Examining the relationship between environmental factors and conflict in pastoralist areas of East Africa

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ABSTRACT

The eastern Africa region has long been known for recurring drought, prolonged civil war and frequent pastoral conflicts. Several researchers have suggested that environmental factors can trigger conflicts among pastoralist communities, but quantitative support for this hypothesis is lacking. Here we use 29 years of georeferenced precipitation and Normalized Difference Vegetation Index (NDVI) data to evaluate long term trends in scarcity of water and forage for livestock, and then ask whether these environmental stressors have any predictive power with respect to the location and timing of 11 years of conflict data based on Armed Conflict Location and Event Data Project (ACLED) and Uppsala Conflict Data Program (UCDP). Results indicate that environmental stressors were only partly predictive of conflict events. To better understand the drivers behind conflict, the contribution of other potential stressors to conflict need to be systematically quantified and be taken into consideration.

Key words: Conflict, East Africa, Pastoralist, Climate and Environmental Factors

1 INTRODUCTION

The eastern Africa region has long been known for recurring drought, prolonged civil wars, and frequent conflicts (Fearon and Laitin, 2003; Oba, 1992; Slegers and Stroosnijder, 2008). Many publications presented climate and environmental factors as major triggers of conflicts among pastoralist communities (Kevane and Gray, 2008). While various hypotheses exist for these phenomenon, it is widely accepted that environmental factors exacerbate conflict (Faris, 2007; Ki-Moon, 2007; Sachs, 2006; Scheffran and Battaglini, 2011). Droughts of various severities have been reported in Northeastern Africa (Benjaminsen et al., 2012; Haro et al., 2005; Little et al., 2001; Raleigh and Urdal, 2007). In recent years the frequency of drought has dramatically increased from 10 years on average in the 1900s to every four years in the 1980s (Huho and Mugalavai, 2010; Morton and de Haan, 1999). Records also show that conflict incidents increased in the last 15 years (Sundberg et al., 2012). In the greater horn of Africa, the frequency of drought has doubled from once every six years to once every three years (Meier et al., 2007). The likely impacts of increasing drought are worse in dry environments where non – equilibrium ecology dominates.

Past studies have given mostly descriptive explanations for the causal relationship between environmental resource scarcity and pastoral conflict (Homer-Dixon, 2010; Kahl, 1998; Markakis, 1998; Mkutu, 2001). Sachs (2006) argued that a drought – induced famine is much more likely to trigger conflict in a place that is already impoverished and lacking any cushion of physical or financial resources. Meier et al. (2007) used georeferenced precipitation, vegetation and forage data of 2002 – 2006 and developed the first well established approach to empirically describe environmental factors that may influence pastoral conflicts. Results indicated that aggravating behavior, along with a reduction in peace initiatives and reciprocal exchanges, is associated with an escalation in pastoral conflict, particularly when coupled with an increase in vegetation that may provide cover for organized raids. More recently Raleigh and Kniventon (2012) used precipitation variability to explore the marginal influence of the climate on conflict and concluded small-scale conflict is likely to be exacerbated with increases in rainfall variability. On the contrary, several authors also argue that unusually wet seasons encourage raiding in pastoralist areas (Adano and Witsenburg, 2008; Meier et al., 2007; Turner, 2004). Some recent quantitative analysis of climate and conflict data have resulted in either a null or negative relationship between scarcity and conflict (O'Loughlin et al., 2012). A new and extensive meta-analysis by Hsiang et al. (2013) concluded that warmer temperature and extreme precipitation lead to an increase in intergroup conflict. All these studies lead to a lack of a clear consensus.

The challenge in producing empirically sound statistical evidence to substantiate the claim that environmental factors trigger conflict emanates from contradicting circumstances to the hypothesis itself. This is mainly because conflict is context-specific and it is hardly possible to find a single cause describing it (GSDRC, 2015). The nexus between environmental factors and conflict has four possible real world scenarios, with circumstances as follow: areas with good (above long-term mean) climatic/vegetation condition where conflict prevails (e.g. Central African Republic, Congo Democratic Republic, South Sudan) , countries with good climatic/vegetation condition and no conflict, poor (below long-term mean) climate/vegetation and persistent conflicts (e.g. Ethiopia, Kenya, Sudan, Uganda) and poor climate/vegetation and no conflict (e.g. Sahel).

The scope of this study is limited to the eastern Africa region, home for 20 million pastoralists, where environmental stresses (e.g. reoccurring drought) and pastoralist conflicts are frequently reported (Kimani, 2008). This communities represent the largest grouping in the world. Pastoralists represent, 60% of total population in Somalia, 20% in Sudan and 12% in Ethiopia. They possess a significant part of the livestock wealth (30–40% in Ethiopia and 70% in Kenya where livestock production accounts for 24% of total agricultural output) (Ahmed, 2002). Given the mixed results from past studies, we anticipated that this focus would best allow us to determine whether or not an association might exist. New remote sensing products have enabled monitoring of long term climate and environmental factors of east Africa. (Balk et al., 2006; Balk and Yetman, 2004; Hulme, 1992; Hulme, 1994; Hulme et al., 1998; Tucker et al., 2005). We used 29 years of vegetation and precipitation data to look at long term trends in scarcity of water and forage for livestock, and then for the 11 years for which we have a detailed conflict analysis (2000-2010) we test whether environmental stresses have any predictive power in locating conflict incidents.

2 MATERIALS AND METHODS

2.1 Study area

The study area comprises nine countries: Djibouti, Eritrea, Ethiopia, Kenya, Somalia, South Sudan, Sudan, Tanzania, and Uganda (Figure 1). Pastoralist communities inhabit the arid and semi-arid land in these countries. Much of the region is characterized by a bimodal precipitation cycle. The main rainy season is from March to May, and shorter rains occur in October and November. The areas of highest relief surrounding Mt. Kenya and Mt. Kilimanjaro and the rugged terrain northwest of Lake Victoria and in southern Ethiopia receive the most precipitation during the main rainy season (Nicholson, 1996).

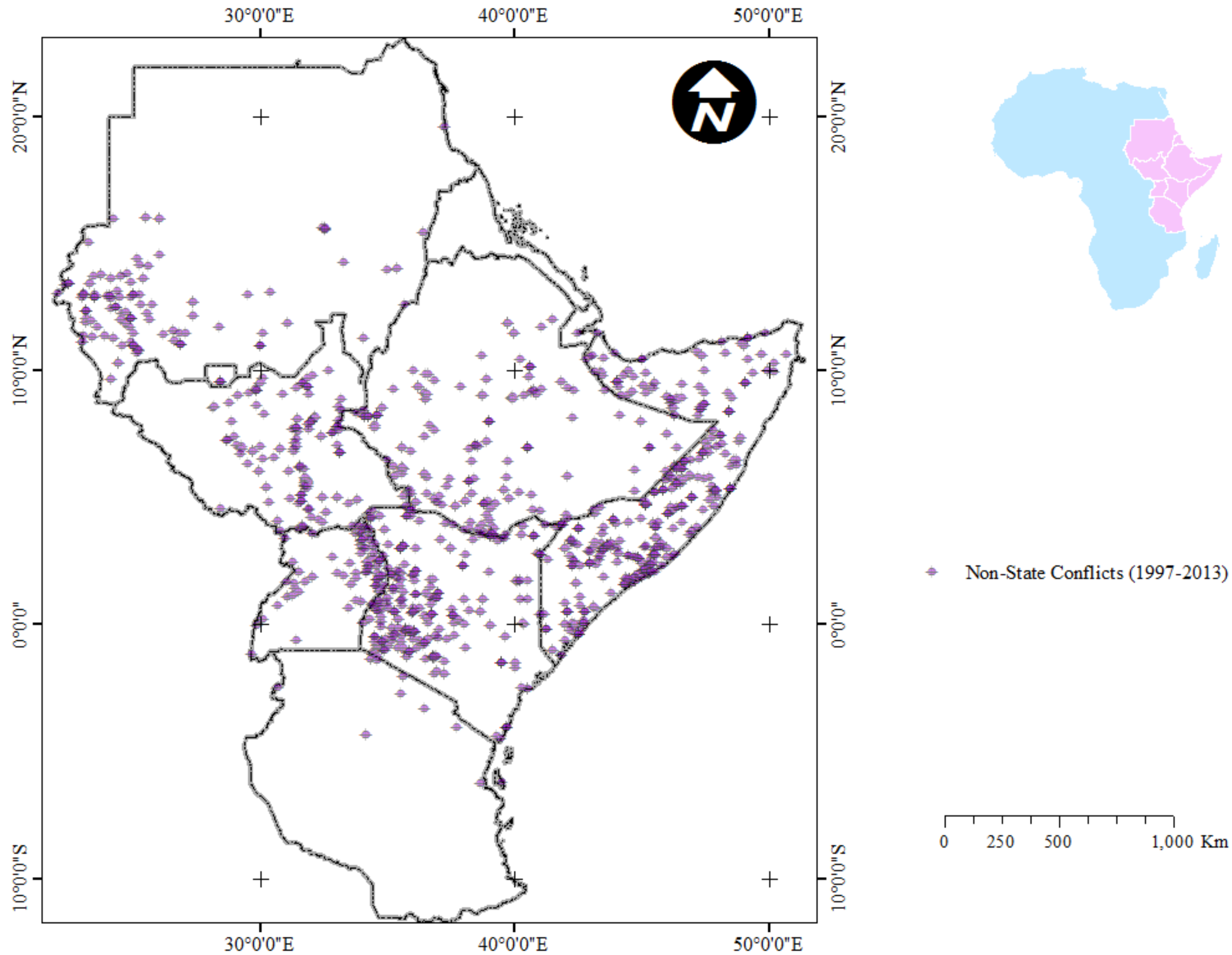

Figure 1. Non – state conflict events of east Africa , actors in non – state conflicts are two organized armed groups, neither of which is the government of a state (Sundberg et al., 2012)

2.2 Data and methods

Climatic and environmental factors that can potentially contribute to conflict in pastoralist areas are mainly linked to the imbalances in the supply and demand of forage and water. Demand for forage and water is driven by the need to sustain humans, livestock, and the cultivation of short duration crops, such as sorghum and millet (Mace et al., 1993). The spatial distribution of these variables can be mapped using geographic information systems (GIS) and remotely-sensed products. The supply side mainly refers to the seasonal precipitation. The use of vegetation indices (VIs) augment the spatial analysis not only as a surrogate to evaluate the aerial distribution of precipitation but also as an indicator of availability of fodder for livestock. With anticipated growth in demand due to population and livestock growth, analyzing the trend in supply could help explain conflict incidences in pastoral areas of East Africa if shortages are predicted. The following datasets were used in the analysis.

2.2.1 Conflict data and analysis

Incidences of conflict in pastoralist areas of East Africa have been extensively published (Oba, 1992; Odhiambo, 2012; Raleigh and Kniveton, 2012; Reuveny, 2007). Conflict data were downloaded from two sources: Armed Conflict Location and Event Data Project (ACLED) (Raleigh et al., 2010) and Uppsala Conflict Data Program (UCDP) Non-State Conflict Dataset (Sundberg et al., 2012). These datasets include the coordinates of the incidences, type of conflict, warring groups, and estimated fatalities among other factors. The UCDP non-state conflict data of 1997 – 2010 are used in this study due to its explicit *i)* definition of conflict, *ii)* actors and *iii)* set of well – defined procedure to the inclusion of an incidence into the database. Eck (2012) provided a detailed comparison of the two datasets. The two datasets are closely comparable in the east Africa. The UCDP data are available up to the year 2010 and therefore the data for the years 2011 to 2013 were taken from the ACLED data. Note that other datasets forced us to limit the final analysis period to 2000-2010, but 1997-2013 was used in this initial stage to locate clusters of conflict.

In locating conflict hotspots we isolated the non – state conflict data for the years 1997 – 2013 and applied Global Moran's I (Getis and Ord, 1992) method to assess if a spatial autocorrelation exists in the conflict dataset (but this method does not actually map where the clusters occur). Spatial autocorrelation measures the degree to which spatial phenomena tend to be clustered or dispersed in space. The Global Moran's I is given by:

$$I = \frac{N}{S_o} \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{i,j} z_i z_j}{\sum_i (X_i - \bar{X})^2} \qquad \text{(Equation 1)}$$

where N is the total number of events (mapped as features),
$w_{i,j}$ is the spatial weight between feature i and j,
z_i and z_j are deviation of of an event measure for feature I from its mean $(x_i - \bar{X})$ and
S_O is the aggregate of all the spatial weights and is expressed as $\sum_{i=1}^{n}\sum_{j=1}^{n} w_{i,j}$

Global Moran's I considers pairs of variables under consideration at locations i and j that are neighboring one another having a spatial proximity represented by a weighting factor w_{ij}. Global Moran's I ranges between -1 and 1. Once existence of clustering is verified, a two-step optimized hot spot analysis (OHSA) is applied in mapping conflict clusters. The first is OHSA run on the 1997 – 2013 dataset to identify areas of persistent conflict occurrence. This eliminates false clusters as the clustering intensity is high only in areas of persistent conflicts. False clusters result from conflict events driven by causes other than environmental stressors (e.g. public riot, conflict between supporters of opponent parties etc.) which occurs occasionally (e.g. on election year). The Getis–Ord Gi* statistic is used in OHSA to generate the z-score to identify where there is intense point clustering (Mitchell, 2005). The Getis–Ord Gi* statistic is given by:

$$G_i^* = \frac{\sum_{j=1}^{n} w_{i,j} x_j - \bar{X} \sum_{j=1}^{n} w_{i,j}}{s\sqrt{\frac{\left[n \sum_{j=1}^{n} w_{i,j}^2 - \left(\sum_{j=1}^{n} w_{i,j}\right)^2\right]}{n-1}}} \qquad \text{(Equation 2)}$$

Where x_j is the event for pixel j, $w_{i,j}$ is the spatial weight between feature i and j created by the incident aggregation procedure and n is equal to the total number of events with in an aggregation polygon. For statistically significant positive z scores, the larger the z score is, the more intense the clustering of high values or a hot spot.

The scale of analysis is a required input for OHSA. The ideal scale of analysis will be a distance that matches the scale of the phenomena being analyzed, in this case distance that pastoralists move their herds in search of water and forage. A realistic distance can be estimated using the incremental spatial autocorrelation. Incremental spatial autocorrelation performs Global Moran's I statistic for a series of increasing distances thereby measuring the intensity of spatial clustering for the respective distance. The analysis returns an increasing z-score with an increase in analysis distance until it reaches a particular distance where the z-score peaks. The distance where the z-score peaks reflect the distance where the spatial processes promoting clustering are most pronounced. This distance should represent the minimum possible distance that a pastoralist moves the herd in search of water and/or graze. It is assumed that in traveling this distance the pastoralists cross their tribal territory and encounters with the adjacent pastoralist community begins. This distance is compared to literature values and adapted in the OHSA analysis. Oba and Lusigi (Oba and Lusigi, 1987) reported an effective grazing distance of 69 – 80 km for camels, 30 – 40 km for cattle and 0 – 20 km for small livestock in the study area.

Once areas of persistent conflict are isolated a yearly time step optimized hot spot analysis (OHSA) was run on aggregated conflict incidents for the 2000 – 2013 time span to map conflict hotspots on yearly basis. This time frame is selected for the yearly time step analysis due to availability of at least 30 conflict events in each year which is a requirement to run OHSA. The conflict events used to identify the hotspots for each year are then used to construct a two standard deviation directional ellipse. A two standard deviation directional ellipse contains approximately 95 percent of conflict events and shows the central tendency, dispersion, and directional trends of conflict events.The two standard deviation directional ellipses that intersecting with cluster of persistent conflict are isolated and are used to extract gridded precipitation and NDVI data for comparison to conflict events.

2.2.2 Climate and environmental data

The availability of water and fodder is the predominant factor in determining the success of a pastoralist community in a given season. Pastoralists move their livestock to areas with good grazing and abundant water in the dry season while in a normal rainy season they return to their ancestral location. A major forcing for a conflict event could be a failed rainy season or abnormally low precipitation which will force the pastoralists to extend a stay in areas that do not belong to the group. Anomalies of the total monthly precipitation and vegetation presence (computed using the Normalized Difference Vegetation Index) help to identify years of such stresses. Anomalies are deviations from the mean and are created by subtracting the long – term average of a given variable from observed data. Standardized anomalies are calculated by dividing these anomalies by the standard deviation of the variable (i.e. $X_z = \frac{X_i - \mu}{\sigma}$). Standardized anomalies provide more information about the magnitude of the anomalies because influences of dispersion have been removed. Comparison of the occurrence and intensity of conflict events to these anomalies help to identify potential flash points.

A spatial co-occurrence of conflict events and a declining trend in the long term precipitation and NDVI observations should also help to partially explain a causal relationship between conflict and scarcity of water and forage. A preliminary graphical inspection is highly instructive and meaningful. Thus a linear trend fit is used to initially determine if a trend exists. However, parametric tests are often misleading in detecting trends of climatological variables due to the normality assumption embedded in them. A more robust approach is a non-parametric test. Thus, the non-parametric Mann – Kendall (Kendall, 1975; Mann, 1945) test was applied in testing trends both in rainfall and NDVI time series.

Failure or delayed onset of seasonal precipitation puts varying stress on pastoralist livelihoods. Even in a normal rainy season, forage scarcity can occur due to overstocking and/or excessive competition from wildlife. The actual distribution of precipitation is more informative in analyzing stress patterns than the anomaly or total amount. An ideal example is the 2007 flood event that devastated pasture and arable land in north east Uganda (Karamoja area) where a negative anomaly was recorded for both the long and short rain seasons. Thus intense precipitation above or below the long term average may still not be available for consumption as the water will be lost in quick runoff. Thus precipitation alone is a weaker argument to relate to conflict events. Nevertheless precipitation can be used as an initial indicator for water stress. The Normalized Difference Vegetation Index (NDVI) (Tucker 1979), is a signal that can be reliably measured at low cost and it is available near real time. Monitoring vegetation provides a more direct indication of the scarcity of forage on pastures that can cause migrations and conflicts. The spatial resolution of the NDVI data shows greater detail than the precipitation data and thus its anomaly could be used as a lead to related conflict events to pasture stress. In a season with an even temporal distribution of precipitation a sustained NDVI signal is expected, while a season with short but intense precipitation is expected to have reduced NDVI. Thus in analyzing conflicts triggered as a result of water and pasture stresses, precipitation and NDVI were used in tandem.

A 10 year drought return period is a normal phenomenon in the past 100 years in east Africa for which pastoralist community developed resilience (Ellis and Galvin, 1994; Lyon, 2014; McCabe, 1990).

Vegetation anomaly within one standard deviation are generally considered as with in a natural range of variability (Mildrexler et al., 2007). In our analysis the standardized anomalies are taken to indicate “failure” when the seasonal precipitation and NDVI are minus one and below. Based on these considerations we have formulated four conceptual failure[1] cycles to identify the climate and environmental stresses: A normal cycle season, a one cycle stress, a 1.5 cycle stress and a two cycle stress. In a normal cycle season both the long and short season anomalies are above minus one. Under the normal seasonal cycle pastoralist communities thrive as abundant water and forage improve herd growth as long as other factors influencing herd size and health (vis-à-vis disease, cattle rustling etc.) remain constant. As the study area is characterized by a bimodal – precipitation distribution (long precipitation followed by short precipitation), one stress cycle represents a failure of long season rain and NDVI followed by subsequent failure of short season rain or NDVI (referred as ‘two season failure’). Pastoralist communities struggle to cope under this cycle by selling part of their livestock to buy cereals. A 1.5 cycle stress is a one stress cycle followed by subsequent failure of the long season rain or NDVI (‘three season failure’). Livestock typically will have lost condition at this stage (and thus value) and hence a considerable part of the herd may need to be sold to match a subsequent increase in price of cereals. Pastoralist communities start feeling the stress in this cycle. In a two cycle stress two years of long and short season rain or NDVI fail (‘four season failure’). At this point in some pastoralist communities, individuals who are not essential to herding may move to urban centers in search of labor, and wives with their children will return to their parents (McCabe, 1990). The ellipses in the definition diagram (Figure 2) depict the effects of the respective cycles on pastoralist livelihood and the shrinking chance of survival (i.e. increased risk – diverging arrow).

[1] Failure in this context refers to a seasonal (both long and short) rainfall below the long term seasonal mean

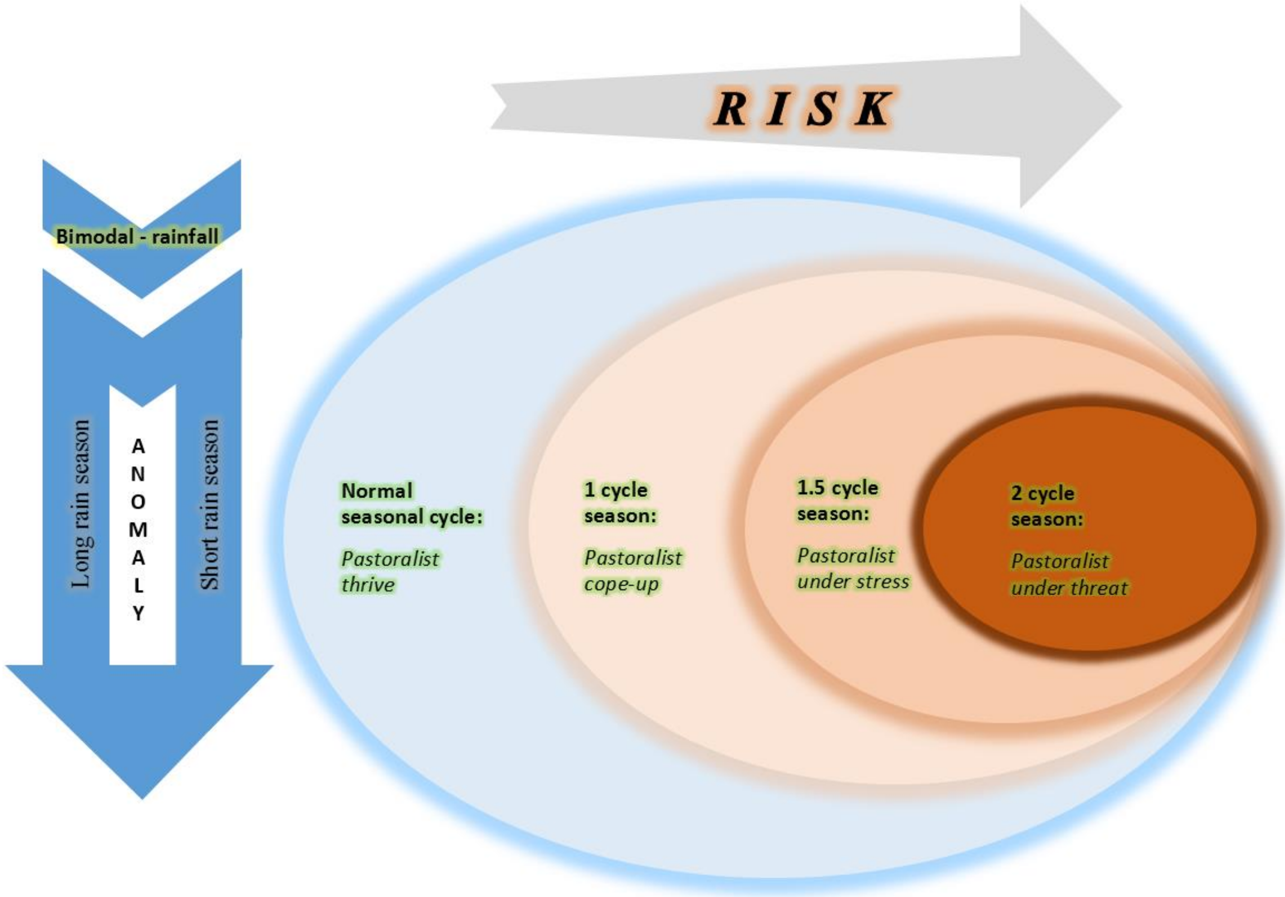

Figure 2. Definition diagram of stress cycles experienced by east African pastoralist communities.

Precipitation and vegetation data are available at varying spatial scale. Precipitation datasets are available either from weather stations (although few are available in East Africa) or from precipitation estimates derived from satellite (Dinku et al., 2011). The spatial resolution of gridded precipitation estimates are much coarser than conflict data, typically ranging from 5 km to 250 km. Average historical monthly precipitation data from CPC[2] Merged Analysis of Precipitation (CMAP), Climate Hazards Group InfraRed Precipitation with Stations (CHIRPS) and Global Precipitation Climatology Project (GPCP) were extracted for areas where conflict clusters are observed. CMAP is a monthly precipitation data set available from 1979 to 2011 constructed on a 2.5° latitude–longitude grid by merging gauge, satellite estimates and numerical models (Xie and Arkin, 1997). The CHIRPS dataset is a 0.05^{o} spatial resolution global gridded monthly precipitation averages product available from 1981 to 2015 are derived by combining satellite observations, average precipitation from stations, and precipitation predictors such as elevation, latitude and longitude (Funk et al., 2013). GPCP is produced utilizing the higher accuracy of the low-orbit microwave observations to calibrate the more frequent geosynchronous infrared observations (Adler et al., 2003). GPCP is monthly analysis of surface precipitation at 2.5° resolution and is available from January 1979 to 2014. All three datasets were compared to NDVI to

[2] Climate Prediction Center of the National Oceanic and Atmospheric Administration (NOAA)

validate the correlation between precipitation and NDVI, but then the CMAP data was used to identify water stresses for the final conflict analysis.

A 25 year period (1981 to 2006), 1 km resolution NDVI product (Tucker et al., 2005) derived from the Advanced Very High Resolution Radiometer (AVHRR) was used to construct the long term NDVI trend map. NDVI products from Moderate – resolution Imaging Spectroradiometer (MODIS) images are also available from 2001 – 2013 at 1 km resolution which was important to extend the temporal overlap with the conflict data (MODIS data was used from 2007-2010). Huete et al. (2002) reported higher temporal profiles fidelity of MODIS derived indices in comparison to AVHRR. Parametric and non-parametric tests were applied to examine trends in precipitation and vegetation anomalies. Seasonal variation and long term trends of precipitation and vegetation were analyzed for each directional ellipse resulted from the OHSA. The geographical boundaries of each region defined from the OHSA were used to extract weighted-averages of precipitation and NDVI time-series. The weighted-averages were computed by applying a weight based on the proportion of the pixel included within the boundary to the spatial average of total pixels located within the boundary. A separate analysis identified the existence of 1, 1.5 and 2 cycles stress within the merged directional polygons from GPCP precipitation data (1979 – 2010 to match the availability of CMAP and conflict data).

Topographic setting also determines the precipitation distribution and thus the abundance of forage for livestock. With reduced evapotranspiration loss and increased orographic rainfall, highland areas have relatively higher available water for vegetation growth. Abundant water and graze can attract neighboring pastoralists possessing large number of herds in an arid landscape. Neighboring areas of abundance shorten livestock travel time. For areas where apparent cross-border conflicts exist, the directional polygons are further split by topography and variation in precipitation and NDVI examined. A significant variation in topography and the consequent higher availability of water and graze can help explain conflict events in highlands. The visible difference in elevation along the Kenya – Uganda border along with the number of conflict events reported in the area demands further exploration of the driver for pastoralist conflict. A 30 m digital elevation model (DEM) was used to isolate major topographic classes in the identified conflict clusters (Figure 3). The precipitation and NDVI in these topographic classes were analyzed along with the conflict events for the time period where all three data sets were available, namely 2000-2010.

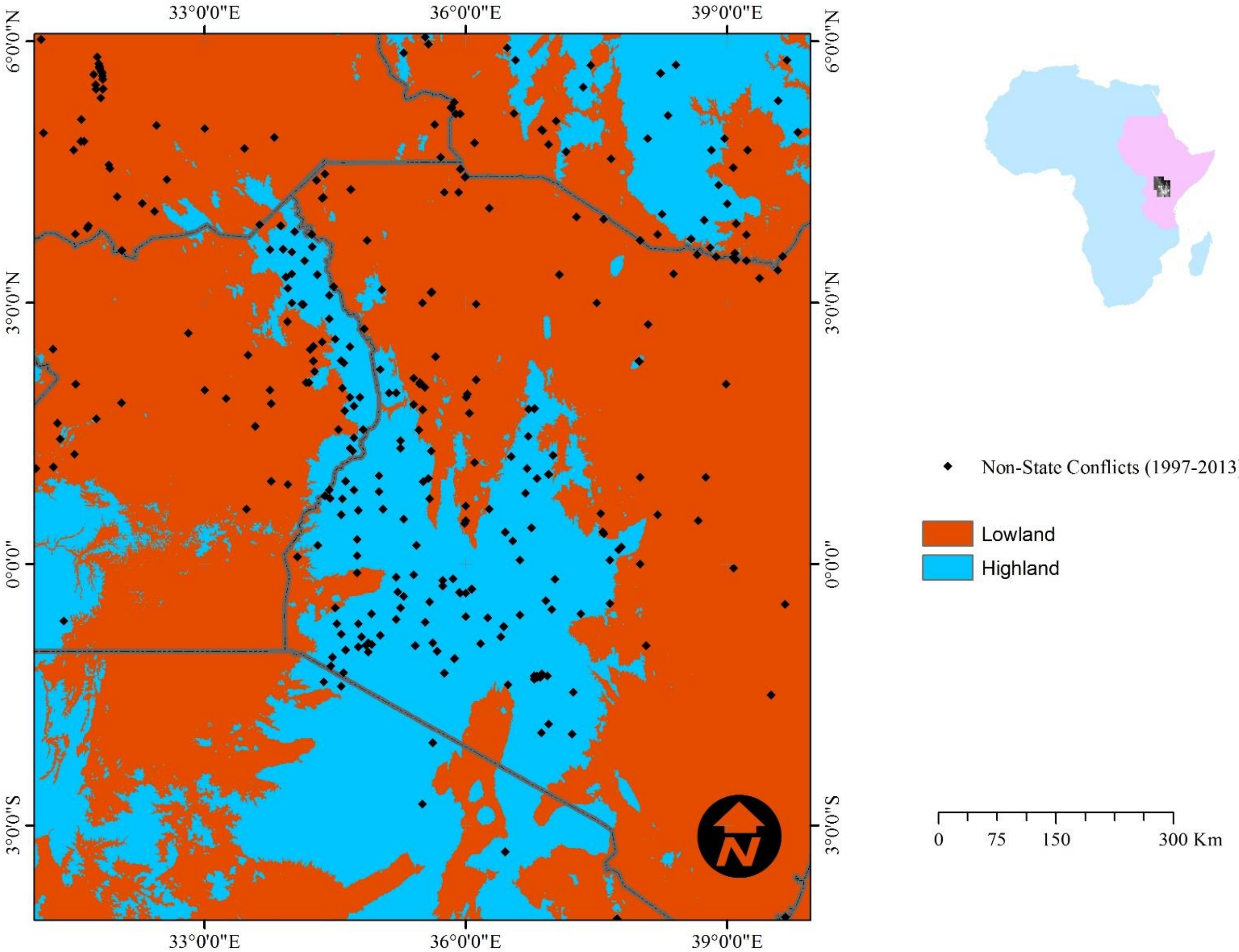

Figure 3. Topographic settings at Kenya – Uganda border, 80% of the conflicts reported occurred in the highland of the Karamoja cluster

3 RESULTS AND DISCUSSION

3.1 Conflicts

The Global Moran's I (Equation 1) analysis showed significant clustering (I=0.053, p=0.000). The incremental spatial autocorrelation analysis indicated that conflict clusters are most pronounced at a 22 km analysis scale. This is an estimated moving distance for small livestock. Literatures indicate goats and sheep are preferred in the post drought herd reconstruction due to their fecundity and hardiness (Oba and Lusigi (1987)).

Analysis on the 1997 – 2013 conflict data helped to identify a major conflict belt stretching along the east – west direction at the borders of Ethiopia, Kenya, Somalia and South Sudan. The belt encompasses the three pastoral conflict clusters identified by the UN Office for Coordination of Humanitarian Affairs (OCHA) as Karamoja (Kenya – South Sudan – Uganda boarder), Moyale (Ethiopia – Kenya border) and Mandera (Ethiopia – Kenya – Somalia border) clusters (OCHA, 2008) (Figure 4). Similar naming as to that of the OCHA is used in subsequent sections to refer to the clusters.

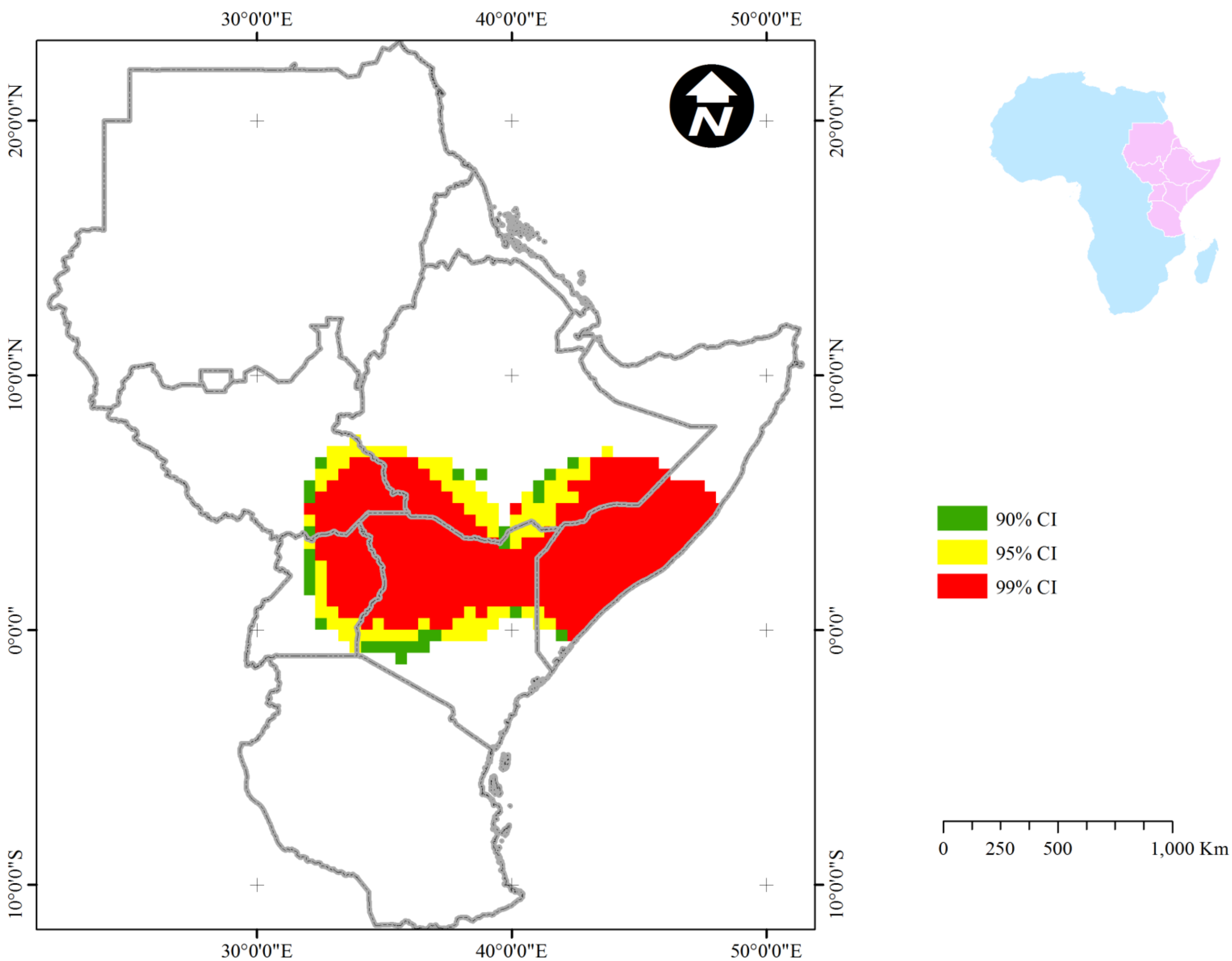

Figure 4. Non – state conflict hot spot of east Africa (1997 – 2013)

Applying OHSA on conflict events of each year from 2000-2013, 15 conflict hotspots were identified (Table 1). These hotspots represent battle grounds for 325 conflict incidents in the 2000 and 2013 time span and are bracketed in the 95% confidence level hotspot belt (Figure 4). Thirteen of these hotspots (referred to from this point on as 'conflictsheds') are areas where conflict among pastoralists has become persistent (independent of environmental variables). Two conflict clusters in West Sudan and South Sudan are not persistent in the 2000 – 2013 analysis period and hence are left out. A third cluster at the Ethiopia – Kenya – Somalia border is also abandoned due to the uncertainty in the nature of the conflicts that persists for more than 20 years due to the civil war in Somalia. The long civil war in Somalia creates difficulty in isolating pastoralist conflicts. During the civil war, conflict incidences were frequent and most of these were among warring warlords. It is hard to identify which ones are among herders. Only conflict events along the Ethiopia – Kenya – Somalia border (also called the Mandera cluster) were thus considered in the analysis as these are previously documented (OCHA, 2008). The Moyale cluster is home to Borana, Gabra, Garre, Guji and Sarawit pastoralists on the Ethiopian side, and

Borana, Samburu, Rendile and Somali pastoralists in the Kenyan side. The area has experienced major persistent conflicts since 1990. The highland in the Karamoja cluster is populated mainly by Iteso and Karimojong whereas the lowland is home to the Turkana community (Odhiambo, 2012).

Table 1. Pastoralist conflict clusters of East Africa, a year by year analysis result (2000 – 2013)

Year	Conflict events	Geographic area	Number of clusters
2000	36	▪ Northern Uganda – Kenya border ▪ South Ethiopia –Kenya border	2
2001	19	▪ Northern Uganda – Kenya border ▪ South Ethiopia –Kenya border	2
2003	32	▪ Northern Uganda – Kenya border ▪ South west Ethiopia – South Sudan border	2
2005	34	▪ Northern Uganda – Kenya border ▪ South west Ethiopia – South Sudan – Kenya border ▪ North east Kenya – Somalia – Ethiopia border	3
2008	75	▪ Uganda – Kenya border ▪ South west Ethiopia – South Sudan – Kenya border	2
2009	53	▪ South Sudan ▪ Northern Uganda – Kenya border ▪ South west Ethiopia – South Sudan border	3
2013	76	▪ West Sudan	1
2000 - 2013	325	▪ Ethiopia – Kenya – South Sudan – Uganda border	1

The resolution of individual year directional ellipses (Table 1) is small as compared to the precipitation grid such that analysis of precipitation trends for individual year conflict clusters appears spatially invariant. The polygons used in extracting precipitation and NDVI are thus constructed by merging overlapping directional ellipses. Thus the individual year conflict cluster polygons along the south Ethiopia and Kenya border are merged to form the Moyale cluster polygon and those at the Uganda and Kenya border are merged to form the Karamoja cluster polygon (Figure 5). The merged polygons are used to extract precipitation (from CMAP) and NDVI anomalies.

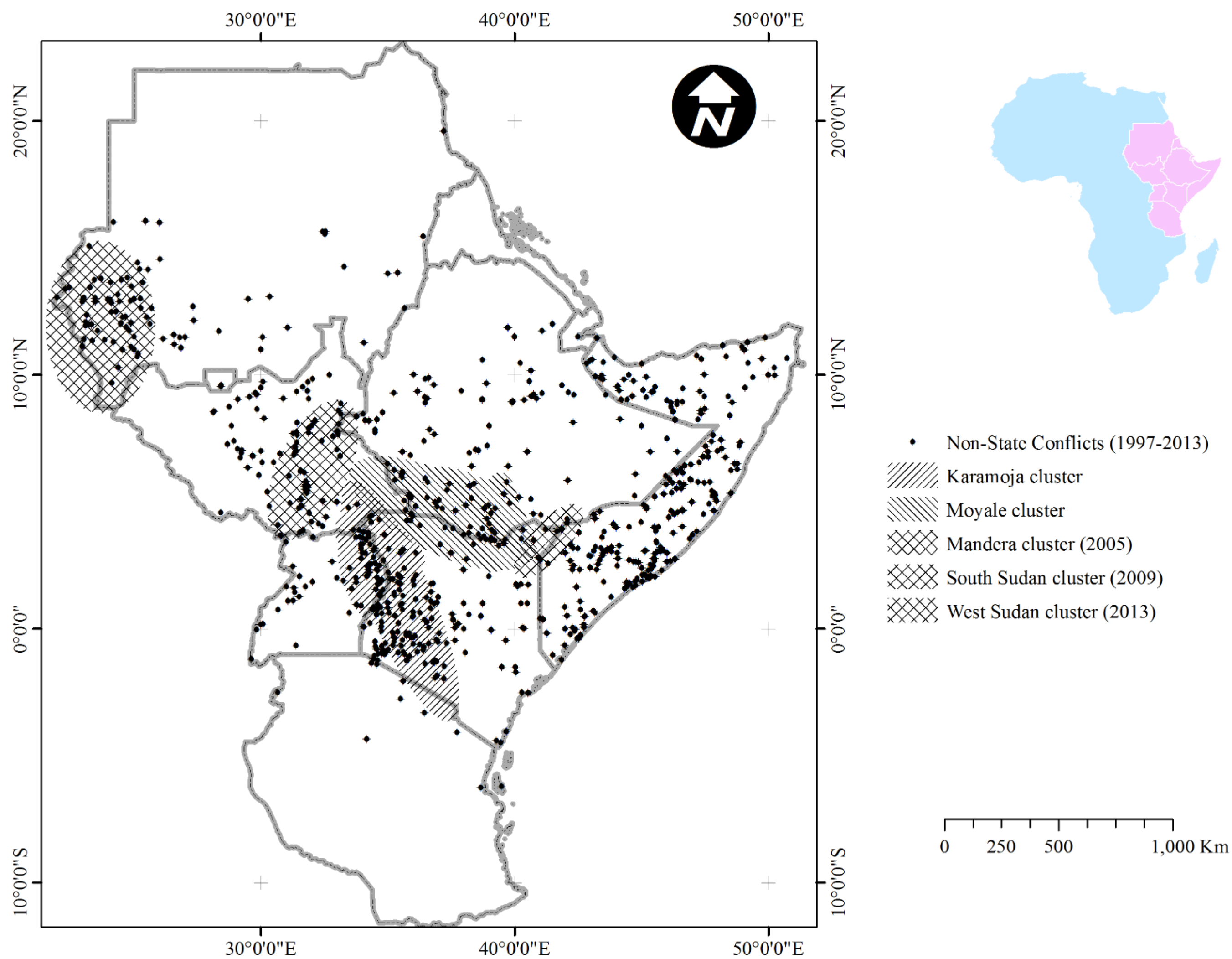

Figure 5. Major clusters of non-state conflicts (1997 – 2013) of East Africa. The South Sudan, West Sudan and Mandera clusters (crosshatch) are left out as isolated incidences or unidentified conflict category whereas the Moyale and Karamoja clusters (simple hatch) are further analyzed for precipitation and NDVI condition

3.2 Precipitation and NDVI anomalies

Figure 6 presents the long (March – May) and short (October – December) season precipitation and NDVI anomalies. A decline in precipitation and NDVI is observed from 1998 through 2010 in the two clusters. A dip in NDVI in 2000 follows a sustained decline in both the long and short season precipitation since 1998. Based on 33 years precipitation and 32 years NDVI data both parametric and non – parametric tests yield a statistically significant ($p < 0.05$) declining trend of the long rainy season precipitation and NDVI of the short rain season in the Moyale cluster. The precipitation and NDVI trends are statistically not significant for Karamoja cluster. Lyon (2014) reported similar finding on precipitation based on a 60 years data analysis for the greater horn of Africa. It is apparent that the failure to adequately represent spatial precipitation variability within the cluster polygons due to the coarser resolution of the precipitation products have an impact on the trend analysis result.

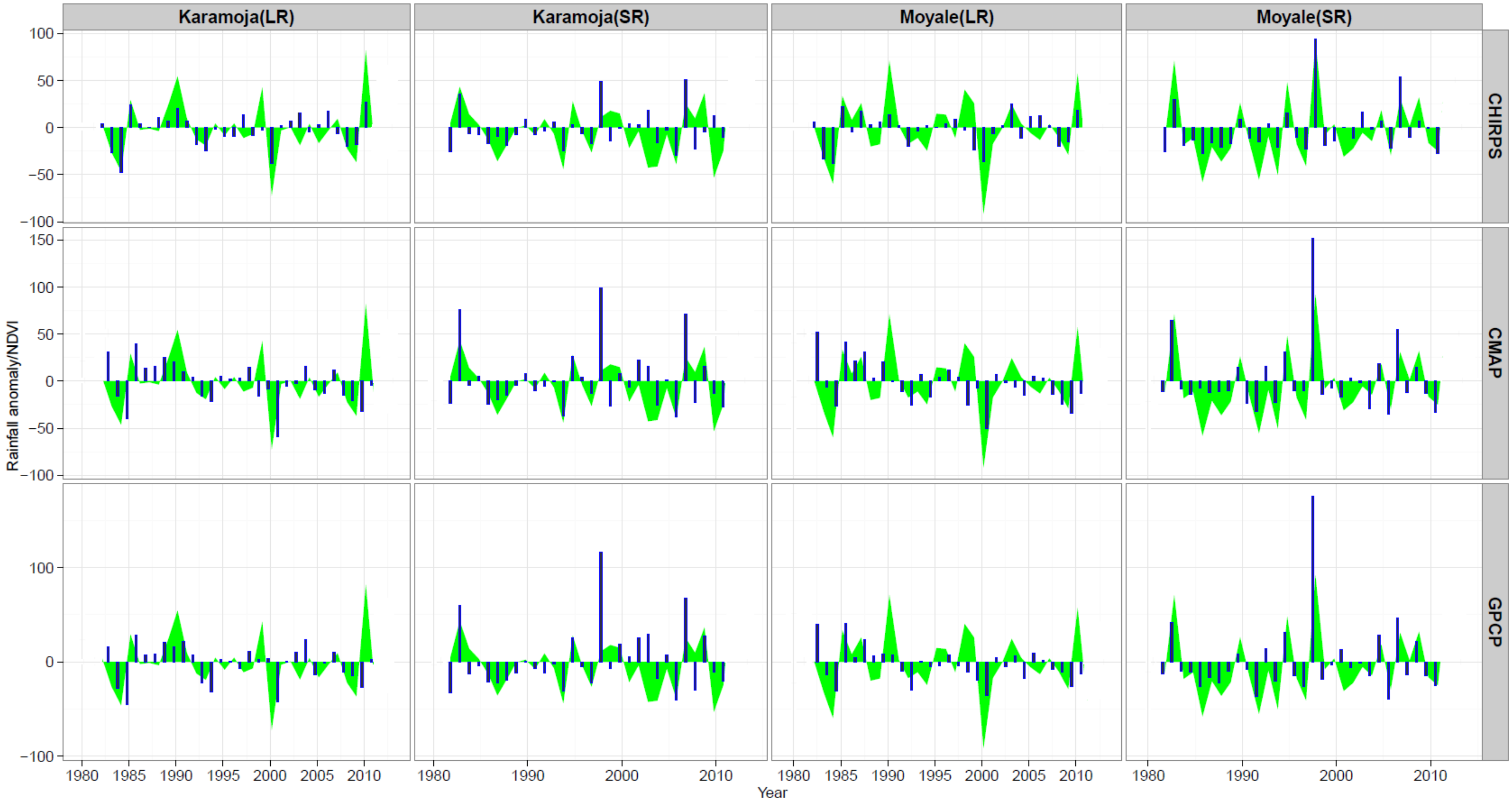

Figure 6. Precipitation (blue) and NDVI (green) anomalies from CHIRPS (Funk et al., 2013), CMAP and GPCP (Adler et al., 2003) for longer (LR) and shorter (SR) rainy seasons, NDVI values are exaggerated 1000 times

3.2.1 Precipitation/NDVI – conflict relationship: Cluster based analysis

a) Moyale cluster

The stress cycle analysis for the three decades where NDVI and CMAP precipitation data were available (1981 – 2010) showed that four season precipitation stress occurred only once in each decade with no NDVI stress observed for the same time span. Three season precipitation stress frequency quadrupled in the second decade but declined to two in the third decade. The comparison outcome for intensity of the drought and number of conflict incidences in the 2000 – 2010 period is shown in Table 2. Conflicts were reported for the years 2001, 2002, 2004 and 2006 while environmental stresses were non-existent. It was only in 2010 that all water stress cycles are observed and yet the number of conflicts are modest as compared to the years 2001 and 2009. 2000 was the only year in the third decade where pasture stress occurred, and there was no precipitation stress that year.

Table 2. Number of conflicts (2001 – 2010) and occurrence of water stress [Rainfall] cycles in Moyale cluster (0 indicates nonoccurrence and 1 indicates occurrence of stress). There was a single one-cycle pasture stress [NDVI] observed in the Moyale cluster in the year 2000.

		20	**18**	**14**	**0**	**8**	**0**	**10**	**0**	**0**	**20**	**14**
Stress cycles	1	[0]	[0]	[0]	[0]	[0]	[0]	[0]	[1]	[0]	[1]	[1]
	1.5	[1]	[0]	[0]	[0]	[0]	[0]	[0]	[0]	[1]	[0]	[1]
	2	[0]	[0]	[0]	[0]	[0]	[0]	[0]	[0]	[0]	[0]	[1]
		2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**

b) Karamoja cluster

The stress cycle analysis for the three decades where NDVI and CMAP precipitation data were available (1981 – 2010) showed that four season precipitation stress occurred only once in the first two decades with no NDVI stress observed during the study period. Three season precipitation stress frequency tripled in the second decade but declined to one in the third decade. The comparison outcome for intensity of the drought and number of conflict incidences in the 2000 – 2010 period is shown on Table 3. Conflicts were reported for the years 2003, and 2009 while environmental stresses were non-existent. It was only in 2010 that all stress cycles are observed and yet the number of conflicts are modest as compared to the years 2001 and 2009. The year 2008 reports considerably higher conflict events for just a three season stress and prior years without any of the stress cycles. As with the Moyale cluster, 2000 was the only year in the third decade where pasture stress occurred, and there was no precipitation stress that year.

Table 3. Number of conflicts (2001 – 2010) and occurrence of water stress [Rainfall] cycles in Karamoja cluster (0 indicates nonoccurrence and 1 indicates occurrence of stress). There was a single one-cycle pasture stress [NDVI] observed in the Karamoja cluster in the year 2000.

		22	**5**	**0**	**24**	**0**	**11**	**0**	**0**	**55**	**9**	**0**
Stress cycles	1	[0]	[0]	[0]	[0]	[1]	[1]	[0]	[1]	[0]	[0]	[0]
	1.5	[0]	[1]	[0]	[0]	[0]	[1]	[0]	[0]	[1]	[0]	[0]
	2	[0]	[0]	[0]	[0]	[0]	[1]	[0]	[0]	[0]	[0]	[0]
		2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**

High prevalence of conflicts in the years 2000 and 2001 follows the full onset of the drought that began in 1999 and lasted until 2001. The year 2008 reports the most conflicts in the Karamoja cluster despite a moderately low negative deviation in the long season NDVI. Interlinking conflict events to precipitation and/or NDVI in Karamoja cluster is exceedingly difficult as this is one of the world's most armed violence-afflicted regions (Bevan, 2008). Large number of conflict events were observed in 2008 However the 2007 flood that devastated pasture and arable land followed by a drought (two cycle stress, Table 3) in the following year (Bevan, 2008; Miljkovic, 2008) may have contributed to more conflict events in 2008. The prolonged drought in the lowland (1998- 2001) of the Karamoja cluster may also drive pastoralists from the lowland cross to the highland. The Turkana nomads inhibiting the lowland are known for high number of mobility per year including cross border ones (Oba and Lusigi, 1987). Unfortunately, these types of conjectures provide plausible explanations for the patterns observed in the data, but not definitive proof or quantitative assessments of the strength of evidence.

3.2.2 Landscape based analysis

In comparing conflict events to precipitation and NDVI at the Karamoja cluster the effect of topography is found to be pronounced. This is mainly because even in a season with below average precipitation, NDVI decline is modest due to a low evapotranspiration. The Karamoja cluster has two distinct topographic regions; a mountainous highland with elevation ranging from 1200 – 1450 meters on the Ugandan side of the border and a lowland with elevation 280 – 1200 meters in the Kenyan side. Comparison of precipitation and NDVI shows that the lowland has considerably lower vegetation cover than the highland (Figure 7). Moreover the vegetation abundance for the short rainy season is comparable to that of the long rainy season. The cattle density in these areas was reported to rise from an average of 40 heads/km^2 in 1982 to 85 heads/km^2 in Kenya and 105 heads/km^2 in Uganda in 1988 (de Leeuw, 1992). On a recent livestock global distribution map Robinson *et al.* (2014) indicated places in eastern Uganda with as much as 250 heads/km^2. Thus vegetation abundance in the highlands attracts pastoralists of the lowland to move livestock to the highlands. The precipitation and NDVI stress cycles of two, three and four seasons in the last three decades are considerably higher in the lowland. The highland experienced only one four season precipitation stress with no NDVI stress for the same period. On the contrary, the lowland suffered nine two season stress, five three season stress and two four season stress cycles in the last three decades.

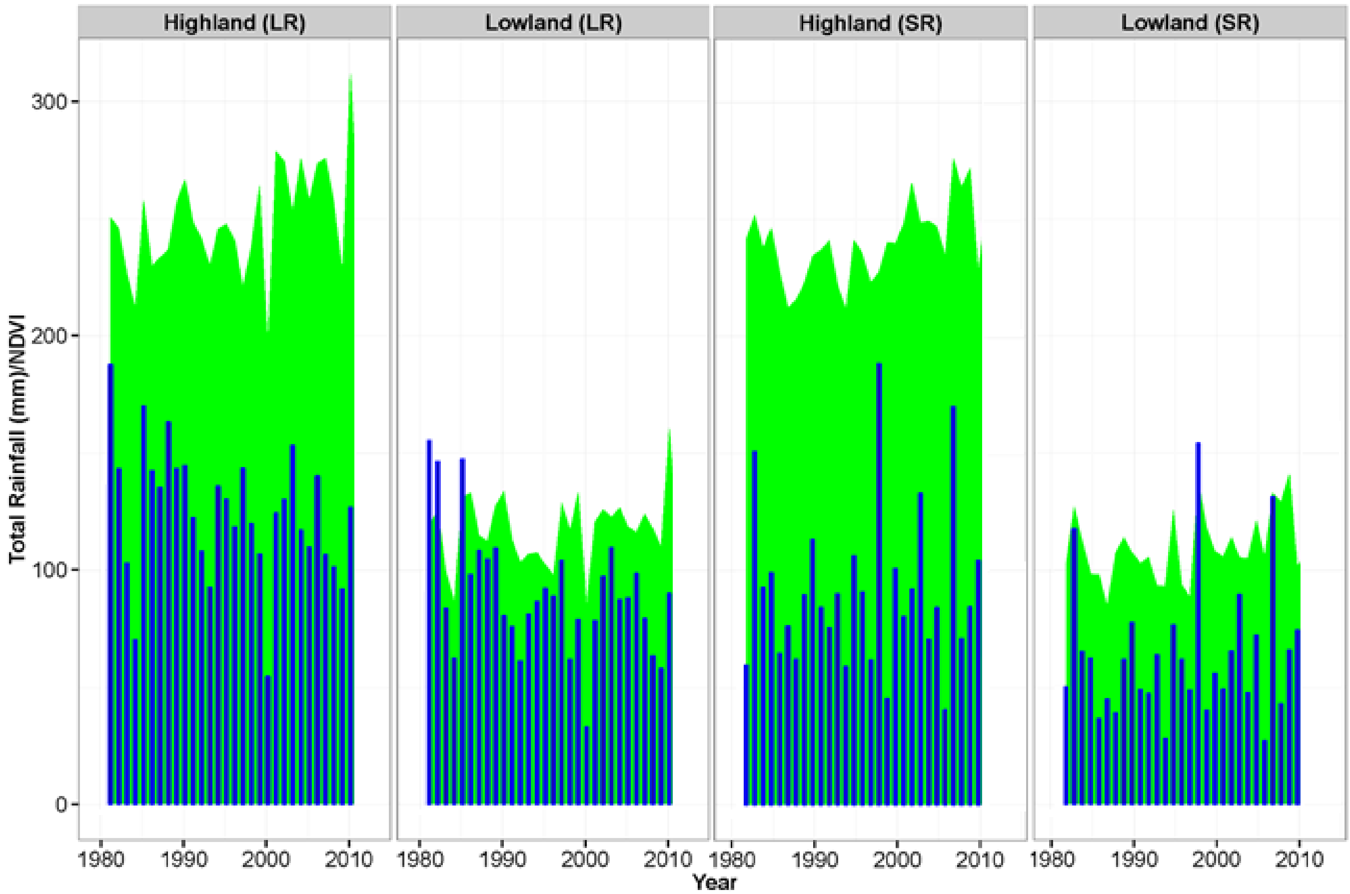

Figure 7. Comparison of precipitation (blue bars) and NDVI (green, exaggerated 500 times) in the Karamoja cluster (1980 – 2010)

4 CONCLUSION

The claim that environmental factors are major drivers of conflict between pastoralists has been challenged repeatedly (Kevane and Gray, 2008; Raleigh et al., 2008; Raleigh and Kniveton, 2012). We found that data on patterns of precipitation and NDVI (forage) fail to explain pastoralist conflicts of east Africa. A major hurdle in connecting the onset of conflict with climate and environmental factors is the unpredictability of pastoralists' response to such stressors. The lag in a response to these environmental stressors depends on the coping mechanisms available to the pastoralists. Pastoralists in possession of drought resilient herds (e.g. camels) will be able to withstand drought for longer without needing to respond than their counterparts possessing cattle and small ruminants. However, a prolonged decline in precipitation and biomass in the region could exhaust all of the coping mechanisms available to pastoralists, shortening the lag between additional environmental stressors and a response. Thus, if a long term decline in precipitation and NDVI existed, it could increase the likelihood of a causal relationship between environmental factors and occurrence of conflict in recent years. It is apparent from the results that precipitation and NDVI stresses are not spatially related to conflict events. The result also showed that the cluster based analysis essentially miss the narratives of conflict triggering processes. A more realistic scenario for the trigger of conflict is the transgression of tribal boundaries by stressed pastoralists into areas where water and graze is abundant. As such the basis for the start of the conflict is the presence of outsiders in the area of plenty of water and graze which belongs to other pastoralist groups. Thus conflict events and abundance of precipitation and NDVI tend to spatially co-occur. The landscape based analysis supports this scenario. Nearly half of the pastoralist conflicts reported in 2000 – 2013 in the Karamoja cluster occurred in the Karamoja highlands.

With no apparent declining trend in NDVI, conflicts may be attributed to shortage of fodder due to increasing number of livestock and competition from wildlife. This is especially true in the western lowlands of Kenya. Population density in all the conflict clusters had also increased exponentially from 1960 – 2000. The fact that pastoralists in the study area live mainly off the milk of their herd and not off their meat (Prins, 1992) suggests an exponential growth in livestock density. With nearly double NDVI, abundant water and shorter herd travel time the eastern Uganda highlands attract cross border migration.

The scale of measurement of precipitation could also be taken as a limitation in the regression analysis. Existing spatial resolutions are too coarse to represent precipitation variability in the varying landscape of the study area. Moreover availability of precipitation doesn't guarantee availability of water. This is because availability of water is a function of factors such as intensity of precipitation events (e.g. intense rains where most water is lost as runoff), soil property, land cover, and topography. None of these variables are accounted for in the regression and hence precipitation alone could not be a good interpreter for occurrence of conflict. Thus the precipitation as a regressor to conflict incidents could not optimally frame pastoral group's reaction to environmental stressors.

The large increase in livestock density especially in the lowlands of Karamoja, and a seemingly abundant forage supply in the highlands of Kenya – Uganda border may indicate a future pastoralist conflictshed. While environmental factors did not appear to be directly strongly correlated with conflict between pastoralists in this analysis, future analysis should investigate other potential stressors that could contribute to the conflict (independently or in combination). In addition to environmental causes, factors such as political, social and economic factors should be systematically quantified and investigated. These include poor collaboration and planning, ineffective use of resources, inability to capitalize on experiences at different levels, inability to share information and barriers to knowledge management, lack or deterioration of social capital, the role of organized crime and widespread possession of small arms (Abdulahi, 2005; Broeck, 2009; Morton, 2007; Mwaûra and Schmeidl, 2002).

The onset of conflict is a culmination of a prolonged process of strife (natural, economic, social, etc.). As such, social groups tend to seek for all available options for survival. Not all members in the social group have the same resilience to shocks; some have better physical or financial conditions than others. It is only when stresses exceed a community's ability to withstand them that a critical mass among the community feels that they have nothing to lose in going to a battle, and thus conflicts begins. The natural, economic, social, and other factors that drive stress leading to conflict are often complicated and intertwined, making them challenging to measure using ordinary methods. Because environmental factors are the most readily quantified factors that contribute to these stresses, many scientists continue to argue that drought and other environmental factors are drivers of conflict. Nevertheless, in addition to analyses like this paper showing that they are not well correlated, there are plenty of anecdotal examples of severe drought that were not accompanied by conflict such as the 2011 Somalia drought and a number of droughts in Ethiopia and Kenya since 1993.

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