Climate Change (IPCC, 2012: 30-36), we first distinguish between exposure and vulnerability to climate change. Exposure means that a particular location is "adversely affected by physical events" (IPCC, 2012: 32), in our case temperature and precipitation extremes. Vulnerability is defined as the "predisposition to be adversely affected" (IPCC, 2012: 32). This understanding of vulnerability has two components, sensitivity and adaptive capacity. Sensitivity "is the degree to which a system is modified or affected by perturbations" (Adger, 2006: 270). Some areas, for instance, are characterized by a high percentage of the population depending on agriculture for income and food generation, thus making them more sensitive to droughts than places with a strong tertiary sector. Adaptive capacity is defined as the ability of a system to change in order to cope with the stress it is facing due to its exposure and sensitivity (Adger, 2006). Examples of adaptation measures include irrigated agriculture or insurance schemes against environmental risks.

However, even a region heavily exposed and very vulnerable to climate change may not experience violent conflict because violent conflict is a complex product of multiple and interacting factors. Even strong proponents of an environment-conflict link claim that "passing the threshold of violence definitely depends on *sociopolitical* factors" (Bächler, 1998: 32). Therefore, the general risk of violent conflict onset is considered as the third component of our risk analysis. The general risk of violent conflict is defined as the likelihood of a violent conflict to break out in a certain area.

Thus, the composite risk index (CRI) will be high for those locations which simultaneously experience a high exposure to adverse temperature and precipitation changes, a high vulnerability vis-à-vis these changes, and a high general risk of violent conflict onset. If climate change increases the risk for violent conflict onset, we assume that this is most likely to happen in these areas.

## 3 ANALYZING THE SPATIAL DISTRIBUTION OF THE RISK FACTORS FOR CLIMATE CHANGE AND VIOLENT CONFLICT

Although there is plenty of sub-national quantitative social, environmental and conflict data available for Kenya and Uganda, we need to find a combination of variables that represents the exposure to climate change, the vulnerability to climate change, and the onset of violent conflict well. The ACLED dataset (Raleigh et al., 2010) can be used to measure violent conflict and thus can serve as a dependent variable in a regression model to search for variables indicating a general risk for violent conflict onset in Kenya and Uganda for the period 1998-2007. The variables that turn out to be sufficient can then be used to for the risk analysis. For each the exposure and the vulnerability to climate change, no adequate dependent variable to be used in a regression analysis could be found. Thus, we draw the indicators for exposure and vulnerability directly from the relevant literature. We check all of the suggested variables for pairwise autocorrelations in the years 1998-2007 to maximize the explanatory power of the CRI for the application year 2008.

### 3.1 Selection of Variables

#### *3.1.1 Exposure to climate change*

Each of the three broad categories discussed above is operationalized through various indicators. Higher temperatures and reduced precipitation are chosen as key indicators for exposure to climate change. This choice is supported by various studies which find a link between these indicators and adverse changes in biological and social systems in East Africa (e.g. Battisti & Naylor, 2009; World Bank, 2013b). We use the average yearly precipitation in the period 2004-2008 compared to the period 1979-2008 to operationalize precipitation changes. With this measurement, we account for the fact that a single wet year is insufficient to compensate the negative effects of various preceding dry years (Temesgen, 2010: 24). Since small changes in precipitation have a much stronger influence in areas with low annual rainfall, we divide the precipitation value through the long-term average for the period 1979-2008. The choice of an appropriate indicator for temperature increases was more difficult because some authors argue for a short-term link between extreme heat events and violence (e.g. Anderson & DeLisi, 2011; Maystadt & Ecker, 2014), while others highlight the importance of medium-term changes in average conditions (Barnett & Adger, 2007; Wischnath & Buhaug, 2014).[i] In order to capture both arguments, we use the change of the annual mean temperature between 2007 and 2008 to operationalize temperature changes (see also Meierding, 2013). We also tested two alternative specifications, namely the deviation of the temperature in 2008 and in the period 2004-2008 from the 30-year mean, but both performed considerably worse in the quantitative and the qualitative evaluation procedure described in section 4. Climate data is obtained from the PRIO-Grid dataset (Tollefsen et al., 2012).

### *3.1.2 Vulnerability to climate change*

With regard to Africa, Busby et al. (2012)[ii] suggest three indicators for measuring vulnerability, namely household and community vulnerability, governance vulnerability/political violence, and population density. The household and community vulnerability basket consists of four indicators: access to daily necessities, health, access to healthcare, and education. Education has long been recognized as a key factor for reduced sensitivity to and enhancing the adaptive capacity vis-à-vis adverse environmental changes (UN, 2004), inter alia because well-educated people are better prepared to find employment outside the agricultural sector or to introduce innovations. In this study, the level of education is measured by the percentage of people who never went to school (KOD, 2009; UBOS, 2006). Access to daily necessities is important since populations with sufficient caloric intake and access to clean water are less vulnerable to climate change. Following Busby et al. (2012), we use child malnutrition as a proxy for this indicator and collect data on it from various Demographic and Health Surveys (DHS Program, 2013). Finally, we consider the concepts health and access to healthcare as closely related and thus use only one indicator for them. Healthy populations can be considered less vulnerable to climate stress such as heat waves or drought-related malnutrition. Infant mortality is usually considered as the best proxy for the health of a given population (Reidpath & Allotey, 2003) and appropriate data is available from the DHS Program (2013).

A high population density indicates a large number of persons affected by an extreme event and limited capacities for adaption through, for instance, migration or more extensive cultivation. Similarly, past political instability/violence has a strong negative effect on the assets and available coping strategies of individual households (Eriksen & Lind, 2006). Data on population density is calculated on the basis of the PRIO-Grid data. The incidence of at least one conflict in the previous year (2007) according to the ACLED dataset is used as an indicator for past political instability.

We also include two additional indicators for vulnerability to climate change not discussed by Busby et al. (2012). The first one is environmental dependence, measured through the percentage of the population economically dependent on agriculture (FAO, 2013). Regions characterized by a high dependence on agriculture can be expected to be especially sensitive to climate change, which has the potential to undermine agricultural production (Battisti & Naylor, 2009). Secondly, we consider soil degradation as an important factor increasing the vulnerability to climate change because degraded soils are very sensitive to temperature and precipitation extremes (Al-Kaisi, 2000). Information on soil degradation is obtained from the GLASOD dataset (ISRIC, 1990), which is still considered the most comprehensive global dataset on soil degradation (Sonneveld & Dent, 2009). Recent studies also highlight the role of local social and cultural institutions in adapting to environmental changes (Adano et al. 2012; Bogale/Korf 2007). Unfortunately, no comprehensive datasets on this indicator are currently available, so we cannot include it into the analysis.

#### *3.1.3 General risk of violent conflict onset*

Possible indicators for the general risk of violent conflict onset are extracted from the literature on the drivers of civil war onset. Civil war research has yet produced the most elaborated results regarding the causes for violent conflict onset, and there are theoretical as well as (preliminary) empirical evidence suggesting that “low-intense disturbance events can be explained by conventional correlates of civil war” (Buhaug et al., 2012: 6). But the question remains whether the factors identified as relevant by the general literature on civil war can explain the onset of low- and high-intensity violent conflict events in Kenya and Uganda around 2008? In order to address this issue, we perform a regression analysis using all factors identified as relevant for the onset of civil war by two meta-studies (Dixon, 2009; Hegre & Sambanis, 2006) as independent variables: low economic growth, medium level of democracy, low level of development, large population and recent political conflicts. We use data on GDP growth by the World Bank (2013a) and on population size by PRIO-Grid. The level of development is measured by data (a) on the under-five mortality rate as provided by the DHS Program (2013) and (b) on the gross cell product (GCP) per capita as provided by PRIO-Grid. We use a binary measure of the incidence of ACLED conflict events (Raleigh et al., 2010) in the previous year as an indicator for past conflicts. Finally, in accordance with current research standards (Vreeland, 2008), the executive constraints (*xconst*) value of the Polity IV dataset (Marshall et al., 2012) is utilized as an indicator for the level of democracy. The more the *xconst* score of a country deviates from four, the more it is either an autocracy (1-3) or democracy (5-7), and the less likely it is to experience violent conflict onset (Vreeland, 2008).

We use the occurrence of at least one conflict event per year according to the ACLED dataset, which is geo-referenced and has a low inclusion threshold, as the (binary) dependent variable. The regression analysis is performed for the decade prior to the reference year of our risk analysis (1998-2007). All independent variables (with the exception of past conflict) are lagged by one year in order to account for endogeneity. The various datasets are transformed into the PRIO-Grid cell format which, for our area of interest, consists of 306 grid cells with an edge length of 0.5°. Missing values are extrapolated from circumjacent years or cells. We run the analysis with a linear and with a logit regression model, but the signs and the significance levels for the different variables do not change. The results are presented in Table 1.[iii]

**Table 1: Results of the regression analysis for violent conflict incidence, 1998-2007**

| **Variable** | **Linear model** | | **Logit model** | |
|---|---|---|---|---|
| | **β** | **SE** | **β** | **SE** |
| GDP growth | .078*** | .003 | .081*** | .019 |
| *xconst* deviaton from 4 | -.07*** | .016 | -.428*** | .108 |
| under-five mortality | -.016 | .0 | -.002 | .157 |
| GCP per capita | .015 | .0 | .0 | .0 |
| population size | .171*** | .0 | .000*** | .0 |
| past conflict (ACLED) | .336*** | .017 | 1.616*** | .244 |

*** = $p < 0.01$; ** = $p < 0.05$; β = standardized coefficient; SE = standard error; N = 3060; dependent variable: violent conflict (ACLED)

Table 1 shows that population size and the occurrence of conflict events in the previous year are positively and significantly related to the binary ACLED conflict variable. The significant and negative effect of a deviation from the *xconst* value of four also indicates a link between a medium level of democracy and a high risk for violent conflict onset. There is no significant relationship between either the under-five mortality rate or the gross cell product per capita and conflict occurance. Finally, GDP growth is significantly and positively related to the dependent variable. This is surprising and contradicts much of the existing literature (Hegre & Sambanis, 2006). We are thus cautious about this finding and will present one specification of the risk index with and one without the economic growth indicator. Based on the regression analysis, we therefore use a medium level of democracy, a large population, the occurrence of a conflict event in the preceding year, and high economic growth (although with some caution) as indicators for a high general risk of violent conflict onset.

### 3.2 Synthesis of Variables

After converting all available data on the remaining indicators into the unified spatial reference structure of the PRIO-Grid cell raster, we check for autocorrelation between the selected variables during the period 1998-2007 in order to reduce the risk of unintentionally giving some factors more weight than others. Not surprisingly, there is a very strong and significant correlation between population size and population density (.905***). Therefore, the former is removed from the index. Child malnutrition is also strongly and significantly correlated with the percentage of the population which never went to school (-.500***). Thus, child malnutrition is dropped from the risk index since schooling data are available at a higher spatial resolution and infant mortality can also be interpreted as a proxy for access to daily necessities. Finally, a strong and significant correlation (-.523***) between the indicators deviation from an *xconst* value of four and agricultural population is detected. Since both indicators refer to very different theoretical concepts and empirical measurements, we decide to use both indicators for the index and multiply each of them by 0.5. In order to account for double counting, we also multiply the indicators population density and political instability/past conflict with 0.5 since they are used as indicators for both vulnerability and general conflict risk. All social, economic and political indicators are lagged by one year in order to avoid endogeneity problems. Exceptions to this rule are the indicators for political instability (which already refers to the previous year) and education (since data on the population which never went to school are only available for one year).

Twelve indicators remain that are used for the risk analysis (see Table 2 for an overview). In order to integrate them into combined indices, for each variable the relevant data for 2008 is sorted by value and the 306 grid cells are divided into nine equal-sized quantiles.[iv] The score of 9 always indicates the rank corresponding to the highest risk (strong exposure, high vulnerability, high general violent conflict risk), while the score of 8 characterizes the second-highest rank, and so on. For each grid cell these scores are then added up (specific variables weighted with 0.5 as described before) to calculate values for the three key concepts, which are then combined in order to produce the composite risk index (CRI). Such a procedure produces relative rather than absolute risk scores and is generally considered to be a suitable way to integrate different datasets in a comprehensible way (Busby et al., 2013; Rustad et al., 2011).

**Table 2: Indicators and datasets included into the risk analysis for 2008**

| Component | Indicators | Operationalization | Data source | Resolution | Remarks | Contribution to CRI |
|---|---|---|---|---|---|---|
| exposure to climate change | higher temperature | av. 2008 – av. 2007 | Tollefsen et al. (2012) | grid cell | | 16.7% |
| | reduced precipitation | av. (2004-2008) – av.(1979-2008), divided through av.(1979-2008) | Tollefsen et al. (2012) | grid cell | | 16.7% |
| vulnerability to climate change | education | % of population never went to school (2002/2009) | KOD (2009); UBOS (2006) | district/county | | 7.4% |
| | health | infant mortality rate (2007) | DHS Program (2013) | DHS region | t-1 | 7.4% |
| | population density | persons/km² (2007) | Tollefsen et al. (2012) | grid cell | t-1; * 0.5 | 3.7% |
| | political instability | conflict occurrence in previous year (i.e. 2007) | Raleigh et al. (2010) | grid cell | * 0.5 | 3.7% |
| | environmental dependence | % of population active in agriculture (2007) | FAO (2013) | national | t-1; * 0.5 | 3.7% |
| | soil degradation | rate of soil degradation (1990) | ISRIC (1990) | ISRIC polygon | | 7.4% |
| general risk of violent conflict onset | GDP growth | annual GDP growth (2007) | World Bank (2013a) | national | t-1 | 13.3% |
| | medium level of democracy | deviation from *xconst* value of 4 (2007) | Marshall et al. (2012) | national | t-1; * 0.5 | 6.7% |
| | population density | persons/km² (2007) | Tollefsen et al. (2012) | grid cell | t-1; * 0.5 | 6.7% |
| | past conflict | conflict occurrence in previous year (i.e. 2007) | Raleigh et al. (2010) | grid cell | * 0.5 | 6.7% |

Explanation: av. = average; t-1 = lagged by one year; * 0.5 = divided through two in order to account for double counting or autocorrelation

3.3 Results

Figures 1-3 show the spatial distribution of the individual indicators constituting the risk components, while Figure 4 shows the integrated maps for each risk component: exposure to climate change, vulnerability to climate change and general violent conflict onset. Higher mean temperatures in Western Kenya as well as Eastern and Northern Uganda can be contrasted with significant precipitation reductions in Southern Kenya, parts of Central Kenya and around the Ugandan shore of Lake Victoria (Figure 1). When combining both indicators, one can detect a particularly high exposure to adverse climate change in South-western Kenya, while North-eastern Kenya and South-western Uganda are hardly affected (Figure 4a).

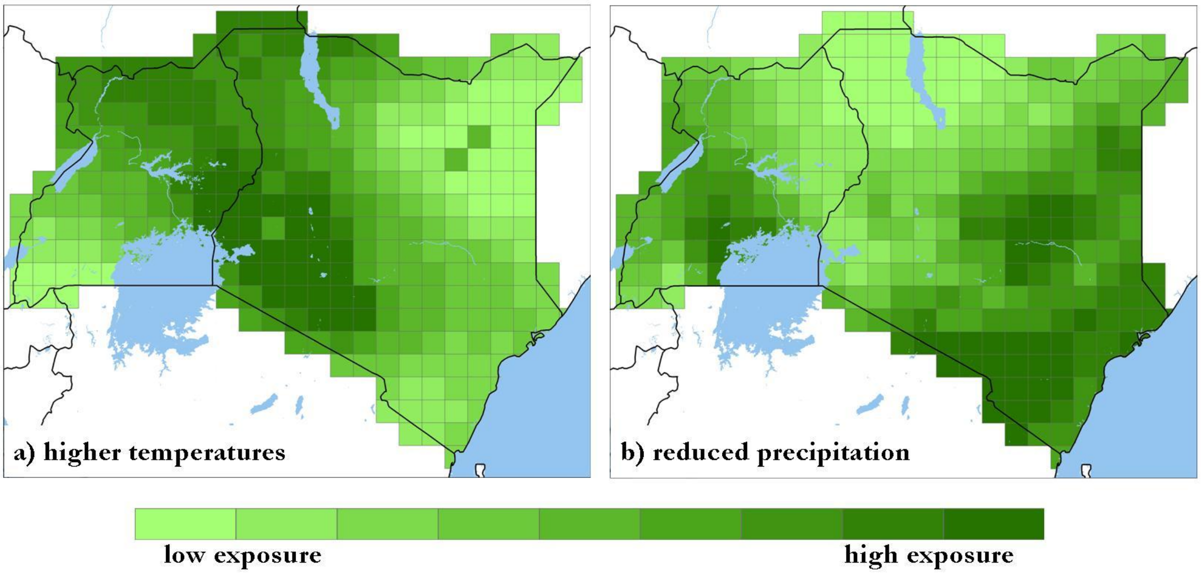


**Figure 1: Components of the exposure to climate change index**

Regarding the six indicators for vulnerability to climate change (Figure 2), we see that Uganda in general is characterized by a higher population density and a more critical health situation (Figures 2b and 2d). By contrast, national-level differences are less important than sub-national variation for the indicators measuring education, political instability and soil degradation (Figures 2a, 2c and 2f). Environmental dependence is the only indicator for which national-level data are used. However, since the percentage of population working in agriculture is very similar in both countries (Kenya: 33.38%; Uganda: 33.44%), they receive the same score in risk analysis (Figure 2e). We combine all indicators and find Uganda to be much more vulnerable to climate change than Kenya (Figure 4b). But there are important sub-national variations. The most vulnerable areas are located in North-eastern and South-western Uganda as well as around the Kenyan shore of Lake Victoria. The least vulnerable areas are found in Central Kenya (especially in the south) and in parts of Central Uganda.

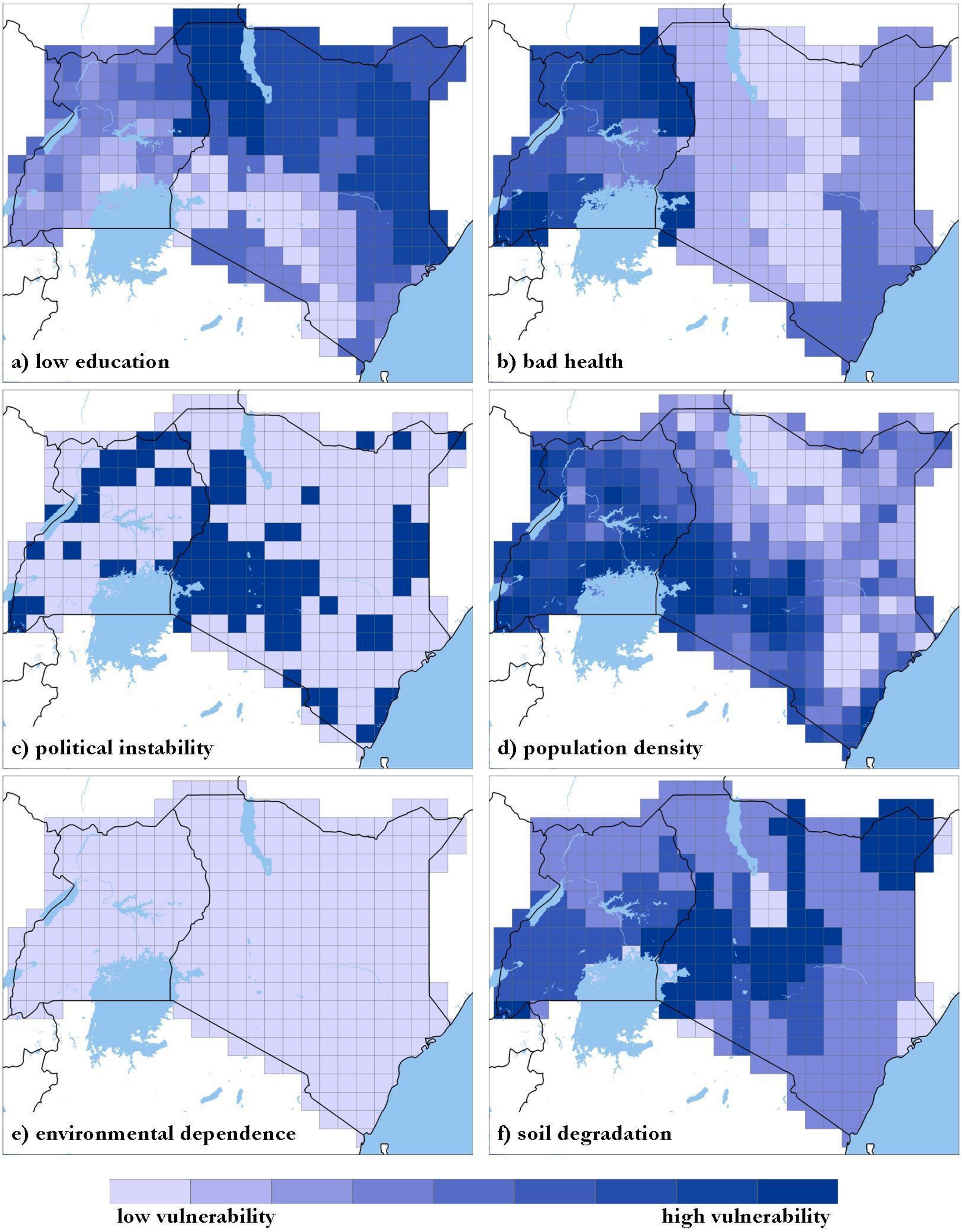


**Figure 2 Components of the vulnerability to climate change index**

The general risk of violent conflict onset contains four indicators (Figure 3), two of which utilize national-level data. Both of these indicators (GDP growth and level of democracy) identify Uganda as more prone to violent conflict onset (Figures 3a and 3b), as does the population density indicator (Figure 3c). It is thus not surprising to see that Uganda has a much higher risk level when combining all four indicators. However, there are high-risk areas in Western and South-eastern Kenya as well (Figure 4c).

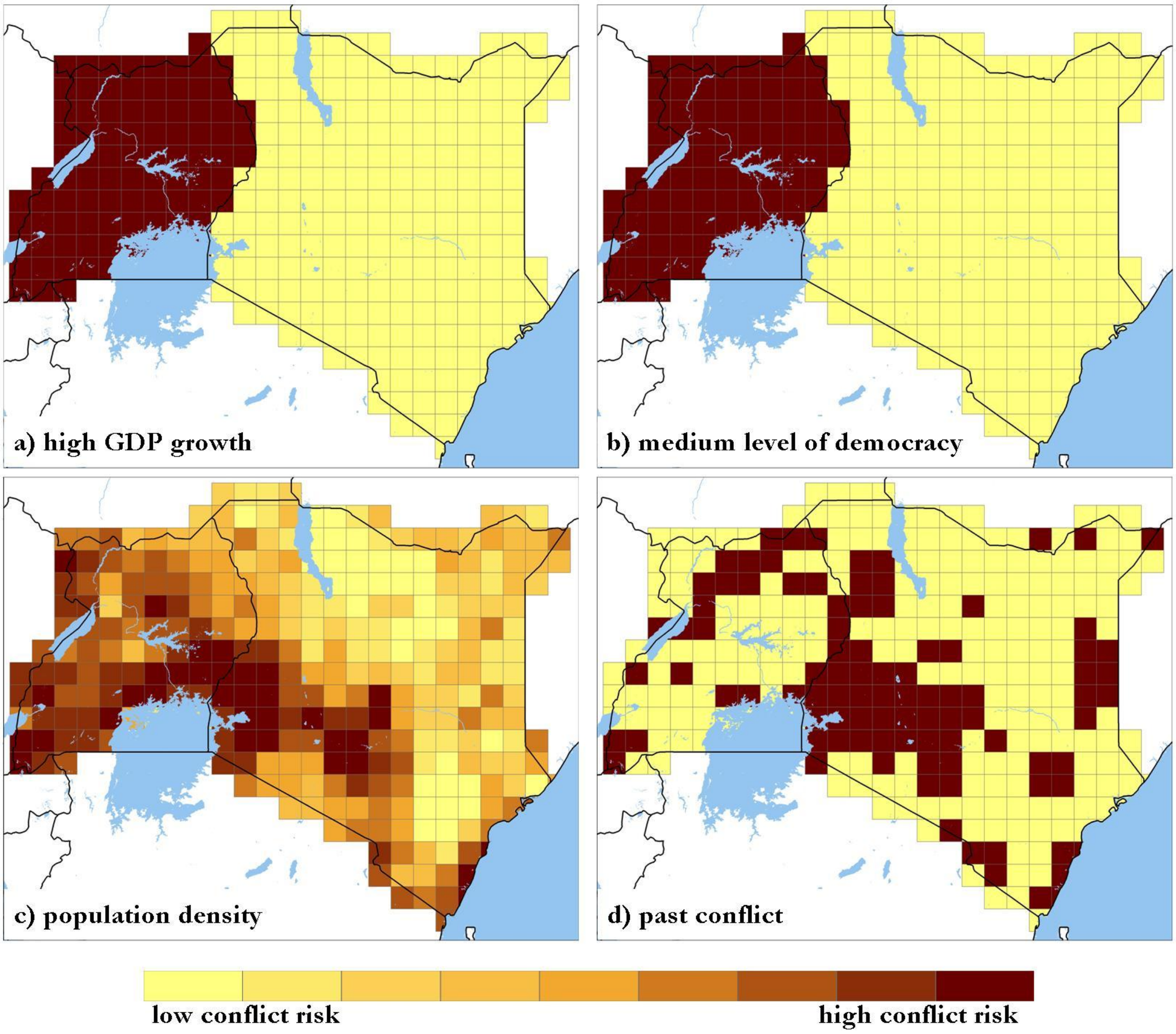


**Figure 3: Components of the general risk of violent conflict onset index**

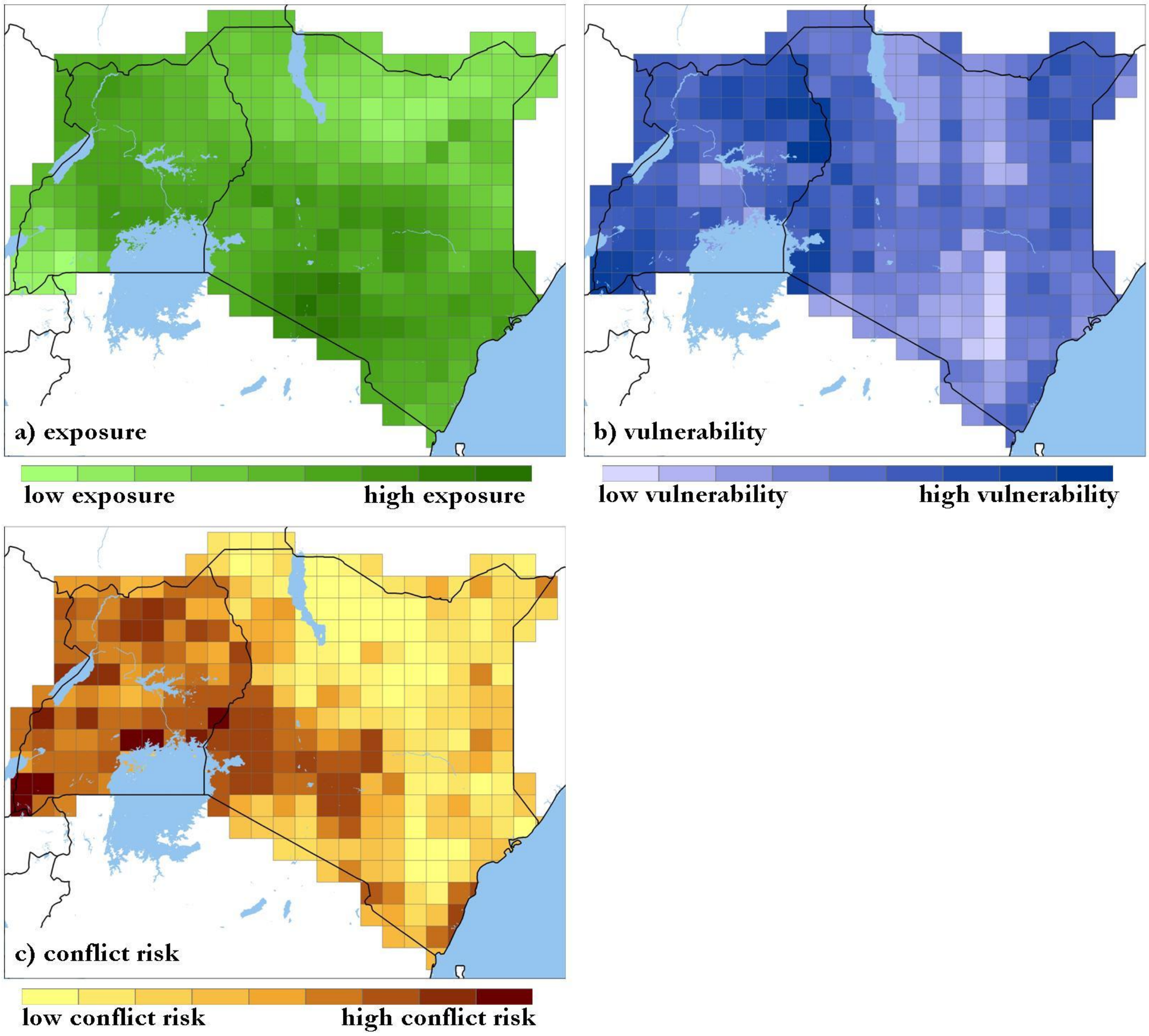


**Figure 4: Components of the composite risk index (CRI)**

As discussed above, a possible link between climate change and violent conflict is most likely to occur in areas characterized by high exposure to climate change, high vulnerability to climate change and high violent conflict risk scores simultaneously. In the next step, the three main components are therefore integrated into various versions of a composite risk index (CRI) (Figure 5). We produce four specifications of the CRI. First, all three components are weighted equally (Figure 5a). Second, the importance of the exposure component is doubled vis-à-vis the vulnerability and conflict risk components (Figure 5b). This specification is in line with positions claiming a strong link between climate change and violent conflict onset (e.g. Burke et al., 2009; Hsiang et al., 2013). In a third specification, the vulnerability basket receives 50% of the weightage, while exposure and conflict risk are each allocated 25% (Figure 5c). This priorization is supported by several studies finding sensitivity levels and adaptive capacities to be crucial in determining human reactions to environmental and climate stress (e.g. Bogale & Korf, 2007; Ngaruiya, 2014). Finally, several authors argue that if at all, climate change is only a very minor factor in stimulating violent conflict when compared to socio-economic and political variables (e.g. Dixon, 2009; Salehyan, 2008). We thus create a specification doubling the weightage of the conflict risk component (Figure 5d).

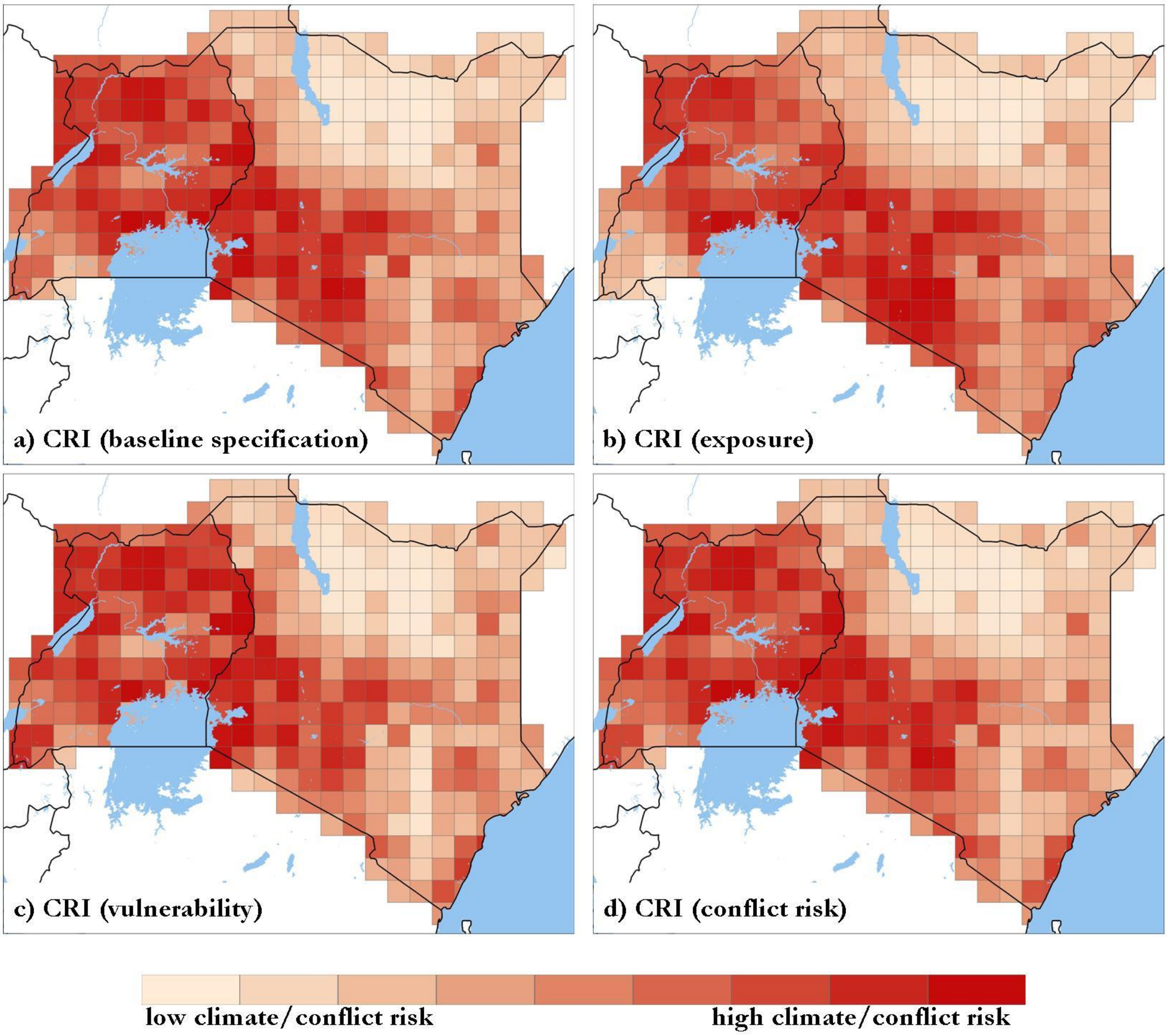


**Figure 5: Composite Risk Index for 2008**
The three components (exposure, vulnerability, conflict risk) are either weighted equally (a) or the weightage of one component is doubled (b-d)

We start our discussion with the specification that gives equal weight to all three main components (Figure 5a). It identifies large parts of Uganda, with the exception of South-western and parts of Central Uganda, as high-risk areas in 2008. The same applies for the South-western quarter and the southern shoreline of Kenya. By contrast, the sum of the exposure, vulnerability and conflict risk scores is low in Northern Kenya, parts of South-eastern Kenya and South-western Uganda in 2008, thus indicating a low risk for climate change-related violence.

This version of the risk index is robust to changes in the specification procedure and is therefore called baseline specification henceforth. When comparing it to the other specifications mapped in Figure 5, one can identify only three regions which are evaluated differently by the various versions of the risk index. South-western Uganda is considered a low to medium risk area by Figure 5a (components weighted equally) and 5d (giving conflict risk more weight). But the same region is described as a low risk area by Figure 5b (giving exposure more weight) and as a high risk area by Figure 5c (giving vulnerability more weight). North-eastern Uganda is portrayed as a high risk area by Figure 5a, 5c and 5d, but as a medium risk area Figure 5b. Finally, central Southern Kenya is a high risk area according to Figure 5a, considered as a very high risk area by Figure 5b, and regarded as a medium risk area by Figure 5c and 5d. The case studies below discuss two of these areas in greater detail.

Finally, Figure 6 compares the baseline specification (Figure 6a) with a version of the risk index from which all national-level data is removed (Figure 6b). Thus, the specification represented by Figure 6b does also exclude economic growth as an indicator for general violent conflict risk. The use of this indicator is supported by the results of our correlation analysis (Table 1), but not by most of the literature on the issue. When only sub-national data are used, the differences between Kenya and Uganda are reduced. Nevertheless, a strong national difference remains and both specifications of the index identify the same high- and low-risk areas. This shows that the on average higher risk scores for Ugandan cells are not primarily driven by national-level data in general or the contestable economic growth indicator in particular.

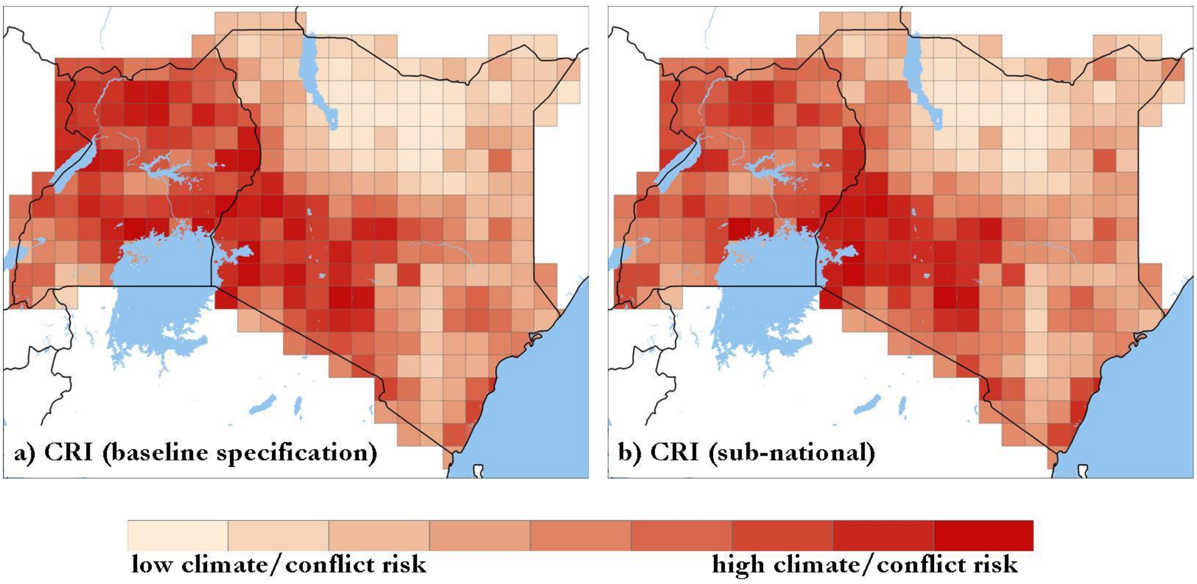


**Figure 6: Composite risk index for 2008 with and without national-level indicators**

<u>4 EVALUATION OF THE COMPOSITE RISK INDEX</u>

In this section, we evaluate the findings of the CRI (baseline specification) by contrasting it with conflict data and case studies available for 2008. In a first step, the correlations between the CRI and four different violent conflict datasets are presented. However, these conflict datasets neither tell us whether the events they register are (possibly) related to climate change, nor do they enable the verification of the individual components/indicators and datasets used. Therefore, in a second step the results of the risk analysis are compared with the findings of three case studies.

4.1 Quantitative evidence

Table 3 shows the correlations between the baseline specification of the CRI and various measurements of violent conflict in 2008. Besides the general ACLED dataset, which collects low- as well as high-intensity political conflict events (Raleigh et al., 2010), we use three datasets. We create a subset of ACLED containing only the category "violence against civilians" (ACLED-VAC) to limit the sample to small-scale events which are considered as more likely to be influenced by climate change (Melander & Sundberg, 2011). For the same reasons, we include the SCAD dataset, which also includes social conflict events below the threshold of civil war (Hendrix & Salehyan, 2012). Finally, the UCDP-GED dataset (Sundberg & Melander, 2013) is utilized despite its relatively high inclusion threshold because most studies on a possible climate-conflict link use the UCDP datasets (Scheffran et al., 2014). Each of the four datasets is used to create a binary variable for the occurrence or non-occurrence of a violent conflict event for each grid cell in the year 2008.

**Table 3: Correlation between the CRI (baseline specification)/ its components and violent conflict occurrence in 2008**

| Variable | ACLED | ACLED-VAC | SCAD | UCDP-GED |
|---|---|---|---|---|
| exposure | .159*** | .140** | .135** | .045 |
| vulnerability | .213*** | .160*** | .056 | .192*** |
| conflict risk | .0406*** | .323*** | .199*** | .173*** |
| CRI (baseline specification) | .358*** | .290*** | .194*** | .177*** |

*** = $p < 0.01$; ** = $p < 0.05$; N = 306

The results of the correlation analysis presented in Table 3 provide some support for the CRI. Not surprisingly, the strongest correlation exists between the conflict risk component and the various measures of violent conflict occurrence. However, the exposure and vulnerability components are also positively and significantly correlated with three of the four conflict variables. But the most important finding is the positive and robust correlation between the baseline specification of the risk index and the various conflict measures. It has to be said, however, that the sample size is rather small (n = 306) and that none of the datasets used distinguishes between conflicts related to climate change (or environmental issues in general) and other kinds of conflicts. This limits the explanatory power of the statistical analysis.

Figure 7 visualizes the relationship between the CRI and the occurrence of violent conflict. It partially confirms the results of the statistical analysis. The usefulness of SCAD is limited in this context since it only captures very few instances of violent conflict in Kenya and Uganda during 2008. Similarly, UCDP-GED, due to its high inclusion threshold, does not capture minor instances of violent conflict (e.g. at the north-western shore of Lake Victoria). There is considerable overlap between the areas with a high composite risk score and the occurrences of violent conflict in 2008 according to the ACLED datasets, although several mismatches exist. This does not imply that any of these conflict events have actually been related to climate change. However, it is interesting to note that many of the conflict events registered by ACLED (and the other datasets) in the dark red areas of Western Kenya (Figure 7) were instances of post-electoral violence or did involve a local militia, the Sabaot Land Defence Force. The larger conflict dynamics which feed these events were political (including elite manipulation). But land scarcity played an important role as well (Simiyu, 2008) and the related stress may have increased with lower agricultural yields due to higher temperatures and reduced precipitation. Future case studies should investigate the possible links between climate change and violent conflict in this area in 2008 in greater detail.

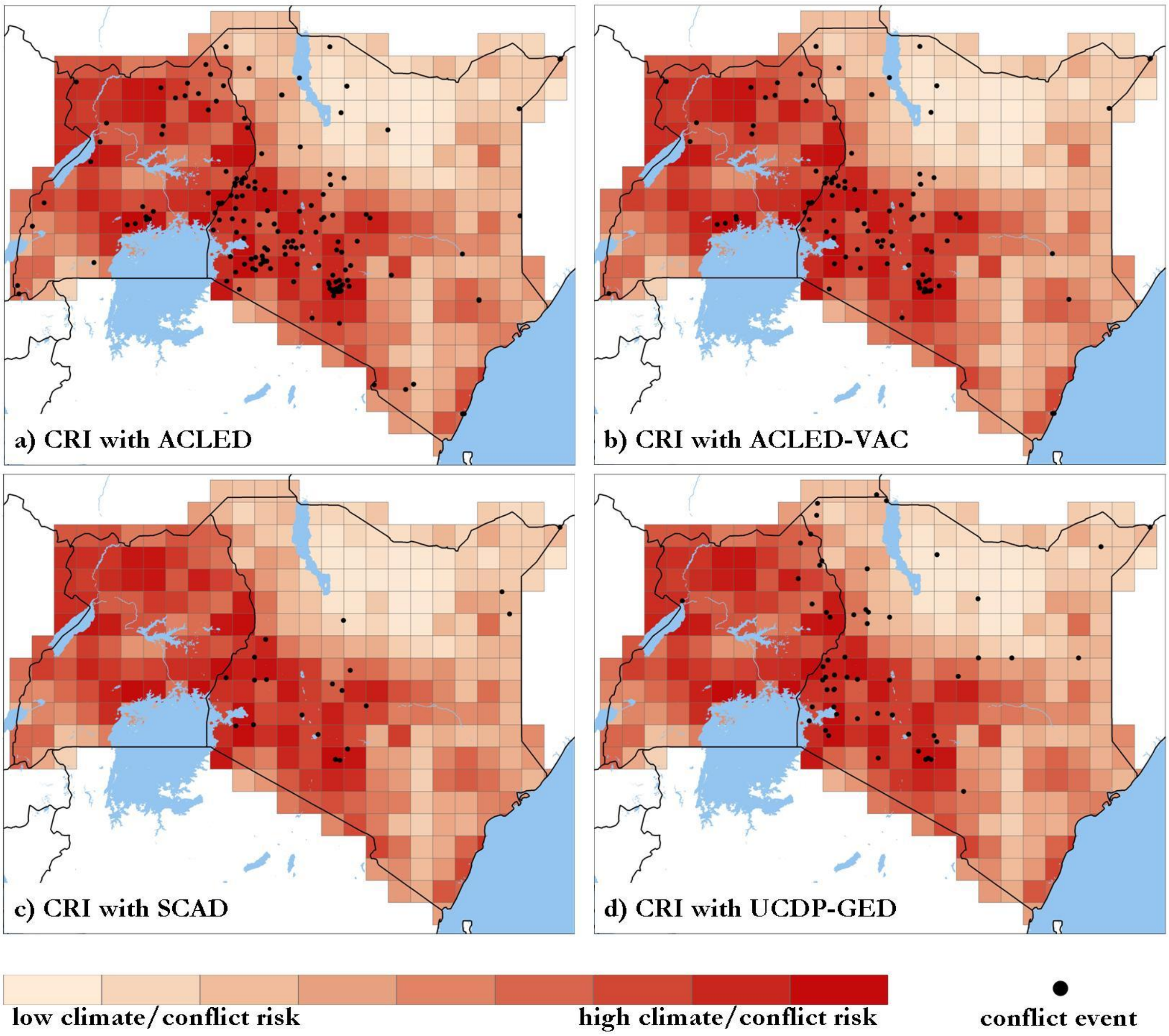

**Figure 7: Comparison of the composite risk index (baseline specification) with four conflict datasets for 2008**

4.2 Case study evidence

In our context, case studies are a helpful testing strategy since they can evaluate the findings of the risk index and its individual components in greater depth. We choose three case studies by applying the diverse case technique (Gerring & Seawright, 2007: 97-101), i.e. we select three quite different regions with respect to their size, location and assessment by the CRI and its components (see Figure 8 and Appendix III). Two of three regions (Loitoktok and Karamoja) are evaluated differently by the various specifications of the CRI (Figure 5). The Loitoktok and Southern Turkana-Pokot North case studies are based on key stakeholder interviews and focus group discussions the authors conducted during field research in the respective regions. Data for the Karamoja case is collected through literature review.

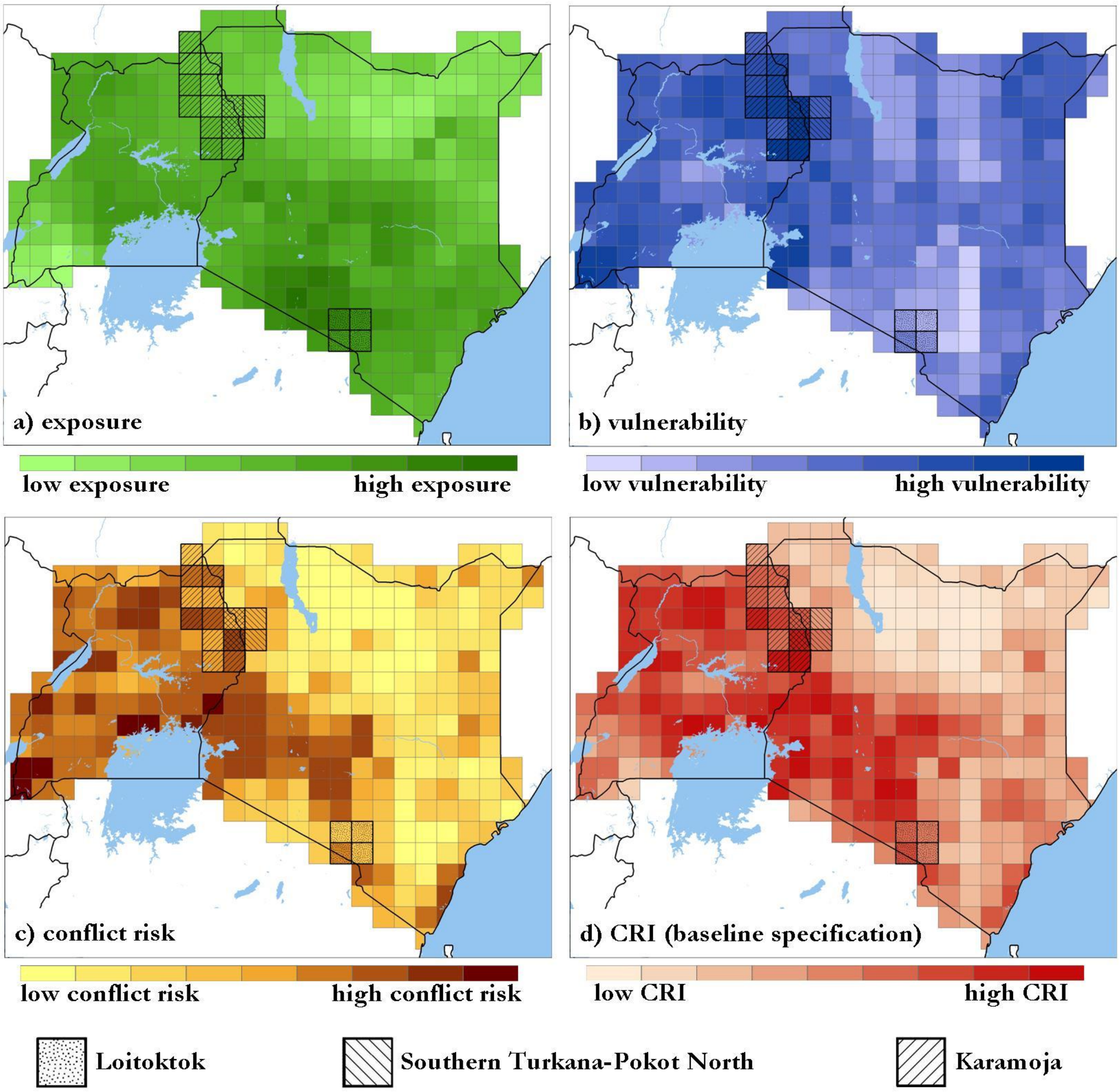


**Figure 8: Case study areas and risk index for 2008**

*4.2.1 Loitoktok*

Loitoktok is an arid to semi-arid district at the Kenyan side of the border with Tanzania. The main livelihoods in the area are agriculture (crops and livestock keeping) and tourism, both of which are particularly supported by water from Mount Kilimanjaro. According to the risk index, Loitoktok was characterized by a medium composite score of exposure, vulnerability and violent conflict risk, which would suggest a medium risk to experience violent conflict related to climate change in 2008 (Figure 8d). Field research, by contrast, suggests a rather low risk for the onset of such conflicts. While there are frequent human-wildlife conflicts in Loitoktok, the general level of inter-group violence is very low and conflicts around natural resources are managed by effective local conflict resolving mechanisms that promote all-inclusive participation (Ngaruiya, 2014; Ngaruiya & Scheffran, 2013).

The high exposure to climate change of Loitoktok suggested by the risk index (Figure 8a) is confirmed by case study evidence. Overall, the region has become dryer and slightly warmer in recent years (Ngaruiya & Scheffran, 2013). One key evidence to support this diagnosis is the diminishing glaciers of Mount Kilimanjaro, which have shrunk by around 85% between 1912 and 2007 (Thompson et al., 2009).

In a similar manner, field research by one of the authors confirms the very low vulnerability diagnosed by the risk index for 2008 (Figure 8b). Health and education levels are relatively high, population density is below the Kenyan average (Government of Kenya, 2009), and the Loitoktok agricultural sector boosts a well-linked functional social network structure that enables high information exchange and promotes diversified activities that cushion the community against drought effects (Ngaruiya, 2014).

The general risk of violent conflict onset in Loitoktok in 2008 is considered to be medium by the risk index (Figure 8c). This stands in contrast to the results of recent field research which finds a low level of political instability and violent conflict in the area. This low conflict risk can be attributed to economic development and associated construction of a new tarmac highway that opened up the region to trade with subsequent increase in settlement zones and financial institutions, and the dense and cohesive social network structure that enhances conflict resolution mechanisms in Loitoktok (Ngaruiya, 2014). Apparently, these network structures are not adequately reflected by the risk index. In addition, the binary past violent conflict measure, which registers a single political clash between supporters of two rival parties during heightened election fever in 2007, seems not sufficient to capture the tradition of peaceful conflict resolution in the area. This highlights the importance of cultural and institutional conditions of conflict resolution.

Overall, the risk index seems to describe exposure and vulnerability of Loitoktok to climate change correctly. However, it overrates the composite risk because it overestimates the general violent conflict onset risk and attributes too much weight to the exposure component vis-à-vis the vulnerability component. The specification of the CRI giving more weight to the vulnerability indicators (Figure 5c) thus seems to draw a more accurate picture of Loitoktok in 2008.

#### *4.2.2 Southern Turkana-Pokot North*

The study area in Southern Turkana and Pokot North lies at the intersection of four grid cells. Especially the Turkana side of the region is characterized by an arid climate and high levels of political and economical marginalization. Turkana is the poorest county in Kenya (Government of Kenya, 2007). The main livelihood for the Turkana is pastoralism, while the Pokot practice some agriculture in addition to pastoralism. Violent livestock raids, especially between the Turkana and the Pokot but also between other pastoral groups, as well as the availability of small arms make the region highly insecure (e.g. Eaton, 2008; Eriksen & Lind, 2009). Previous studies (Eriksen & Lind, 2009; Mkutu, 2006) and field research conducted by one of the authors suggest a strong relation between climatic conditions, resource availability (especially water and pasture) and the occurrence of violence. Against this background, one would expect the area to appear as dark red in Figure 8d. However, Southern Turkana-Pokot North is only classified as a medium risk area by the CRI (baseline specification).

Figure 8a shows that Southern Turkana-Pokot North is classified as hardly exposed to adverse climate change. This is mostly driven by a positive trend in precipitation diagnosed by the satellite-based PRIO-Grid data. This stands in strong contrast to the local perception of the Pokot and especially Turkana communities, who reported an increase in drought frequency and duration as well as increased rainfall variability and unpredictability (Schilling, 2012; Schilling et al., 2014).

The level of vulnerability varies within the region (Figure 8b). The two western cells of the case study region show a very high level of vulnerability, while the two eastern cells are characterized by medium vulnerability. The west-east difference is among other factors due to the western cells belonging to Uganda. When the western cells are attributed to Kenya, their vulnerability is reduced to a medium level as well. Field research suggests that on the one hand, the local communities and their pastoral lifestyle are well adapted to the harsh climatic conditions. But the strong dependence on water, land and pasture makes pastoralism very sensitive to climate change on the other hand (Schilling, 2012). The practice of commercial cattle raiding aggravates this situation because stolen cattle is increasingly sold to non-local actors, resulting in a outflow of cattle resources from the region, particularly on the Pokot side (Eaton, 2010; Schilling et al., 2012). The risk index adequately captures this duality in a medium to high level of vulnerability.

The high level of violent conflict and instability that was prevalent in the region in 2008 and the previous years is only partially reflected by Figure 8c. This can be explained by the two national-level measures used to operationalize the general risk for violent conflict component, which both identify Uganda as more prone to violent conflict onset than Kenya. Even more important, the binary past conflict variable derived from ACLED is unlikely to adequately represent the high levels of violence prevalent in the region. This would not change much if one uses the number of conflicts rather than a binary conflict measure since ACLED only registers nine conflict events for the area in 2007 (while SCAD registers no conflict event), which is still far below the number of violence incidents field research would suggest (CEWARN, 2010; Ember et al., 2012; Schilling et al., 2012).

In summary, the risk index underestimates the conflict risk and especially exposure to climate change of Southern Turkana-Pokot North. According to field research, the region suffers from high exposure, medium vulnerability and high violent conflict risk simultaneously. One would therefore consider the region as a very-likely case for the occurrence of climate-change related violent conflict in 2008. This is not adequately reflected by the medium risk score of the CRI.

*4.2.3 Karamoja*

The Karamoja sub-region is located in the North-eastern part of Uganda and covers twelve grid cells. The region is arid to semi-arid and marked by low levels of annual rainfall. Large parts of the population rely on pastoralism to sustain their livelihoods. The region is described by the CRI (baseline specification) as a high risk area (Figure 8d). The existing literature and databases on the region support this impression. CEWARN (2010), for instance, registers 210 incidents of pastoralist conflict with 203 fatalities in 2008 for the Ugandan Karamoja cluster. Local histories of violence and political instrumentalization are crucial to understand such incidents (Eaton, 2008), but these occur quite often around temperature- and precipitation-sensitive natural resources like water or pasture. Cattle raids are frequently used to restock herds after droughts (Bevan, 2008; FEWS NET, 2005; Inselman, 2004).

Nevertheless, support of qualitative data for the CRI does not necessarily imply support for each of its three components. The risk index describes Karamoja as having experienced a low to medium exposure to climate change in 2008 (Figure 8a). This finding is driven by temperature as well as precipitation increases. Field researchers and local actors alike, however, report not only higher temperatures, but also less rainfall and more droughts in recent years (Stites et al., 2010;

UNOCHA, 2008). Thus, like in Southern Turkana-Pokot North, there is a considerable difference between satellite data on and local actors' perceptions of precipitation changes.

The risk index further portrays Karamoja as very vulnerable to climate change (Figure 8b). This is confirmed by the literature, which considers the region to be "more vulnerable to the effects of climatic shocks, principally drought, than any other region of Uganda" (UNOCHA, 2009: 2). Karamoja suffers from a high environmental dependence (Stites et al., 2010) as well as distressing levels of education, access to daily necessities and health (Bevan, 2008; Powell, 2010).

Finally, Karamoja is characterized by widespread, low-level violence (Jabs, 2007). According to CEWARN (2010), for instance, there have been at least 512 incidents of pastoralist conflict causing 866 fatalities in the years 2007 and 2008. This stands in contrast to the medium to high general risk of violent conflict onset diagnosed by the risk index for 2008 (Figure 8c). As with Southern Turkana-Pokot North, it seems that the indicators used for the general conflict risk component do not adequately capture the state weakness and culture of violence prevalent in the region. ACLED, for instance, registers the occurrence of a violent conflict in 2007 in only half of the cells covering Karamoja, which is unlikely given the large amount of violent conflict events described in the literature as well as by CEWARN (2010) for this year. Even worse, SCAD registers violent conflict events in none of these twelve cells in 2007.

In sum, the findings of the risk analysis and the qualitative literature largely agree regarding the vulnerability and composite risk for Karamoja. The exposure and general violent conflict onset risk, by contrast, are described as too low by the risk index. Therefore, the region should appear in an even darker red in Figure 8d. The specification of the CRI giving more weight to the vulnerability components (Figure 5c) seems to describe Karamoja better.

#### *4.2.4 Discussion*

The comparison with three case studies provides mixed support for the risk index. The baseline CRI's assessment of Karamoja in 2008 is largely supported by the case study. By contrast, the CRI overrates the risk for Loitoktok and clearly underestimates the risk for Southern Turkana-Pokot North.

Regarding the three components, there is agreement between the vulnerability assessments of the risk index and those of the case studies for all three cases. The risk index also correctly describes Loitoktok as highly exposed to climate change in 2008. For Southern Turkana-Pokot North and Karamoja, there is a mismatch between satellite data measuring precipitation increases and local inhabitants' perceptions of declining rainfalls. This finding is in line with the results of other studies (Murtinho et al., 2013; Ovuka & Lindqvist, 2000). Possible explanations include limitations in the climate data (e.g. grid density) or a too strong focus on annual averages (Ovuka

& Lindqvist, 2000). It is also possible that temperature increases in recent years have put the dry land vegetation under severe stress so that even higher precipitation levels are insufficient to prevent drought-like conditions on the ground (Ziervogel et al., 2008: 19). Such gaps between satellite measurements and local perceptions provide severe challenges for quantitative studies investigating the links between precipitation and conflict patterns. This is the case for efforts to generate risk indices and maps, but also for regression analyses (e.g. Fjelde & von Uexkull, 2012; Hendrix & Salehyan, 2012; Theisen et al., 2012).

Although the general risk of violent conflict component is based on a regression analysis of the drivers of violent conflict in the time period 1998-2007, it overestimates the conflict risk of Loitoktok and underestimates the conflict risk of Southern Turkana-Pokot North and Karamoja in 2008. One explanation for this is the inability of the past conflict indicator to adequately capture institutionalized structures of cooperation (as in Loitoktok) or violent competition (as in Karamoja and Southern Turkana-Pokot North). This might even be the case for the available geo-referenced datasets of small scale conflicts in general since they have problems to adequately capture instances of violence in peripheral areas (Ide & Scheffran, 2014).

## 5 CONCLUSION

This study argues that if a link between climate change and violent conflict exists, it is most likely to occur in areas experiencing simultaneously a high exposure to climate change, a high vulnerability to climate change, and a high general risk of violent conflict onset. We assessed the spatial distribution of these factors at a resolution of 0.5° in Kenya and Uganda in 2008 and integrated them into various specifications of a composite risk index (CRI). A quantitative evaluation supported the findings of this analysis, while the comparison of the CRI with three case studies yielded mixed results and identified important issues for future large-N studies on climate change and violent conflict.

In the introduction, we discussed three ways in which our multi-method analysis contributes to the existing literature. First, it can be a helpful tool for policy makers, development workers and security analysts who try to cope with the societal impacts of climate change (and violent conflict), although it is inherently difficult to predict future violent conflict events (Schneider et al., 2010). Second, our analysis supports researchers in identifying relevant areas for in-depth case studies. The example of violence in Western Kenya (and especially in Mount Elgon) in 2008 has already been mentioned in section 4.1. Several most-likely and most-unlikely cases as well as mismatches (high composite risk scores but no actual conflict onset or vice versa) can be identified from Figures 4, 5 and especially Figure 7, too. Finally, our analysis enables the "ground check" of large spatial datasets (and related theories). Examples of this include the limits of satellite-based precipitation and geo-referenced past conflict data (see section 4.2). Equally important is the lack of comprehensive data on local networks and institutions, which were found to be highly important in shaping resilience to climate stress and violent conflict. In Loitoktok, for instance, cohesive social network structures and the availability of widely accepted conflict resolution mechanisms are key to understand the low vulnerability and low general violent conflict risk of the local communities (Ngaruiya, 2014). This is in line with the recent findings of other researchers, which consider the availability and legitimacy of conflict resolution mechanisms as crucial for conflict prevention and inclusive natural resource management (Benjaminsen & Ba, 2009; Bogale & Korf, 2007). Local political and economic developments that are connected to the national level, such as the commercialization of cattle raiding in Southern Turkana-Pokot North or the political instrumentalization of pre-existing tensions in Karamoja, are equally important but not yet sufficiently captured in by existing datasets, too. Advances regarding these data issues would strengthen regression analyes on the climate-conflict link as well as other efforts to map climate risk (Busby et al., 2013) or environmental conflict (Bocchi et al., 2006) hotspots.

Finally, the empirical adjustment of a risk index is a never ending process. As soon as finer-grained theories, new empirical evidence or improved datasets enter the stage, they can be used to improve and specify the CRI. It is also possible and desirable to conduct such a risk analysis with projection data for future scenarios as well as for other parts of Africa and the world.

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[i] Both measurements can be justified on the basis of the recent IPCC (2013) report, which predicts higher average temperatures as well as more heat anomalies for East Africa

[ii] There are various differences between our analysis and the approach of Busby et al. The four major ones in our view are: a) Busby et al. identify areas vulnerable to climate-related hazards, while we focus on the spatial distribution of risk factors for climate change and violent conflict. b) Busby et al. do therefore not incorporate a general violent conflict risk component, while we do. c) Busby et al. prioritize data that are available for large parts of Africa, while we prioritize data that that are available at a high spatial resolution for Kenya and Uganda. d) Busby et al. use the historic occurrence of climate-related disasters as the exposure indicator, while we use short- to medium-term temperature and precipitation changes.

[iii] The residuals have been tested for autocorrelation. The result of the Durbin-Watson-Test was 2.079, which implies that no autocorrelation is present.

[iv] When there is little variation within the data, we utilize natural breaks. In case of national-level data, we divide all countries on which data are available into 18 quantiles (in order to account for very strong international differences) to define national scores for Kenya and Uganda. Cells which experienced violent conflict in 2007 are scored 7, while those who were not are scored 3. See Appendix II for more details.