Consilience

SCHOLARLY ARTICLE

The Effect of the Spatial Resolution of Conflict Data on the Analysis of Drought as a Determinant of Civil War Onset: Africa, 1980-2001

Chikara Onda[1]

Abstract:

With the steady decrease in freshwater availability and the growth of world population, freshwater distribution is likely to become an increasingly prominent source of conflict. Given that civil wars by definition occur within national boundaries and therefore involve factors that vary within the country in which they occur, past studies examining the determinants of civil conflict using the state as the unit of observation are inherently flawed. Improvements in the accuracy of the delineations of such conflict should increase the ability to determine the local determinants of civil war. This analysis focuses on Africa between 1980 and 2001, utilizing a refined version of the International Peace Research Institute, Oslo (PRIO) Armed Conflict dataset at the 0.25-degree resolution, and juxtaposing this data on rainfall data using GIS analysis. Using socioeconomic factors as control variables, we perform a logistic regression analysis, comparing the correlation coefficients from this analysis to those of a previous study using conflict centroids with radii as the units of observation. Thus, this study aims to explore the effect a change in the spatial level of resolution of conflict data has on our ability to analyze geographic determinants of war outbreak. We find that, despite the altered delineation of conflict data, the statistical analysis produces similar results that confirm the causal relationship between drought and civil war outbreak. This calls to attention the need for further international cooperation in assisting developing nations to develop infrastructure for the sustainable management of water resources.

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Introduction:

In the last several decades, civil war has become the predominant form of conflict, as 27 of 32 instances of armed conflict ongoing in 2007 are occurring on the intrastate level[2]. Accompanying this trend, we have observed a steady increase in the number and magnitude of quantitative studies on the causes of civil war[3,4]. Recently, studies have confirmed the effect of environmental factors upon conflict. For instance, in a report released in 2007, the United Nations Environment Programme ties conflict in Sudan to key environmental factors, including freshwater availability, within the country[5]. However, it is only very recently that researchers have begun to examine the effects of the environment and natural resource availability upon internal war outbreak.

Past studies that concern the links between conflict and environmental scarcity, more specifically on resources such as freshwater, forests, and arable land, tend to use the nation as the unit of analysis, and therefore lack the spatial analysis of internally variant factors[6,7,8,9]. However, since *internal* conflict would presumably depend on *internal* factors (i.e. those that vary by region), if studies on civil war are to isolate specific factors, these must incorporate higher degrees of spatial resolution than those offered by nationally aggregated statistics**.**

Sambanis at Yale University has already compiled an extensive review of the recently voluminous quantitative literature on civil war[10]. Therefore, the aim of this study is not to introduce a new theory on the determinants of internal conflict. Rather, it aims to explore the effect an improvement in the level of spatial resolution of civil war data through clearer delineations of conflict zones has on our ability to analyze geographic determinants of war outbreak. Namely, we examine the effect of freshwater scarcity, determined through rainfall variation, on the outbreak of internal war in Africa.

Recent studies find significant correlations between rainfall and conflict. A team led by Miguel from University of California at Berkeley utilizes rainfall variation as an instrumental variable to assess the impact of economic growth (or lack thereof) on civil conflict in Africa between 1981 and 1999, using the nation as the unit of observation[11]. A later study by Levy et al.[12] at the Center for International Earth Science Information Network (CIESIN) at Columbia University employs data from the International Peace Research Institute, Oslo (PRIO)

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[2] Buhaug, H. (2007). "UCDP/PRIO Intrastate Conflict Onset Dataset, 1946-2006". *International Peace Research Institute, Oslo*. Retrieved December 25, 2007 from http://new.prio.no/CSCW-Datasets/Data-on-Armed-Conflict/UppsalaPRIO-Armed-Conflicts-Dataset/Armed-Conflicts-Version-4-2007.

[3] Fearon, J.D. and D.D. Laitin. (2003). "Ethnicity, Insurgency, and Civil War". *The American Political Science Review*, 97 (1): 75-90.

[4] Collier, P. and A. Hoeffler. (2004). "Greed and grievance in civil war". *Oxford Economic Papers*, 56 (4): 563-595.

[5] United Nations Environment Programme. (2007) "Sudan: Post-Conflict Environmental Assessment". Retrieved on December 25, 2007 from http://postconflict.unep.ch/publications/ UNEP_Sudan_synthesis_E.pdf.

[6] Homer-Dixon, T.F. (1994). "Environmental Scarcities and Violent Conflict: Evidence from Cases". *International Security*, 19 (1): 5-40.

[7] Hauge, W. and Ellingsen, T. (1998). "Beyond Environmental Scarcity: Causal Pathways to Conflict". *Journal of Peace Research*, 35 (3): 299-317.

[8] Homer-Dixon, T.F. (1999). *Environment, Scarcity, and Violence*. Princeton, NJ: Princeton University Press.

[9] de Soysa, I. (2002). "Ecoviolence: Shrinking Pie, or Honey Pot?". *Global Environmental Politics*, 2 (4): 1-34.

[10] Sambanis, N. (2002). "A Review of Recent Advances and Future Directions in the Quantitative Literature on Civil War". *Defence and Peace Economics*, 13 (3): 215-243.

[11] Miguel, E., S. Satyanath, and E. Sergenti. (2004). "Economic Shocks and Civil Conflict: An Instrumental Variables Approach". *Journal of Political Economy*, 112 (4): 723-753.

[12] Levy, M.A., C. Thorkelson, C. Vörösmarty, E. Douglas, and M. Humphreys. (2005). "Freshwater Availability Anomalies and Outbreak of Internal War: Results from a Global Spatial Time Series Analysis". *Human Security and Climate Change: An International Workshop*, Oslo, Norway, June 21-23.

conflict database[13]; this study maps each instance of internal conflict between 1979 and 2002 as a centroid of a determined latitude and longitude with a buffer of given radius to perform a similar analysis. This later study not only incorporates a higher degree of resolution in terms of conflict data, but also brings together a monthly time-series of water availability produced by the International Research Institute for Climate and Society (IRI) at Columbia University[14] alongside spatially explicit demographic data from CIESIN, in order to gain further insight into the local determinants of civil war outbreak. Although a number of measures are used to assess the relationship between water availability and conflict outbreak, analysis using instances of high intensity (Level 3) conflict[15] produced the strongest results.

We undertake a similar method; this time, however, we use the relevant data for Africa from a more "refined version of the conflict location data… [b]ased on descriptive information on the location of various battles" generated by Buhaug and Rød at the Centre for the Study of Civil War (CSCW) at PRIO, which delineates past conflicts into irregular polygons[16]. As the delineation of conflict zones is of a higher spatial resolution than in previous studies, directly comparing the coefficients resulting from the two statistical analyses should yield noteworthy results; this should shed light upon the effect, and ultimately the necessity, of higher levels of resolution in conflict data in the study of armed conflict. Such improvements in the understanding of the determinants of internal war may bear a good deal of predictive value, which would in turn aid in shaping policy in the realm of conflict prevention.

Hypotheses:

As discussed above, decreases in rainfall levels are generally thought to increase the chances of civil war onset. Because freshwater availability affects the distribution of wealth, Collier and Hoeffler at the Centre for the Study of African Economics at the University of Oxford argue that water scarcity decreases the opportunity cost of rebellion; that is, water scarcity decreases the return from peaceful economic activities due to minimal wages and high unemployment, thereby increasing the relative rates of return from rebellion[17]. Also, as drought may affect one region more adversely than another, disparities in freshwater distribution may increase the likelihood of civil conflict over these limited resources.

Although the above correlation between water scarcity and conflict outbreak has been manifested in the aforementioned studies on the effect of freshwater scarcity on internal conflict[18,19], more distinct delineations of the

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13 Gleditsch, N.P., P. Wallensteen, M. Eriksson, M. Sollenberg, and H. Strand. (2002). "Armed Conflict 1946-2001: A New Dataset". *Journal of Peace Research*, 39 (5): 615-637.

14 Lyon, B. and A.G. Barnston. (2005). "ENSO and the Spatial Extent of Interannual Precipitation Extremes in Tropical Land Areas". *Journal of Climate*, 18 (23): 5095-5109.

15 The PRIO Armed Conflict dataset defines "war" (Level 3) as any armed conflict that exceeds 1000 battle-related deaths per year.

16 Buhaug, H. and J.K. Rød. (2006). "Local determinants of African civil wars, 1970-2001". *Political Geography*, 25 (3): 315-335.

17 Collier, P. and A. Hoeffler. (2004). "Greed and grievance in civil war". *Oxford Economic Papers*, 56 (4): 563-595.

18 Miguel, E., S. Satyanath, and E. Sergenti. (2004). "Economic Shocks and Civil Conflict: An Instrumental Variables Approach". *Journal of Political Economy*, 112 (4): 723-753.

19 Levy, M.A., C. Thorkelson, C. Vörösmarty, E. Douglas, and M. Humphreys. (2005). "Freshwater Availability Anomalies and Outbreak of Internal War: Results from a Global Spatial Time Series Analysis". *Human Security and Climate Change: An International Workshop*, Oslo, Norway, June 21-23.

geospatial extent of conflict should reduce the likelihood of the erroneous inclusion of non-conflict regions with those in conflict. Such an improvement in accuracy would further clarify the spatial variation within countries, increasing the precision with which the effect of determinants, or, in our case, of freshwater availability, on civil war onset can be examined. This brings us to our hypotheses:

H_1: Increasing the level of spatial resolution of the geographic delineation of conflict data should produce stronger correlations in the analysis of freshwater availability as a determinant of civil war onset;

H_2: There should remain a strong correlation between rainfall deviations below baseline levels and the likelihood of falling into high-intensity conflict despite this change in resolution.

Data:

For comparison with the previous quantitative analysis using circular conflict zones, this study similarly involves the geospatial statistics developed from spatially and temporally harmonized datasets. We utilize the aforementioned water and climate archives from the IRI in order to produce spatial indicators of water stress. Data is available in monthly increments for the period covering 1979 onwards. Since the likelihood of conflict is expected to increase during the year following instances of water scarcity, the rainfall data is lagged by one year. Therefore, our analysis on the effect of rainfall anomalies on internal war onset includes instances of internal armed conflict from 1980 onwards.

Conflict Data:

The analysis uses the PRIO database to identify the internal wars in Africa for the period studied. However, we utilize the spatially explicit dataset developed by Buhaug and Rød, which delineates conflicts into irregular polygons (see *Figure 1*, below), instead of the circular, centroid-radius conflict zones. We mapped these onto a 0.25-degree resolution raster grid version of ESRI's *Digital Chart of the World* using GIS. We then applied a 0.25-degree fishnet over the conflict data and merged the two:

This process allows us to organize the continent of Africa by grid-year and assign each an outbreak variable, set to 1 in the grid cells corresponding to conflict zones and 0 to those without conflict. Since this study focuses on instances of conflict *outbreak*, grid-years applying an ongoing conflict in years subsequent to the outbreak year were censored out of the analysis and thus set to missing in the database.

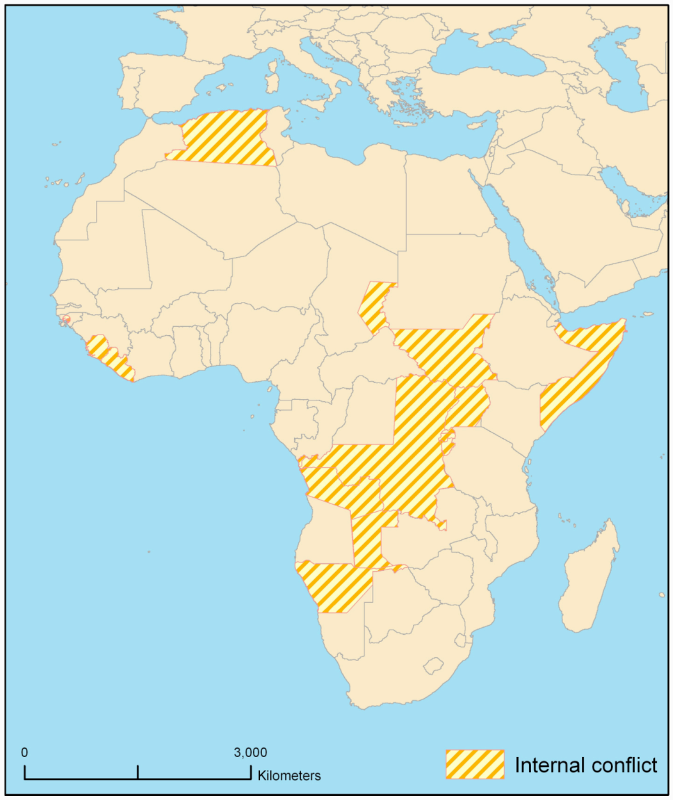

Figure 1: Instances of high-intensity internal conflict, Africa, 1980-2002

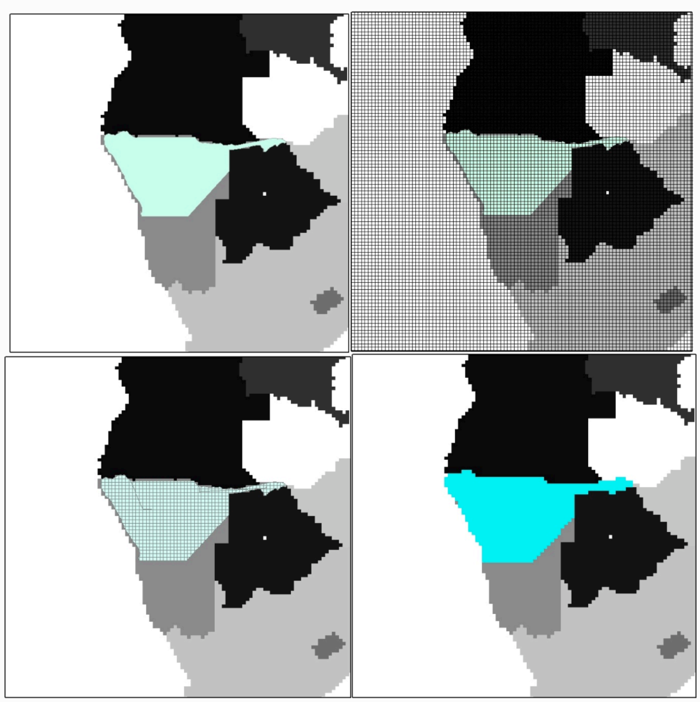

Figure 2: Converting the 1980-1983 South Africa (Namibia) conflict polygons to conflict grids, using a 0.25-degree fishnet

Since the analysis of Level-3 conflicts listed in the PRIO database produced the most noteworthy results in the previous study by Levy et al., we have limited analysis to these:

Location	Start Year	End Year	Percent of territory coded as outbreak grid	
			circles	*polygons*
South Africa (Namibia)	1980	1988	74.5	60.2
Uganda	1981	1991	93.7	100.0
Sudan	1983	1992	58.1	31.3
Somalia	1989	1992	98.9	100.0
Angola	1990	1994	3.3	26.5
Chad	1990	1990	26.0	16.4
Liberia	1990	1990	100.0	100.0
Rwanda	1991	1992	66.7	48.5
Algeria	1993	2001	29.4	31.2
Zaire (Congo)	1997	1997	98.1	76.1
Angola	1998	1998	58.0	60.9
Burundi	1998	1998	83.3	100.0
Guinea-Bissau	1998	1998	27.9	28.6
Rwanda	1998	1998	100.0	100.0
Sierra Leone	1998	1999	82.7	100.0

Figure 3: Conflicts included in the analysis[20]

Demographic Data:

Demographic data is often unreliable due to the lack of resources, quality control, and the referencing of spatial and temporal resolution. However, processed datasets such as CIESIN's Gridded Population of the World (GPW) allow for the overcoming of such shortcomings in data. Currently in its third version, the dataset is comprised of explicitly georeferenced population estimates for over 350,000 subnational units. The data is based upon standard GIS gridding algorithms that produce population estimates at a resolution of 2.5 minutes in both latitude and longitude[21].

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[20] Note that The Uganda (1979), Mozambique (1981-1992), Chad – Libya (1987), South Africa (1989-1993), Congo-Brazzaville (1997), and Ethiopia – Eritrea (1998-2000) conflicts included in the previous study were omitted from the analysis, as these were not present in the Buhaug and Rød dataset.

[21] Balk, D., F. Pozzi, G. Yetman, A. Nelson, and U. Deichmann. (2004). "Methodologies to Improve Global Population Estimates in Urban and Rural Areas". *Annual Meetings of the Population Association of America*, Boston, MA, March-April.

Rainfall Data:

We assess rainfall variation using the Weighted Anomaly Standardized Precipitation (WASP) index[22]. The WASP index measures the monthly difference between observed rainfall and average values over the period 1980-2002, weighing monthly anomalies to the average monthly rainfall's fraction of annual rainfall:

$$WASP_N = \frac{1}{\sigma_{WASP_N}} \bullet \sum_{i=1}^{N} \left(\frac{P_i - \overline{P_i}}{\sigma_i} \right) \frac{\overline{P_i}}{\overline{P_A}}$$

where P_A = avg. total annual percipitation

P_i = observed monthly precipitation in the i^{th} month in the sum

$\overline{P_i}$ = climatological avg. value for the i^{th} month

$\frac{\overline{P_i}}{\overline{P_A}}$ = avg. monthly fraction of annual precipitation

σ_i = standard deviation of anomalies of monthly precipitation

We utilized yearly totals of the monthly WASP indices so as to render the measures of rainfall variation compatible with the annual conflict data.

Methodology:

In order to facilitate the comparison with the previous study using by Levy et al., we apply the scripts for the logistic regression model used in this previous study upon both the circular and polygonal conflict zones. We used the grid cell as the unit of analysis and conflict outbreak as the dependent variable. As mentioned earlier, grid-years for ongoing conflict were censored from the analysis.

As in the previous study, we implement a simplified version of the Political Instability Task Force model, which encompasses measures of infant mortality rates, trade openness, and perceived levels of democracy (also known as polity)[23]. In accordance with the model, values for infant mortality rates and trade openness are relative to the world means, while the polity measure is a binary variable set to 1 for polity scores in the intermediate range between -5 and 7. Each variable uses the country as the unit of measurement but is implemented at the grid-cell for the purposes of the statistical analysis.

The analysis also uses grid-cell population as a control variable. Previous studies, such as that performed by Fearon and Laitin, have confirmed that population has a direct causal relationship to the probability of civil war[24]. This is particularly important when dealing with sub-national units of analysis, because population varies drastically within a given country, and conflict is largely unlikely in relatively uninhabited areas. CIESIN's GPW dataset was used for these purposes. However, since time series data was not available, we use the dataset's population count for the year 2000 throughout the analysis.

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[22] Lyon, B. and A.G. Barnston. (2005). "ENSO and the Spatial Extent of Interannual Precipitation Extremes in Tropical Land Areas". *Journal of Climate*, 18 (23): 5095-5109.
[23] Esty, D.C., J.A. Goldstone, T.R. Gurr, P.T. Surko, A.N. Unger, and R.S. Chen. (1998). "The State Failure Project: Early Warning Research for US Foreign Policy Planning". J.L. Davies and T.R. Gurr (eds). *Preventive Measures: Building Risk Assessment and Crisis Early Warning Systems*. Boulder, CO: Rowman and Littlefield.
[24] Fearon, J.D. and D.D. Laitin. (2003). "Ethnicity, Insurgency, and Civil War". *The American Political Science Review*, 97 (1): 75-90.

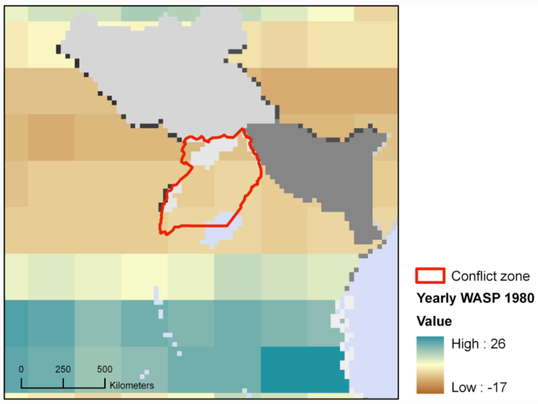
Results:

Variables	**Centroid-radius**			**Irregular Polygon**		
	Coefficient	*S.E.*	*significance*	*Coefficient*	*S.E.*	*significance*
Infant Mortality	0.154	0.011	0.000	0.429	0.012	0.000
Trade Openness	-0.002	0.000	0.000	0.000	0.000	0.260
Polity -5 to 7	0.509	0.022	0.000	0.331	0.027	0.000
Rainfall Deviations	-0.053	0.001	0.000	-0.037	0.001	0.000
Population (natural log)	1.84	0.050	0.000	2.252	0.076	0.000
Population (squared)	-0.099	0.003	0.000	-0.127	0.004	0.000
Constant	-12.892	0.211	0.000	-15.622	0.316	0.000

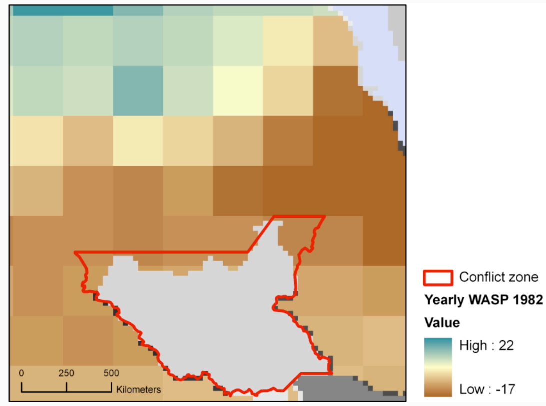
Figure 4: Logistic regression results for varying conflict data resolutions, with the outbreak of high-intensity conflict as the dependent variable and all independent variables lagged one year

The results of the logistic regression show no drastic difference in correlation coefficient between high-intensity conflict and the independent variables, as seen in *Figure 4* above. Both analyses show a strong relationship between rainfall deviations below baseline levels and the likelihood of high-intensity conflict outbreak the following year. The other variables assessed under the Political Instability Task Force model show similarly strong correlations, with significances at the 0.001 level, with the exception of trade openness when using irregular polygons as the conflict zones. However, a difference is seen in the magnitude of the coefficients. Apart from the similar natures of the correlations (positive or negative), there seems to be no pattern that determines which level of data resolution produces the coefficient of a higher magnitude.

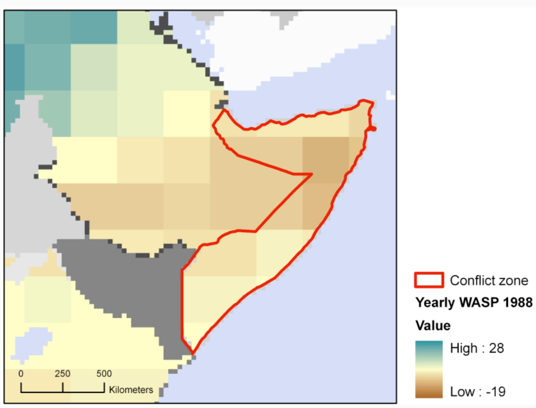
Figure 5: Conflict polygons juxtaposed over total Weighted Anomaly Standardized Precipitation (WASP) indices for preceding year



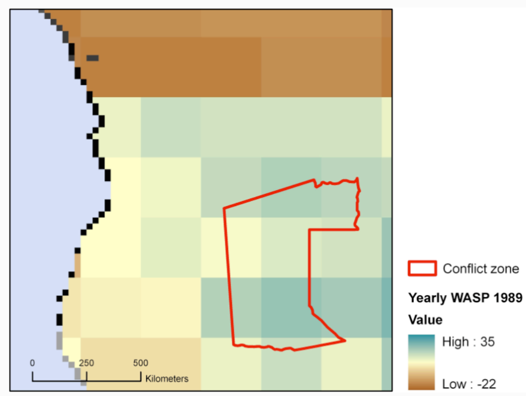
Uganda (1981-1991)



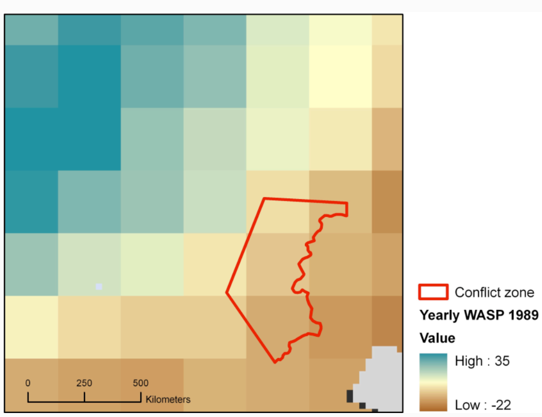
Sudan (1983-1992)



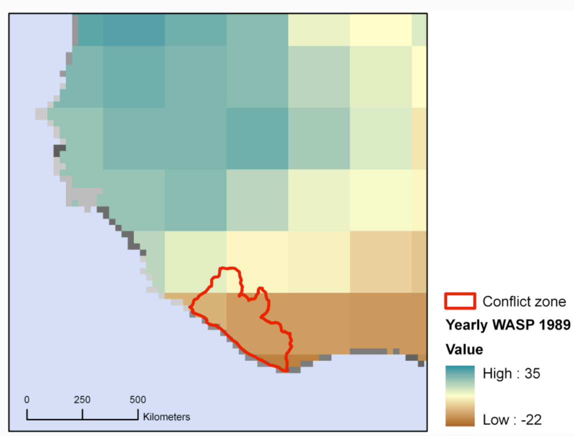
Somalia (1989-1992)



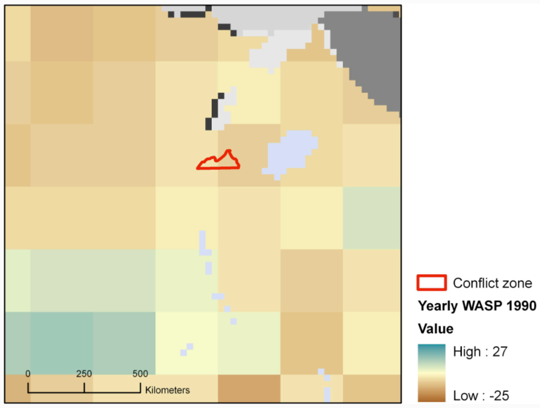
Angola (1990-1994)



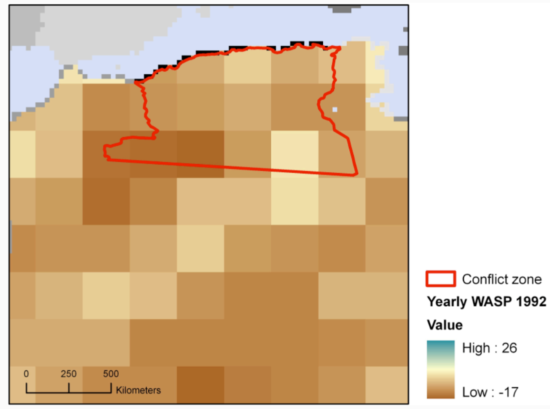
Chad (1990)



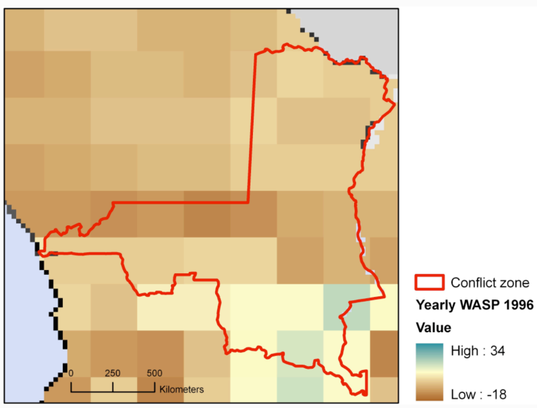
Liberia (1990)



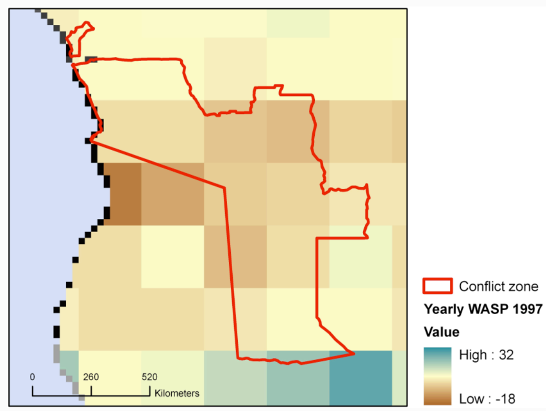
Rwanda (1991-1992)



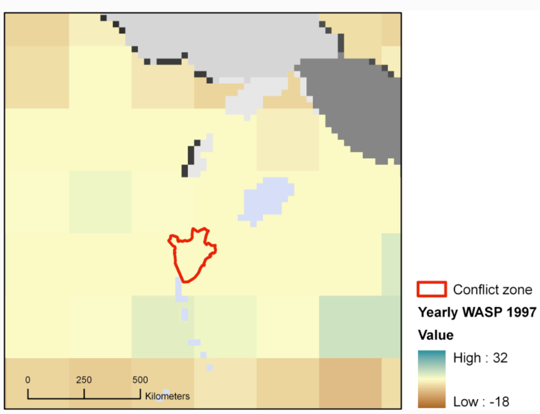
Algeria (1993-2001)



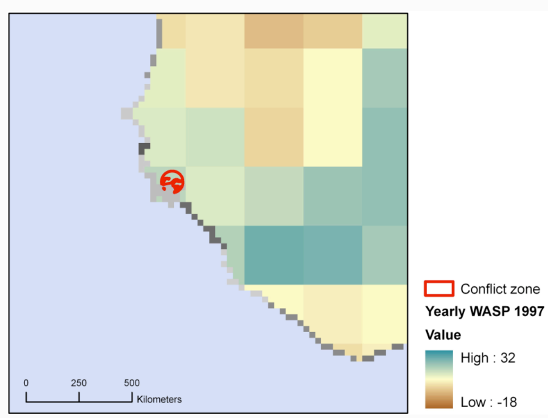
Zaire (1997)



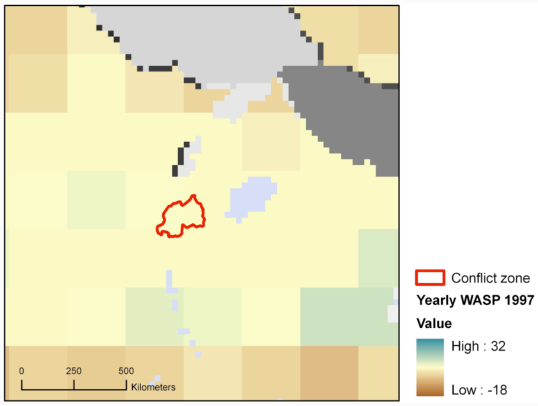
Angola (1998)



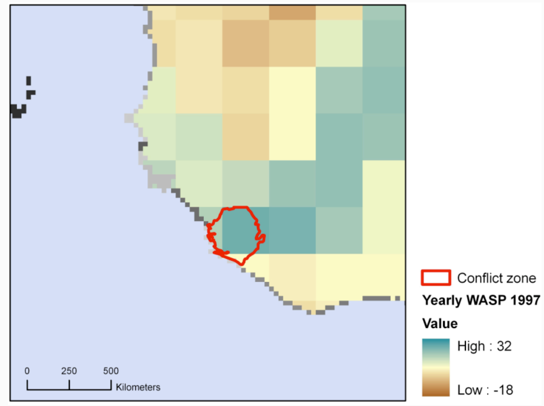
Burundi (1998)



Guinea-Bissau (1998)



Rwanda (1998)



Sierra Leone (1998-1999)

Discussion:

Looking at *Figure 4*, it is apparent that the difference in conflict data resolution has some effect on the outcome of the logistic regression analysis, though the nature of this effect remains unclear. This raises the question of whether it is worth obtaining more precise conflict data when studying civil war. However, the lack of a clear pattern may be due to the fact that, while the conflict data is indeed more precise, much of the other data remains coarse. For example, the WASP data remains at a lower resolution of 2.5 degrees, the population data was not part of a time series, and factors under the Political Instability Task Force model were measured only to a national level.

Moreover, since sparsely populated areas are highly unlikely to reach the 1000 battle-related deaths required for a region to be classified as being in high intensity conflict, these regions would not be marked as conflict zones in the analysis, virtually by default. Thus, the inclusion of population measures within the regression analysis may have distorted the results.

Finally, when examining the spatial differences between the two datasets, there seems to be less of a difference than would be expected. This is particularly true for Uganda (1981-1991), Somalia (1989-1992), Liberia (1990), Burundi (1998), Rwanda (1998-1999), and Sierra Leone (1998-1999), a group that amount to a third of the conflicts in the dataset, where the presumably higher-resolution conflict polygons essentially occupy the entire country. When taking these cases into account, we are left to question the ability, and perhaps the need, to create such clear-cut boundaries of conflict beyond the precision of the general areas of conflict indicated by the centroids and approximate buffer zones, since the economic impacts of drought would clearly be felt in geographically disparate regions due to the nature of trade.

Conclusion:

Despite a lack of significant difference between the coefficients produced by the logistic regression analyses using irregular polygon and centroid-radius geospatial delineations of the instances of internal conflict in question, we find a consistently strong correlation between rainfall deviations below baseline levels and the likelihood of falling into high-intensity conflict; we therefore reject H_1 and accept H_2. Although the effect of an improvement in spatial resolution of conflict data may not be apparent, further progress will require the use of data of equally improved resolutions, not only in conflict data, but also in the other variables included in the regression analysis, most notably in freshwater availability.

Further insight may be gained by examining the regional factors of the areas included in the centroid-radius delineations but not in the polygons, and, in particular, what these regions excluded in the higher resolution conflict data have in common. One possibility is that these regions are sparsely populated, which could, as mentioned earlier, alter the outcome of the analysis.

Finally, one major hindrance to the breadth of this study was the availability of WASP data, which limited the study to a mere 15 conflicts. If more data were available, a more robust statistical analysis could be performed, not only increasing the statistical strength of the study, but also raising the interesting question of regional differences in the various causal factors surrounding civil war onset.

Thus, this study highlights the need for further rigorous studies employing the latest statistical and geospatial tools available, in order to identify the determinants of the outbreak of armed conflict with increased confidence. Such work would have implications on policy, potentially prompting individuals and organizations on both the international and domestic levels to prioritize threats and to take measures in order to avert conflict outbreak. As previously elucidated, poverty can decrease the opportunity costs of rebellion by reducing the return from peaceful economic activities; this increases the relative rates of return from rebellion, which would, in turn, threaten the region's security. Given that limited freshwater availability aggravates poverty, global climate change, and the consequent changes in rainfall distribution pose a threat to developing nations' security. Since many of these nations do not have the economic nor technological means by which to withstand the effects of climate change, it is necessary for developed nations to begin assisting developing nations to develop infrastructure for the sustainable management of water resources. For such action to be taken, studies using data of higher resolution are therefore vital, so that the determinants of conflict outbreak can be further isolated, and so that regions facing the largest threats can be identified.

Acknowledgements

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