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# Darfur: rainfall and conflict

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**Abstract**
Data on rainfall patterns only weakly corroborate the claim that climate change explains the Darfur conflict that began in 2003 and has claimed more than 200 000 lives and displaced more than two million persons. Rainfall in Darfur did not decline significantly in the years prior to the eruption of major conflict in 2003; rainfall exhibited a flat trend in the thirty years preceding the conflict (1972–2002). The rainfall evidence suggests instead a break around 1971. Rainfall is basically stationary over the pre- and post-1971 sub-periods. The break is larger for the more northerly rainfall stations, and is less noticeable for En Nahud. Rainfall in Darfur did indeed decline, but the decline happened over 30 years before the conflict erupted. Preliminary analysis suggests little merit to the proposition that a structural break several decades earlier is a reasonable predictor of the outbreak of large-scale civil conflict in Africa.

**Keywords:** climate, rainfall, Sahel, Sudan, Darfur, conflict

*'Darfur, at its core, is a conflict of insufficient rainfall'.*
-Jeffrey Sachs

## 1. Introduction

The crisis in Darfur is one of the world's most significant conflicts. Since fighting began in earnest in 2003, the conflict has forced over two million people to flee their villages for the comparative safety of refugee camps and has led to at least 200 000 excess deaths (United States Government Accountability Office 2006). Influential voices such as those of United Nations Secretary-General Ban Ki-moon, former Vice President of the United States Al Gore, the United Nations Environment Program, Columbia University professors Jeffrey Sachs and Mahmood Mamdani, and popular commentators including Stephan Faris writing in *The Atlantic Monthly*, have recently asserted or implied that the Darfur civil war is a climate crisis (Gore 2006, Sachs 2006, Faris 2007, Mamdani 2007a, 2007b, Moon 2007, United Nations Environment Program 2007). The contention is that declining rainfall and land degradation intensified violent struggles over water, pasture and farmland culminating in a full-blown civil war in 2003. The government of Sudan also has promoted this narrative, attributing the conflict in Darfur to environmental change. While non-environmental causes of the conflict are noted, the thrust of this emerging narrative of the Darfur crisis seems to be that if there had been more rain there would not have been war and consequent human catastrophe.

Many of these commentaries link Darfur to broader concerns about global climate change. The Stern report (2007) on the economics of climate change, for example, argued that the Darfur conflict resulted from the long periods of drought during the 1970s and 1980s in Northern Darfur and consequent breakdown in coping strategies. Giannini *et al* (2003) demonstrated that rainfall decline in the Sahel was partly attributable to changing ocean temperatures and that changing ocean temperatures were partly the result of global warming. It is easy to jump to the conclusion that Darfur augurs a violent future for Sahelian Africa as global climate change intensifies.

Careful attention should be paid to examining the rainfall explanation of the emergence of violence in Darfur. Commentators suggesting a climate change explanation for the Darfur conflict rarely present data to validate their claims, instead relying on a general understanding that Darfur is part of the Sahel, an area where rainfall has been low, variable, and in decline.

This paper makes two points through analysis of several sources of data on rainfall in the Darfur region and African countries more generally. The first point is that Darfur rainfall patterns only weakly corroborate the claim that climate change explains the conflict. There is no evidence that a short-term drought preceded the eruption of major conflict in 2003. Rainfall in Darfur did not decline significantly in the years immediately prior to the crisis. Furthermore, short-term but significant droughts in 1984 and 1990 did not provoke wide-spread conflict. As for the assertion that long-term rainfall decline has led to the crisis, there is no evidence of a downwards trend. Instead, rainfall in Darfur exhibited a flat trend, though with high variability, in the thirty years preceding the conflict (1972–2002). There is, however, evidence of a structural break to a lower level of rainfall in northern Darfur in the early 1970s. So the claim that rainfall change caused the conflict is a claim that a structural break thirty years prior to the conflict was the cause of the conflict.

The second point is that structural breaks to lower mean rainfall levels appear to be uncorrelated with subsequent conflict in other countries in Africa. Other Sahelian African countries have experienced similar breaks in their overall average rainfall, yet levels of violence have been nowhere near those of Darfur. Many African countries that have not experienced structural declines in rainfall nevertheless saw increased conflict over the past several decades. In a multivariate estimation, measures of structural breaks in rainfall are not significant in explaining the incidence of conflict.

## 2. Data sources

Darfur, the westernmost province in Sudan, like most of arid and semi-arid Africa, is marked by a good deal of climatic variability. The region spans several environmental zones, ranging from Saharan Desert in the far north of the province to African Sahel and Savanna regions further south. Rainfall is characterized by marked seasonality with a long dry season and shorter wet season from June to October. Rainfall increases from north to south, with Saharan regions receiving low and intermittent rainfall, Sahelian regions ranging between 100 and 500 mm per year, and Savanna regions ranging from 500 to 1000 mm per year. The wet season exhibits much variability within years, between years, and across short distances.

Large long-term fluctuations in climate are an inherent feature of climate in Sahelian regions. Interdecadal and interannual variability are the norm (Hulme 2001). Nicholson (2001) finds that during the 1820s and 1830s dry conditions prevailed with many lakes drying up. Rainfall then returned to higher levels, but the first decades of the 20th century again experienced low rainfall. Sahelian rainfall increased to high levels during the 1930s–1960s. The late 1960s–1990s saw lower rainfall (Foley *et al* 2003). The evidence of the 1990s and 2000s is of mean rainfall levels above the 1961–1990 average. Indices of vegetative cover also suggest improvements in the last decade of the 20th century (Prince *et al* 2007).

This paper makes use of three data sources with measures of rainfall from Darfur and other relevant regions. The Climate Research Unit (CRU) of the University of East Anglia provided us with rainfall station records for Sudan for the period 1881–2006. Since the early 1990s, rainfall station data for Darfur appears to have been collected and reported only in the three main towns of El Geneina, El Fasher, and Nyala. The Darfur rainfall station data begins in 1917 for El Fasher, in 1928 for El Geneina, and in 1920 for Nyala[3]. We also include the station of En Nahud, in western Kordofan, the province neighboring Darfur. Data from the rainfall stations is also available in the Global Historical Climatology Network (GHCN-Monthly) data base of the National Climatic Data Center of the US Department of Commerce[4]. Complete GHCN data only go up to 1992 for Sudan, and contain mostly missing variables after that.

The second source is the rainfall dataset known as GPCP Version 2 Combined Precipitation Data Set of the Global Precipitation Climatology Project (hereafter GPCP), a blending of estimates from satellite and rain gage measures (Adler *et al* 2003). These precipitation estimates are available for nodes of a 2.5° × 2.5° latitude–longitude global grid array. The data start in 1979. The data for the Sahelian nodes were obtained through an interactive website that enables users to obtain time series from the GPCP[5].

A third source is the historical monthly precipitation dataset for global land areas from 1900 to 1998, gridded at 2.5° latitude by 3.75° longitude resolution, created by Hulme *et al* (1998) for the Climate Research Unit of the University of East Anglia[6]. This data uses various techniques to average rainfall station data into grids. We use the four observations for Darfur that are located at 12.5° latitude and 15° latitude and 22.5° longitude and 26.25° longitude. The 12.5° latitude measures lie roughly on the same latitude as En Nahud, but to the west, in Darfur.

Figure 1 is a Google Earth image that shows the locations of the rainfall stations, the GPCP nodes, and the Hulme nodes. The three sources are highly correlated, but the GPCP and Hulme series generally lie above the rainfall station series (i.e., they have greater values for rainfall totals), presumably because they are averaging rainfall data from both northern and more southerly stations to impute rainfall to the nodes.

## 3. Short-term drought as a precipitating factor in the Darfur conflict

Sachs (2005), writing in *Scientific American*, observed in the context of a discussion of Darfur that '... studies have shown that a temporary decline in rainfall has generally been associated throughout sub-Saharan Africa with a marked rise in the likelihood of violent conflict in the following months.' He was presumably referring to the work of Miguel *et al* (2004),

[3] The CRU data appear to match a previously published chart of rainfall patterns in El Fasher, El Geneina and Nyala in Teklu and Von Braun (1991). Drought and Famine Relationships in Sudan: Policy Implications, International Food Policy Research Institute and the rainfall pattern for El Fasher presented in the report on Darfur by Tearfund (2007). Darfur: relief in a vulnerable environment.

[4] http://www.ncdc.noaa.gov/oa/climate/ghcn-monthly/

[5] http://disc2.nascom.nasa.gov/Giovanni/tovas/rain.GPCP.2.shtml

[6] 'gu23wld0098.dat' (Version 1.0) constructed and supplied by Dr Mike Hulme at the Climatic Research Unit, University of East Anglia, Norwich, UK. The work was supported by the UK Department of the Environment, Transport and the Regions (Contract EPG 1/1/85). Downloaded from http://www.cru.uea.ac.uk/∼mikeh/datasets/global/

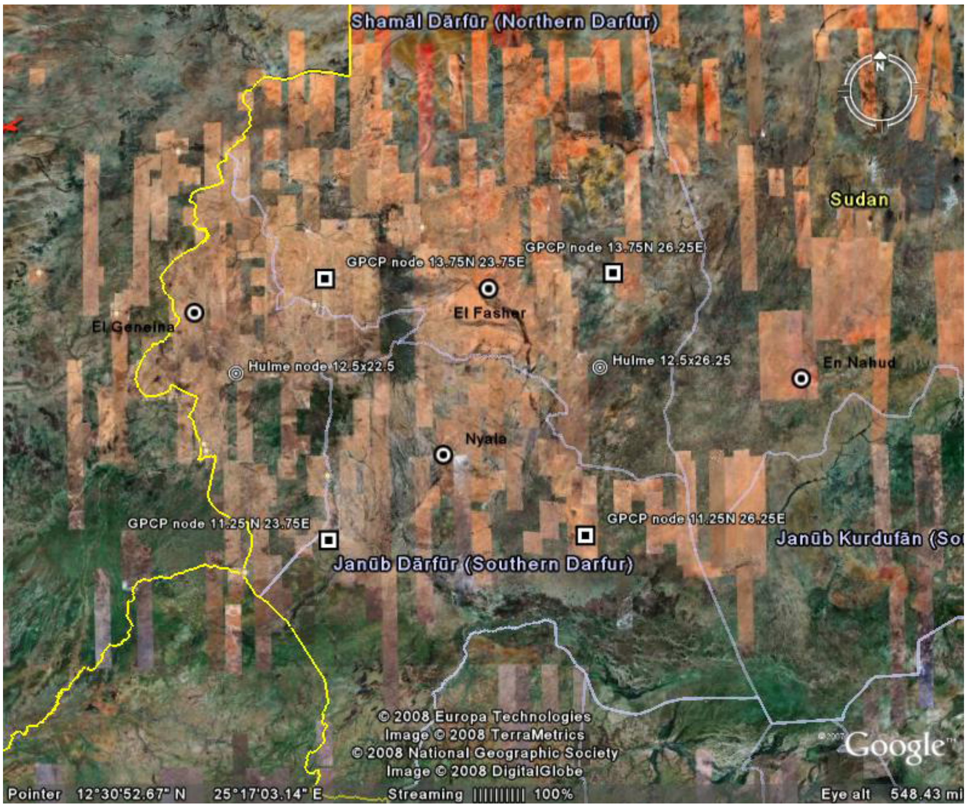


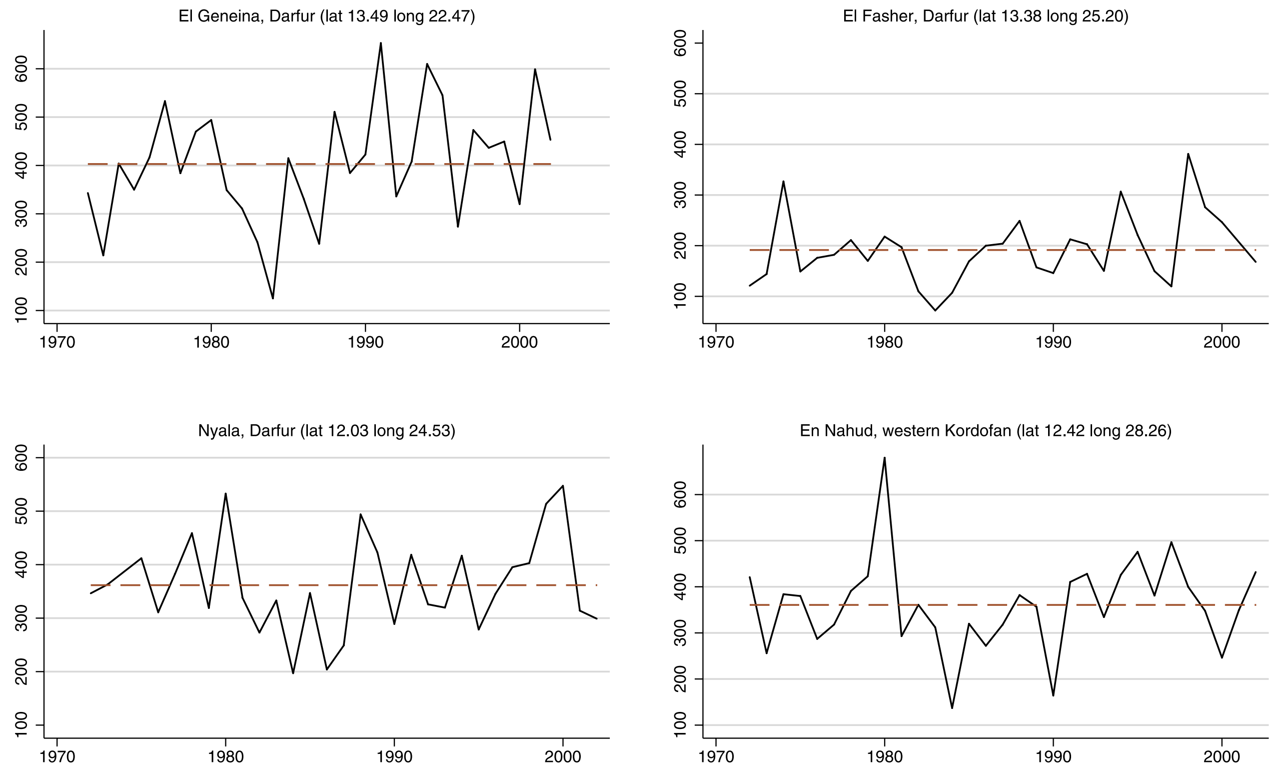

**Figure 1.** Approximate location of rainfall stations, Hulme nodes, and GPCP nodes, Darfur, Sudan.

who presented evidence from sub-Saharan African countries showing that short-term declines in rainfall affected GDP and that declines in GDP were associated with increased likelihood of conflict. That is, the Miguel *et al* study used a measure of rainfall change as an instrumental variable in estimating how changes in GDP per capita might spark subsequent conflict. The study was clear that only as rainfall changes were mediated via incomes would there be a reasonable empirical basis for linking rainfall to conflict (p 745): 'While it is intuitively plausible that the rainfall instruments are exogenous, they must also satisfy the exclusion restriction: weather shocks should affect civil conflict only through economic growth.'

The focus in the Miguel *et al* paper on how rainfall affected income and how income affected conflict was an indirect way to examine the more relevant relationships between rainfall and consumption or rainfall and assets. A population that experienced large swings in rainfall, from low to high to low to high, might reasonably be expected to have adapted to the fluctuations with savings mechanisms for storing surplus from the good years so that consumption would not decline in the bad years. Short-term decline in rainfall would then be viewed by residents as a lamentable but normal part of the ecosystem, and would not provoke large-scale violent conflict. People would be richer were rainfall higher, but they might not necessarily feel themselves to be impoverished were rainfall to be low.

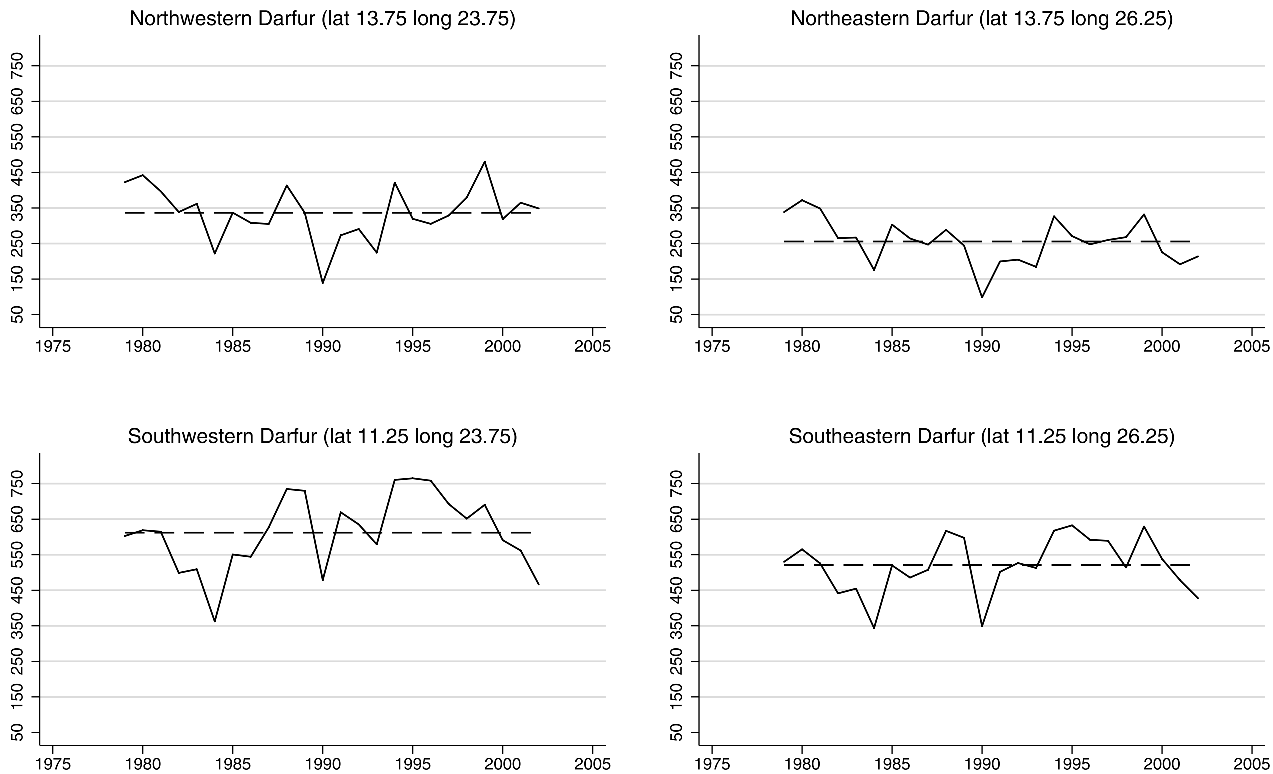
Unfortunately, good time series data on consumption and assets are not available for the regions of most interest, namely poor and conflict-prone countries in Africa. For Darfur, there has been limited research on how robust livelihood outcomes are to changes in rainfall. De Waal (1989), for example, argued that Darfur populations were quite resilient to extreme drought. Gray and Kevane (1993), took issue with this characterization for neighboring central Kordofan, finding villagers rapidly losing assets following the drought of 1990. Parallel research in Sahelian West Africa has been assessing the adaptive capacity to drought conditions (Mortimore 1989, Mortimore and Adams 2001, Raynaut 2001), concluding that Sahelian populations are far more adapted in terms of maintaining incomes and livelihoods than many commentators had imagined. Reardon *et al* (1988) noted some time ago the paradox that populations in more northerly Sahelian ecosystems in Burkina Faso, where average rainfall was low and variability high, experienced more stable incomes in the event of droughts than more southerly Sahelian populations.

In any case, rainfall data shows no evidence of short-term decline below normal rainfall in Darfur preceding the conflict. The years leading up to the crisis are not out of the norm of variability for the thirty year period prior to the crisis. Figure 2 shows data for the period 1972–2002 for the four rainfall stations relevant to the situation in Darfur (El Geneina, El Fasher, Nyala and En Nahud). The final data point before the outbreak of heavy conflict, 2002, shows rainfall close to the 30 year mean levels for all four stations. Figure 3 shows data for the four locations in Darfur that are nodes for the rainfall estimates of the Global Precipitation Climatology Project (GPCP). These charts also show no significant decline leading up to the conflict of 2003. Both



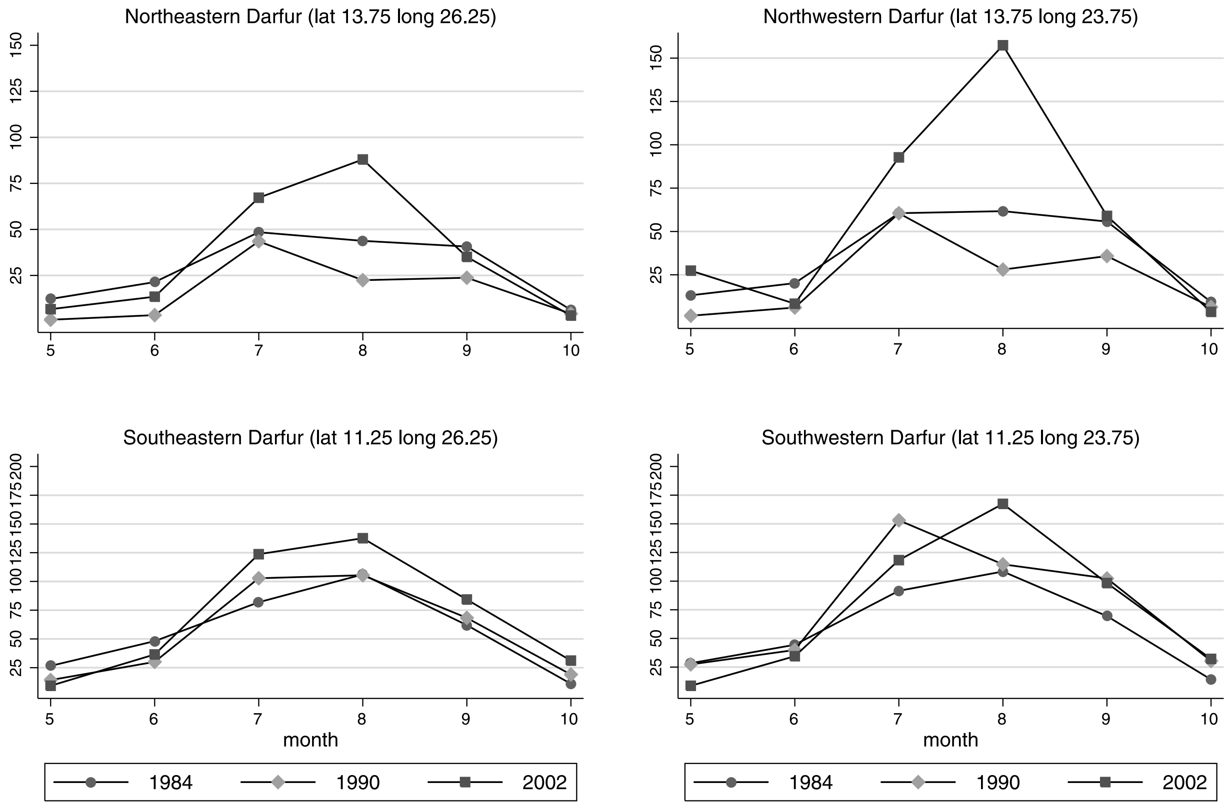

Source: Sudan rain station data provided by David Lister, Climatic Research Unit, University of East Anglia

**Figure 2.** Rainfall at four rain stations in Darfur area (annual mm), 1972–2002 (dashed lines are mean rainfall for period).




Source: GPCP Version 2 Combined Precipitation Data Set

**Figure 3.** Rainfall at four latitude–longitude nodes in Darfur (annual mm), 1979–2002 (dashed lines are mean rainfall for period).




Source: GPCP Version 2 Combined Precipitation Data Set

**Figure 4.** Distribution of monthly rainfall in Darfur in 1984, 1990 and 2002.

the rainfall station data and GPCP data map the substantial declines in 1984 and 1990. These declines did not provoke large-scale conflict, even though they generated considerable population displacement. Figure 4 presents the distribution of monthly rainfall for the four GPCP nodes, comparing 2002, the rainy season that preceded the large-scale conflict that erupted in the dry season of early 2003, to the drought years of 1984 and 1990. Rainfall was comparatively high in 2002 and evenly distributed, suggesting that if there was a proximate drought event that could have triggered a large-scale outbreak of violence, it would have been in 1984 or 1990.

The evident lack of a linear trend in the 30 year period 1972–2002 for the rainfall station data and the 23 year period 1979–2002 for the GPCP data is not an artifact of the starting date. Indeed, because of the serious drought of 1984, if the starting year for estimating a trend is in the early 1980s then trend rainfall has been upwards over the 20 year period 1982–2002. For all ten starting dates over the period 1965–1974 and for all four rainfall stations, the estimated coefficient on the variable for year is not statistically significant at the 5% level in a regression explaining rainfall totals over 30 year periods, with only two exceptions for 1965 and 1966 in Nyala. A similar result obtains for the GPCP data when estimating a linear trend for each span of years ending in 2002 and starting with 1979 and continuing through 1988. The coefficients on the variable measuring the year are not significant, with only one exception. (These results are available upon request.)

The rainfall data thus suggest there was no short-term decline below normal rainfall that precipitated the conflict of 2003. Neither was there any statistically significant trend decline in rainfall for the thirty year period prior to the outbreak of the conflict. As the section 4 will make clear, to make the claim that change in rainfall caused the conflict one would have to go back more than thirty years prior to the outbreak of the conflict to find a meaningful change in rainfall.

## 4. Long-term rainfall: trend decline or structural break?

At one time it was thought that rainfall in Darfur was declining rapidly (Eldredge *et al* 1988). As seen above, there was no trend in rainfall in Darfur for the thirty year period 1972–2002. For longer periods of time, say 50 year periods, there is however considerable evidence of a decline[7]. Table 1 reports the coefficients on the variable measuring the year in regressions explaining annual rainfall totals for various 50 year periods, starting in 1942. Since the starting date used in estimating a trend might generate a spurious trend (if the start date was an outlier year of high rainfall), we estimate the trend coefficient for every start date. Each time period is 50 years or,

[7] Although data for rainfall stations do go back to the 1920s, the purpose here is to examine how changes in rainfall might have caused the outbreak of major conflict in Darfur in 2003. We believe there is little value in examining how rainfall patterns were different in the 1920s and 1930s (or the 1940–1970 period, for that matter) in explaining the outbreak of conflict in 2003.

**Table 1.** Estimates of trend in rainfall station data, for fifty year periods, with various start years. (Note: for years after 1952, trend is calculated for time period ending in 2002. Source: Sudan rain station data provided by David Lister, Climatic Research Unit, University of East Anglia.)

| Period | Nyala | El Geneina | En Nahud | El Fasher |
|---|---|---|---|---|
| 1942–1992 | −3.54[a] | −5.50[a] | −2.84[a] | −3.87[a] |
| 1943–1993 | −3.78[a] | −5.86[a] | −2.78[a] | −3.90[a] |
| 1944–1994 | −3.88[a] | −6.01[a] | −2.81[a] | −4.11[a] |
| 1945–1995 | −3.68[a] | −5.70[a] | −2.38[a] | −3.57[a] |
| 1946–1996 | −3.53[a] | −4.73[a] | −1.77 | −3.43[a] |
| 1947–1997 | −3.63[a] | −4.75[a] | −1.65 | −3.90[a] |
| 1948–1998 | −3.95[a] | −4.74[a] | −1.52 | −4.19[a] |
| 1949–1999 | −4.19[a] | −5.06[a] | −1.52 | −4.00[a] |
| 1950–2000 | −3.61[a] | −4.89[a] | −1.37 | −3.05[a] |
| 1951–2001 | −3.16[a] | −5.24[a] | −1.54 | −3.04[a] |
| 1952–2002 | −3.51[a] | −4.53[a] | −1.53 | −3.08[a] |
| 1953–2002 | −3.51[a] | −4.47[a] | −0.64 | −2.75[a] |
| 1954–2002 | −3.42[a] | −3.89[a] | −0.73 | −1.80[a] |
| 1955–2002 | −3.19[a] | −3.46[a] | −0.87 | −1.85[a] |
| 1956–2002 | −2.91[a] | −3.12[a] | −0.60 | −1.71[a] |
| 1957–2002 | −2.85[a] | −3.14[a] | −0.28 | −1.79[a] |
| 1958–2002 | −2.76[a] | −3.22[a] | −0.11 | −1.89[a] |
| 1959–2002 | −2.71[a] | −3.47[a] | 0.01 | −1.65 |
| 1960–2002 | −2.78[a] | −3.36 | 0.45 | −1.51 |
| 1961–2002 | −2.74[a] | −2.58 | 0.31 | −1.48 |
| 1962–2002 | −2.73[a] | −2.21 | 0.63 | −1.14 |
| 1963–2002 | −1.98 | −1.25 | 0.44 | −0.94 |
| 1964–2002 | −1.09 | −0.03 | 1.07 | −0.63 |

[a] Indicates trend coefficient is statistically significant with $p$-value of 0.05 or lower.

for those where 50 years would go beyond 2002 (the end date of interest), the number of years included in the time period is 2002 minus the starting year.

All of the rainfall stations except En Nahud exhibit strong negative trend declines when starting the time period in the 1940s or 1950s, years of high rainfall. Note that the coefficients on the variable measuring year get smaller as the datasets for which the trend is estimated start later. By the early 1960s, none of the rainfall stations have statistically significant trends, and this continues through the late 1960s as noted above. The downwards trend over the long durée is also apparent using the Hulme 2.5° × 3.75° dataset. The node located at 12.5° latitude and 26.25° longitude is approximately 150 km to the southeast of El Fasher; the other node is closer to El Geneina at 12.5° latitude and 22.5° longitude. The slopes of the rainfall trends for these nodes are declines of 3.7 mm and 2.6 mm per year, respectively, for the 1940–2002 period.

The notion of gradual trend decline in Darfur, however, is misleading. Figure 5 shows the rainfall levels measured at the various rain stations for the period 1940–2002, with the mean levels of rainfall for the two time periods, 1940–1972 and 1972–2002. What seems to have happened to rainfall in El Fasher and other Darfur locations is a break around the late 1960s and early 1970s in the basically stationary time series of rainfall. For the period 1940–1972, rainfall in the four rainfall stations fluctuated around a stable mean, and for the period 1972–2002 rainfall again fluctuated around a stable but lower mean. The variance of rainfall was the same for both time periods for three of rainfall stations, but not for El Fasher, where the variance was somewhat smaller for the more recent period. If the two time periods, 1940–1972 and 1972–2002, are considered separately, simple regression analysis indicates no statistically significant trend for either time period for any of the four rainfall stations. Very similar patterns emerge when only looking at July–August–September rainfall totals, when looking at the length in months of the rainy season (i.e. how many continuous months of decent rainfall) and the beginning month of the season (what was the first month in a two-month period of decent rainfall). These measures are robust to the cutoffs in what constitutes decent rainfall.

We estimated trend and break regressions for the two Hulme nodes that are in central Darfur and for the four rainfall stations (the GPCP series only begins in 1979 and so cannot be used for this analysis). One regression estimates a linear trend for the period 1940–2002, the other estimates rainfall using a simple dummy variable taking on the value 1 for years after 1971 and 0 otherwise. For the four rainfall stations, the $R$-square is higher for the simple break in intercept model, by a large amount (the $R$-square coefficients for the trend regressions are around 0.12, for the break models they are around 0.24). For the Hulme data the break model also provides a better fit, though the difference in $R$-square is more modest (from 0.26 to 0.33).

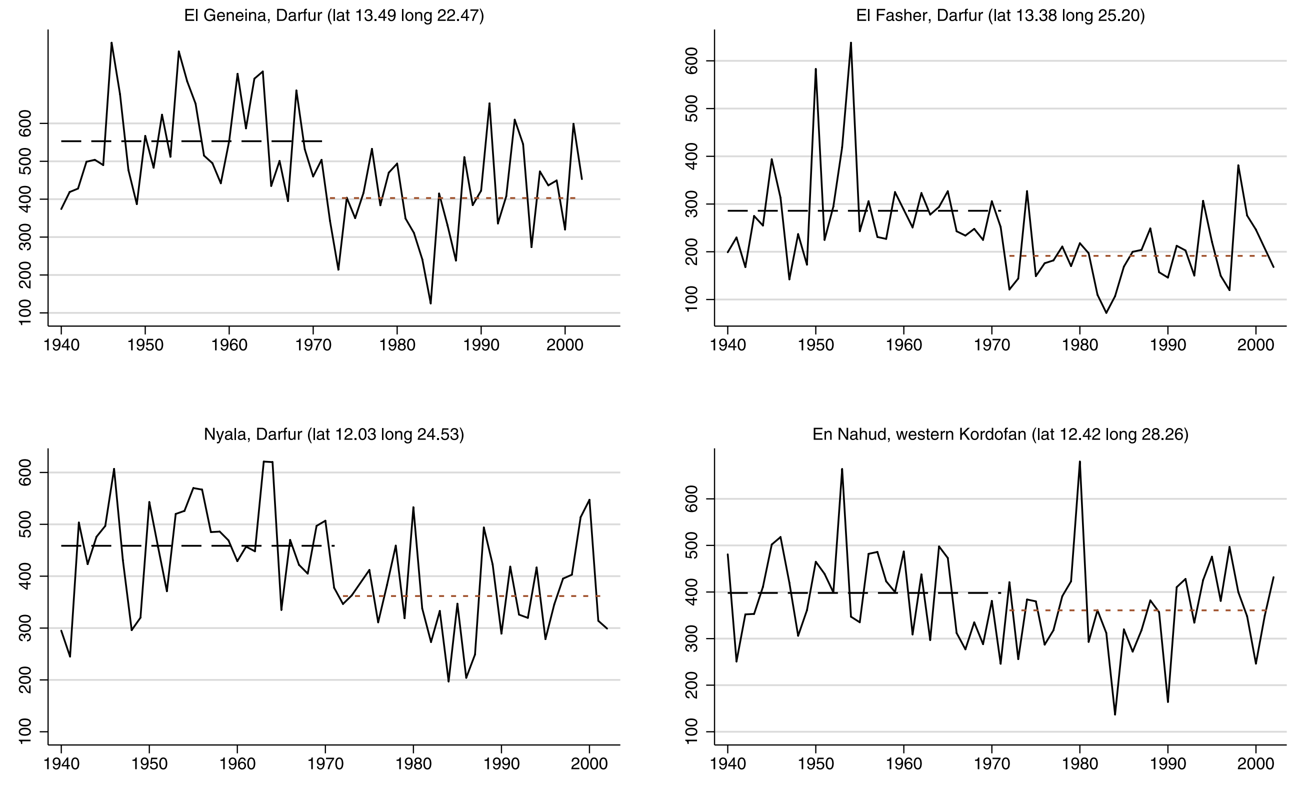
In order to determine the timing of the structural break for the relevant Darfur nodes, we run the non-parametric test of Pettitt (1979). The test statistic is given by the maximum value of $|U_t|$ for all time periods in the data, and where,

$$U_t = 2\sum_{1}^{t}(\mathrm{Rank}_i) - t(T+1).$$

That is, the rainfall totals are ranked, and then for a possible break year $t$ (counting from the first period) the sum of ranks of rainfall totals in periods (years) before the break year is calculated, and from this is subtracted the break period times $T+1$ where $T$ is the total number of periods. A break in the series is statistically significant if the statistic is larger than the appropriate cutoff from the distribution under the null hypothesis of no break or change. The possible break year, or change point, is the year with the largest absolute value of $U_t$.

Table 2 presents the results for the rainfall station data. Breaks in rainfall to lower mean rainfall occurred in 1971 for El Fasher, and around that year for the other rainfall stations and Hulme nodes. Given that the break points are very close to 1971, we calculate the mean rainfall for all stations for the 1940–1971 and 1972–2002 periods. The drops in mean rainfall are quite large: about 100 mm for the Darfur rainfall stations, and 40 mm for En Nahud. The findings are similar to other studies. Mahe *et al* (2001), for example, find a change point around 1970 for Sahelian rainfall in West Africa.

To summarize the analysis of longer-term data, the characterization of rainfall in Darfur as ‘declining’, with the implication of rainfall getting lower and lower, fluctuating around a declining mean, is misleading. The rainfall evidence suggests instead a break around 1971. Rainfall is basically stationary over the pre- and post-1971 sub-periods. The break is larger for the more northerly rainfall stations, and is less noticeable for En Nahud. Rainfall in Darfur did indeed decline,




Source: Sudan rain station data provided by David Lister, Climatic Research Unit, University of East Anglia

**Figure 5.** Rainfall at four rain stations in Darfur area (annual mm), 1940–2002 (dashed lines are means for 1940–1971 and 1972–2002).

**Table 2.** Pettitt test for change point in series of Darfur rainfall annual totals. (Sources: Sudan rain station data provided by David Lister, Climatic Research Unit, University of East Anglia, Hulme data is gu23wld0098.dat (Version 1.0), provided by Mike Hulme, Climatic Research Unit, University of East Anglia; tests use observations 1940–2002.)

| Rainfall station | Value Uk | Critical K | Year of break | Mean rainfall before 1971 | Mean rainfall after 1971 | SD before break | SD after break |
|---|---|---|---|---|---|---|---|
| El Geneina | 621 | 373 | 1971 | 553 | 403 | 124 | 120 |
| El Fasher | 675 | 365 | 1971 | 286 | 191 | 104 | 68 |
| Nyala | 562 | 356 | 1970 | 459 | 362 | 95 | 89 |
| En Nahud | 465 | 373 | 1965 | 398 | 361 | 94 | 100 |
| Hulme 2.5 $\times$ 3.75 | | | | | | | |
| Lat 15, long 22.5 | 579 | 315 | 1964 | 475 | 352 | 141 | 95 |
| Lat 15, long 26.25 | 415 | 315 | 1968 | 314 | 238 | 91 | 74 |
| Lat 12.5, long 22.5 | 615 | 315 | 1970 | 631 | 488 | 108 | 96 |
| Lat 12.5, long 26.25 | 577 | 315 | 1970 | 422 | 325 | 71 | 71 |

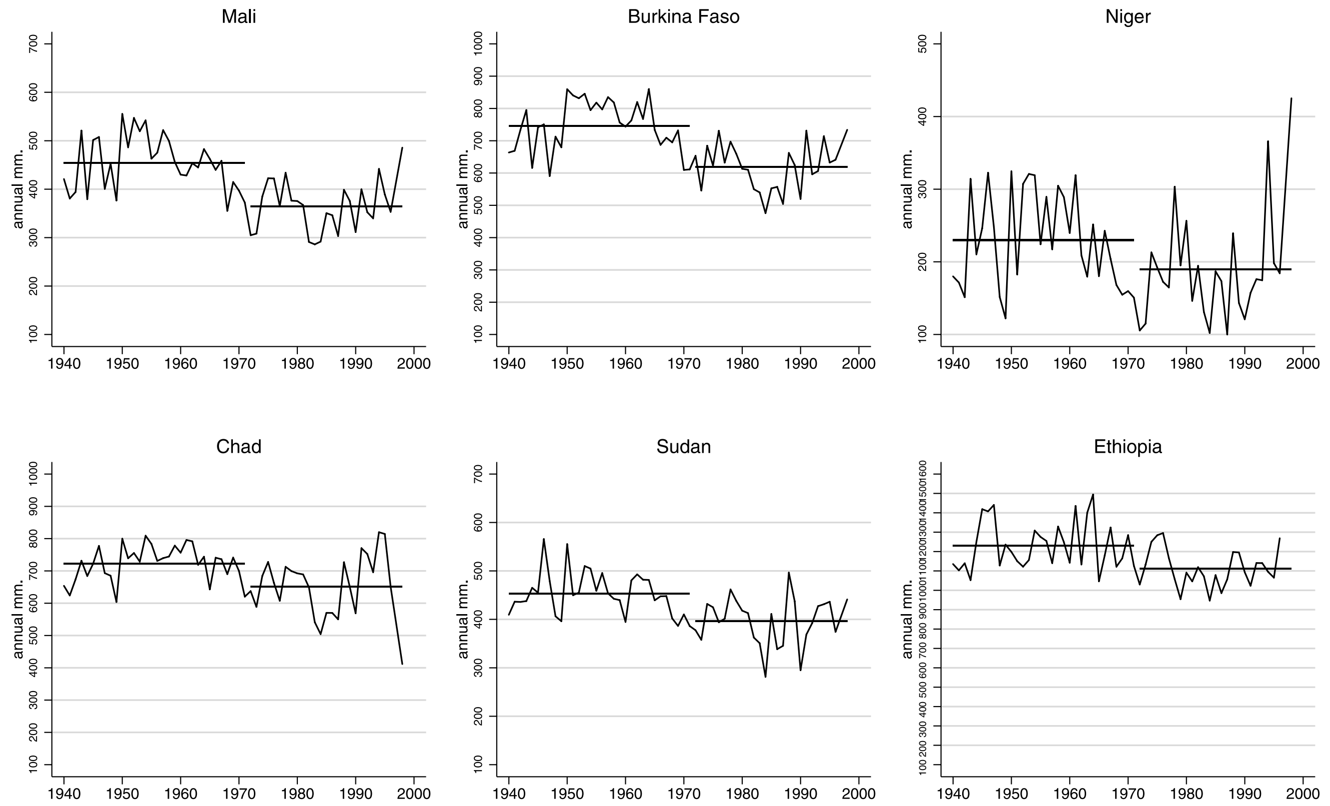
but the decline happened over 30 years before the conflict erupted.

## 5. Structural shifts in rainfall as explanation of conflict in sub-Saharan Africa

We turn now to consider whether structural shifts generally have been associated with increased outbreaks of conflict. Mamdani (2007a, 2007b), for instance, asserted that the drought in the 1970s in Darfur led to a situation where ‘co-operation turned into an intense struggle over diminishing resources’.

Figure 6 uses the Hulme dataset to present the average rainfall at the country level (taking the simple average of all nodes that lie in the country) for various countries and suggests that other Sahelian countries experienced structural declines in the early 1970s. Given the relative absence of civil conflict in Mali, Burkina Faso and Niger, perhaps the structural decline in rainfall explains very little of the Darfur conflict.

We conducted an exercise to increase the sample size and use an agreed-upon measure of civil conflict. We calculated the break or change year in rainfall totals for every country in sub-Saharan Africa, using the Hulme dataset, for time period 1940–1998. The country rainfall totals were simple averages of




Source: gu23wld0098.dat (Version 1.0), provided by Mike Hulme, Climatic Research Unit, University of East Anglia

**Figure 6.** Rainfall in six Sahelian countries, 1940–1998 (dashed lines indicate means levels for 1940–1971 and 1972–1998).

all nodes falling with the country borders. We dropped nodes where more than 10 observations were missing for the time period. Six small countries that did not encompass a node were included, with the rainfall totals calculated from the nearest relevant nodes. The Pettitt test was used to determine the break year. For each country with a break year identified by the Pettitt test, we calculated the magnitude of the structural break as the difference between mean rainfall for the time period before the break and mean rainfall for the time period after the break. We then used the Miguel *et al* dataset of civil conflicts to note any possible effects of a structural decline in rainfall on civil conflict. We calculated the number of years of conflict in the decades of the 1980s and the 1990s (any conflict as measured by the Peace Research Institute Oslo (PRIO), serious war as measured by PRIO, and the Collier war measure as used in Miguel *et al* and which are drawn from the UCDP/PRIO Armed Conflict Dataset[8]).

The results are in table 3. Twenty-two of thirty-eight countries experienced structural breaks. All of the Sahelian/West African countries saw structural breaks, and all except Ethiopia were in the 1967–74 period. Few of the southern, eastern and central African countries experienced breaks, and the break for Somalia was positive. The table makes clear that there was no obvious relationship between structural breaks and resulting conflict decades later. Of seventeen Sahelian/West African countries experiencing structural breaks, only three saw extended conflict during the 1980s. The same three (Ethiopia, Chad and Sudan) continued with conflict in the 1990s, and were joined by a number of others. Country experts would be unlikely to ascribe those other conflicts to declines in rainfall (e.g. Burkina Faso's short war with Mali and modestly bloody coup d'état). For the non-Sahelian countries, there was a mix of cases of extended war and structural break. No pattern is evident. Crosstabs and multiple regression analysis of various measures of war against the presence or absence of a structural break suggest no pattern.

Preliminary analysis, then, suggests little merit to the proposition that a structural break several decades earlier is a reasonable predictor of the outbreak of large-scale civil conflict. Too many other factors are at play.

## 6. Conclusion

We have considered and rejected the argument that Darfur's conflict is best thought of as a climate change conflict. There was no change in rainfall as a short-term trigger to the conflict. There is no evident cross-country pattern in the correlations between structural breaks in rainfall and incidence of conflict in later decades. The two points of this paper, that the proper characterization of rainfall in Darfur is of a structural break in around 1971, with stationary rainfall after that, and that there is no correlation in African countries between structural breaks in

[8] http://new.prio.no/CSCW-Datasets/Data-on-Armed-Conflict/UppsalaPRIO-Armed-Conflicts-Dataset/

**Table 3.** Structural breaks in rainfall and incidence of large-scale civil conflict (years during decade when country in conflict). (Note: source: Rainfall data from gu23wld0098.dat (Version 1.0), provided by Mike Hulme, Climatic Research Unit, University of East Anglia; conflict data from Miguel *et al* (2004), who in turn use various sources cited in their paper.)

| Country | Year of break | Difference between pre-and post-break mean rainfall (mm) | Years of war (PRIO) | 1980s years any civil conflict (PRIO) | Years of war (Collier) | Years of war (PRIO) | 1990s years any civil conflict (PRIO) | Years of war (Collier) |
|---|---|---|---|---|---|---|---|---|
| *Sahel/West Africa* | | | | | | | | |
| Gambia, The | 1967 | 259 | 0 | 1 | 0 | 0 | 0 | 0 |
| Guinea-Bissau | 1967 | 342 | 0 | 0 | 0 | 1 | 2 | 0 |
| Mali | 1967 | 97 | 0 | 0 | 0 | 0 | 2 | 0 |
| Niger | 1967 | 54 | 0 | 0 | 0 | 0 | 6 | 0 |
| Sudan | 1967 | 65 | 7 | 7 | 7 | 7 | 9 | 9 |
| Benin | 1969 | 108 | 0 | 0 | 0 | 0 | 0 | 0 |
| Burkina Faso | 1969 | 137 | 0 | 1 | 0 | 1 | 2 | 0 |
| Cote d'Ivoire | 1969 | 190 | 0 | 0 | 0 | 0 | 0 | 0 |
| Guinea | 1969 | 378 | 0 | 0 | 0 | 1 | 2 | 0 |
| Mauritania | 1969 | 46 | 0 | 0 | 0 | 0 | 0 | 0 |
| Senegal | 1969 | 199 | 0 | 0 | 0 | 1 | 7 | 0 |
| Chad | 1970 | 76 | 8 | 9 | 8 | 3 | 8 | 0 |
| Liberia | 1970 | 564 | 0 | 1 | 1 | 1 | 2 | 2 |
| Sierra Leone | 1970 | 508 | 0 | 0 | 0 | 2 | 9 | 9 |
| Ghana | 1974 | 183 | 0 | 2 | 0 | 0 | 0 | 0 |
| Togo | 1974 | 146 | 0 | 1 | 0 | 0 | 1 | 0 |
| Ethiopia | 1977 | 138 | 9 | 9 | 9 | 2 | 6 | 2 |
| *Other* | | | | | | | | |
| Angola | | | 9 | 9 | 9 | 8 | 10 | 10 |
| Burundi | | | 0 | 0 | 1 | 1 | 8 | 9 |
| Congo, Dem. R. | | | 9 | 9 | 0 | 2 | 3 | 8 |
| Congo, Rep. | | | 0 | 0 | 0 | 3 | 3 | 3 |
| Gabon | | | 0 | 0 | 0 | 0 | 0 | 0 |
| Kenya | | | 0 | 1 | 0 | 0 | 0 | 0 |
| Lesotho | | | 0 | 0 | 0 | 0 | 1 | 0 |
| Malawi | | | 0 | 0 | 0 | 0 | 0 | 0 |
| Mozambique | | | 9 | 9 | 9 | 3 | 3 | 3 |
| Rwanda | | | 0 | 0 | 0 | 5 | 9 | 5 |
| South Africa | | | 9 | 9 | 0 | 4 | 4 | 0 |
| Swaziland | | | 0 | 0 | 0 | 0 | 0 | 0 |
| Tanzania | | | 0 | 0 | 0 | 0 | 0 | 0 |
| Uganda | | | 9 | 9 | 8 | 3 | 8 | 0 |
| Zambia | | | 0 | 0 | 0 | 0 | 0 | 0 |
| Zimbabwe | | | 0 | 0 | 0 | 2 | 2 | 0 |
| Somalia | 1959 | −73 | 1 | 9 | 8 | 2 | 2 | 2 |
| Central Afric. R. | 1969 | 121 | 0 | 0 | 0 | 0 | 0 | 0 |
| Nigeria | 1969 | 114 | 0 | 0 | 4 | 0 | 0 | 0 |
| Cameroon | 1971 | 102 | 0 | 1 | 0 | 0 | 0 | 0 |
| Botswana | 1978 | 89 | 0 | 0 | 0 | 0 | 0 | 0 |

rainfall and subsequent conflict, would seem to cast doubt on the applicability of an explanation for the conflict in Darfur as due to rainfall change.

Casting doubt is not the same as ruling out. It is certainly possible that a structural break to a lower level of rainfall in Darfur in the 1970s led to disruption or decline in the livelihoods of those poorer Darfurians at the median or lower quintiles of the income and asset distribution. We contend, however, that there is little systematic evidence that the structural break in rainfall led to a downwards spiral for large fractions of the Darfur population. There is much evidence that Sahelian societies have coped with semi-arid conditions of low rainfall with high variability, both temporally and spatially (Mortimore 1989). These environments are tough for humans, but most regions see evolving strategies such as income diversification, agricultural intensification and migration, rather than large-scale violence. Moreover, some recent studies of satellite imagery of vegetation over the past twenty-five years have found a greening trend in Sahelian Africa, including Darfur, suggesting that farmers, herders and regional ecosystems have not been in a downwards spiral of lower biomass production (Eklundh and Olsson 2003, Sjöström 2004, Herrmann *et al* 2005, Olsson *et al* 2005).

This does not mean that life in Sahelian Africa with low rainfall is an idyll: there are endemic low-level struggles over resources, particularly between herders and farmers. But generally conflict does not erupt into warfare because regional institutions and central governments have projected their authority into Sahelian hinterlands and curbed violent situations before they have intensified. Sahelian West Africa, for example, has seen no outbreak of larger-scale conflict because governance institutions function reasonably well in terms of preventing local conflicts from becoming scorched-earth campaigns such as that seen in Darfur.

Other Sahelian sub-regions that have developed wide-spread conflict on the scale of Darfur, such as the long-lasting civil conflicts in Chad and the various wars in Ethiopia and Eritrea, are only implausibly linked to climate change. What makes Darfur different from West Africa and similar to Chad, Ethiopia and Eritrea? The answer is straightforward: an elite ruling the country from the capital that has preferred to exclude peripheral populations from genuine participation in political processes and has repeatedly revealed a willingness and ability to use large-scale violence, often against civilian populations, in response to perceived threats from the peripheral regions. In Sudan, this willingness to use large-scale indiscriminate violence was evident in the civil wars encompassing Southern Sudan and the Nuba Mountains (Johnson 2003). Individuals who constitute the present military regime in Sudan are being indicted or are being considered for indictment by the International Criminal Court, and the defense that they were reluctantly embroiled in a local conflict induced by climate change has little merit.

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