DANGEROUS GEOGRAPHY: SPATIAL DISTRIBUTION OF LIVESTOCK RAIDING IN NORTHWESTERN KENYA

Teferi Abate Adem
Carol R. Ember
Ian Skoggard
Human Relations Area Files
Yale University

Eric C. Jones
The University of Texas at El Paso

A. J. Faas
San Jose State University

In a previous study, Ember and associates (2012) found that livestock-related violence involving the Turkana was higher in dry months, drier years, and when months were drier than expected between the years of 1998–2009. This article has data on livestock-related violence from media reports, together with localized and georeferenced spatial and rainfall maps, to explore the question of whether and how strongly landscape variations (e.g., in topography, rainfall variability, and hydrology) predict the place and intensity of livestock raids. Our findings broadly replicate a longstanding land-use dilemma well documented in ethnographic accounts. During the wet season, Turkana herders camp in relatively safe areas at the center of the district. With the onset of the dry season, they must move away to access pasture in blocks along the boundaries with hostile ethnic groups. Much of the raiding by the Turkana on others occurs along the borders where the rainfall pattern is relatively reliable. By contrast, most of the raiding against the Turkana occurs while the herds are on transitional moves, splitting from, and coalescing at, the margins of expansive plains, en route to patches of dry-season ranges. While most of the results are consistent with ethnographic reports, we do find some spatial patterns that were not previously apparent, particularly regarding water. We suggest that policy interventions at mitigating livestock raids need to take account of links between spatial conditions and the onset of localized raiding incidents. (Livestock raiding, pastoral conflict, Turkana, Northwestern Kenya)

This article explores spatial patterns of livestock raiding in Turkana district, northwestern Kenya, using some data-collection methods not often considered by ethnographers. First, the data are on violence from media reports. Second, the georeference places in these reports—using Geographic Information System (GIS)—permit seeing what land/water forms are nearby. Third, we use rainfall data from NASA. All of these data are pinpointed to 30x30 km quadrants in and around Turkana District. We undertake this essay not to

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minimize or dismiss the extraordinary contribution of in-depth ethnographic research, but rather to see if these data, triangulated with information from ethnographers, can help our understanding of such violence.

Turkana pastoralists, like other East African nomadic herders, seasonally move through a variety of biophysical environments or ecosystems. Ethnographic accounts indicate that mobility decisions are influenced not just by availability of pasture and water but also by other factors including risks of losing livestock to raiding by other ethnic groups. Herd managers seek to minimize this risk by adjusting their migration routes and the duration of their stay at a particular location to fit the changing security conditions. They typically move to places deemed safer while abandoning dangerous areas (see, e.g., McCabe 2004 for Turkana and O'Leary 1984 for Rendille and Gabra). Not surprisingly, this strategy suggests that herders of various ethnic groups maintain a degree of familiarity with local temporal and spatial conditions that may provide opportune times for the onset of livestock raids.

While such local spatial conditions are the focus in this essay, we do not presume that risks of livestock raiding can be explained solely by geographic features. Generations of scholars in anthropology and related disciplines have attributed pastoral violence to a combination of cultural (e.g., Fukui and Turton 1979), economic (see McPeak, et al. 2011; Fleisher 1998; Bollig 1990), and political (e.g., Abbink 2007; Eaton 2008; Hagmann and Alemmaya 2008) factors in addition to, and in interaction with, ecological factors (e.g., Gray, et al. 2003; Homer-Dixon 1999; Bollig 1993; Ember, et al. 2012). In this exploratory paper, we focus on landscape-level features for heuristic reasons.

By doing so, we hope to contribute to recent debates on possible effects of drought-induced resource scarcity on the intensity of livestock raids. For example, livestock-related violence involving the Turkana is higher in dry months, drier years, and when months are drier than expected (Ember, et al. 2012). The results run contrary to Witsenburg and Adano's (2009) study in the neighboring Marsabit district, where they found livestock-related violence to be higher in wetter months and wetter years when both pasture and water are abundant (see also Adano and Witsenburg 2004). Here, we change from the temporal focus of these studies to a different set of questions about spatial distribution of livestock-related violence. Does frequency of livestock raids and resulting casualties differ across different landscape features? If so, what landscape features predict more incidents and deaths? Are there relationships between livestock-related violence and specific water features (rivers, seasonal springs, and wells) or patches with better or worse rainfall? If, as we hypothesize, drought-induced resource scarcity is an important factor leading to the increased likelihood of livestock-related raids, we expect pastoralists to head for regions that have more water, either because of more predictable rainfall or the presence of water features.

By systematically exploring links between livestock raids and landscape-level variations in topographic and resource conditions, possible answers to these questions can be provided and achieve two goals: (1) use data encoded in a GIS to explore links between specific spatial conditions that may help predict likelihoods of livestock raids and their intensities, and (2) use ethnographic data to corroborate and further develop our understandings of these findings. As in Ember, et al. (2012), the measures of livestock-related violence involving Turkana are derived from media reports from 1998 to 2009. We also used rainfall data from the United States National Atmospheric and Space Administration's Tropical Rainfall Measuring Mission (TRRM) for the same time period.

With the help of GIS expert collaborators from a larger project on agent-based modeling of violence in eastern Africa, this study also constructed a grid of quadrants as the units of analysis—each measuring 0.25x0.25 decimal degrees or about 30x30 km square area. These units include 95 quadrants inside Turkana District and additional ones in surrounding regions (see Appendix A, Figures 1 and 2). Within Turkanaland, these relatively small units constitute about half of the grazing radius of most herding units, which covers an estimated 12.5 square kilometers from the main camp (Dyson-Hudson and McCabe 1985:72). More specifically, the units broadly match the kind of primary land-use units distinguished by individual herd managers based on differences in soils, micro-climates, vegetation, hydrology, and physiographic features including variations in altitude and topography (McCabe, et al. 1999:109–21). Furthermore, the units are also in some agreement with the type of "physiographic or ecological zones" researchers in the South Turkana Ecosystem Project (STEP) identified in the district (Little, et al. 1999:317–30; see also Ellis and Coppock 1985:315–31). Some of our analyses also include quadrants outside Turkanaland, since the Turkana do attack outside their borders and are attacked outside Turkana District.

Mitigating pastoral violence, of which livestock raiding is one specific form, has been a key policy agenda for intergovernmental co-operation among eastern African countries. In 2002, for example, member states of the Intergovernmental Authority for Development (IGAD) launched a collaborative program called Conflict Early Warning and Response Mechanism (CEWARN) which, among other goals, seeks to provide appropriate mechanisms for early warning and intervention. The Turkana, together with the Karamojong, Dodos, Toposa, Nyangatom, and Dassenech peoples living in the cross-border areas of Kenya, Uganda, South Sudan, and Ethiopia, constitute one of the "cluster areas" chosen for this intervention. The empirical evidence generated in this essay should inform this initiative. We also hope to supplement the anthropological and historical literature that tends to lack a quantitative foundation for supporting its otherwise rich description of the many causes, courses, and consequences of livestock violence among East African pastoral communities.

THE SETTING

In the 1980s, when anthropologists Dyson-Hudson and McCabe (1985:54) began their intensive study of four nomadic pastoral families in southern Turkana, the district was suffering from the onset of yet another seasonal drought. Locally named "luchu," that drought was devastating and lasted for three dry seasons. The study families of Angorot, Lorimet, Atot, and Lopericho responded, as they have been doing for generations (cf. Gulliver 1951 and 1985), by moving their herds and households from the low productive central plains used during wet seasons to the highly productive patches of dry-season ranges at the southern half of the district.

McCabe's detailed records of each herd owner's movement strategies over the course of the ensuing years reveal substantial family-level variability in the number of moves and distances traveled. During the second year of the drought (1980–1981), for example, Angorot moved his main camp 16 times and covered a distance of 129 km. Meanwhile, Lorimet moved only seven times and covered just 60 km. However, when the drought was about to end a year later, Lorimet changed camp 19 times and covered a staggering distance of 323 km, while Angorot traveled only 177 km and moved 15 times (McCabe, et al. 1999:118).

The records also show that each herd owner tried to make best use of scarce forage by dividing the herd, often consisting of camels, cattle, sheep, goats, and donkeys, into smaller species- and productive-specific groups. While this strategy reveals commonality in the coping strategies of each herd owner, there was again a substantial variability in the extent each herd owner pursued this. Ribo, for example, separated his camels only for two months of the entire three-year period of 1979–1981, while Lorimet did so for 12 months. Likewise, Angorot separated his small stock for only five months, but Lopo surpassed him by separating his for 18 months (McCabe 1990).

These family-level drought responses illustrate three salient features of Turkana social organization and production practices well described by generations of anthropologists. First, the basic production unit in Turkana, as in other East African nomadic pastoral societies, is the herding unit (*awi*), generally composed of a man, his wives, children, and (depending on his wealth in livestock) dependent members (Dyson-Hudson and McCabe

1985:71). Under the leadership of the head, members of this unit provide all the labor needed for taking care of a single herd complex.

Second, success as a herding unit manager requires, among other things, access to water and various kinds of grazing areas needed by each kind of livestock. In an arid ecology, like Turkana district where vegetative productivity is greatly dependent on localized rains, this is better achieved by moving across varied topographic features. Theoretically, each Turkana herder owner could do so by freely moving within the boundaries of his sectional territory. In practice, however, a herd owner's moves are limited within a smaller home range (*ere*), which is determined by the area where he habitually returns when forage is abundant after the rains, and also determined in part by his rights in private wells (Dyson-Hudson and McCabe 1985:271).

Third, caring for the herd complex involves many more responsibilities than the more obvious tasks of watering and feeding livestock. A good herder would, for example, ensure the health of his animals by taking measures like avoiding riverine forest infested with tse-tse, removing blood-sucking parasitic ticks, and nursing sick animals, including with medication when available (McCabe 1990:89). More relevant for this article, members of each herding unit are responsible for guarding their livestock from both human predators and wild beasts. Some of the measures for doing this include, among other actions, avoiding dangerous places whenever possible, hiding animals (e.g., when powerful armed predators are spotted nearby), and branding them with clan marks to make them easily identifiable. In the most extreme cases, this responsibility involved risking one's life while trying to physically defend animals from raiders (McCabe 2004).

DATA COLLECTION AND MEASURES

For this study the quadrant was the unit of analysis. We correlate the livestock-related violence measures per quadrant with the topographical and rainfall features of that quadrant. Our measures are described below.

Livestock-Related Violence

The reports about livestock-related violence come from the media and news reports about Turkana collected by Ember and colleagues (2012) that appeared in the LexisNexis online database from 1998 to 2009 (http://www.lexisnexis.com/hottopics/lnacademic). As Ember, et al. (2012) describe, each article was read to assess whether it referred to Turkana people and whether it reported any livestock-related violence, raids, or attempted violence. A database was designed to have a record for each violent incident. The focus was explicitly on livestock-related violence and all of the following needed to be present to count as livestock-related violence involving Turkana: (1) raids were socially organized at least on one side; (2) the violence involved Turkana as attackers or attacked in or bordering Turkana District; (3) the incident involved attempted or actual theft of livestock, involved disputes over access to water or pasture for livestock, or were stated to be retributions for previous livestock raids.

Other information recorded from the news reports included the news source and byline, headline, author, date of conflict, place of conflict, ethnicity of attacking party, ethnicity of attacked party, number of people reported killed in the incident, number of people reported wounded, reported atrocities, property destroyed or stolen, number and type of livestock taken, weapons used, and purported reasons for conflict. For the purposes of this current study, only place and date of livestock-related violence, ethnic groups involved, number of casualties for each incident, and number of raids were used in analyses. To be included in this study, a livestock raiding had to involve Turkana as "attacker" or "attacked."

The four measures of livestock-related violence for each quadrant are: (1) the number of reported human casualties during livestock raids when the Turkana were attackers; (2) the number of reported human casualties during livestock raids when the Turkana were attacked; (3) the number of raids in which Turkana were attackers; and (4) the number of raids in which Turkana were attacked.

The number of casualties was the most widely reported statistic in the news media besides the reports of incidents themselves. Media and news reports only reported violence involving more than one ethnic group, suggesting a bias in reporting towards inter-ethnic conflict and away from intra-ethnic conflict. We know from ethnographic reports that the Turkana engage in some intra-ethnic livestock raiding. Since no intra-ethnic raids were reported during the 12-year period based on our search criteria, we are concerned that a lack of an incident report does not necessarily mean that no livestock raid occurred. It seems that the media will pick up the more spectacular incidents and underreport the minor ones. Number of deaths per report helps control for possible media biases since only the reported instances are compared. Therefore we also looked at the number of deaths when incidents are reported as a second measure of violence intensity.

Mapping Conflicts

Violent cases were assigned spatial co-ordinates based on the place named in the incident reports. Multiple databases were used to match these place names to co-ordinates. These include the Global Administrative Areas database (www.gadm.org), the Armed Conflict Location and Event Dataset (www.acleddata.com/), and the GeoNames database (www.geonames.org). In some cases, the place names made reference only to broad administrative areas for which we had to calculate a centroid. However, 82 percent of the violent cases were assigned co-ordinates for a specific place, while 9 percent referred to Locations (an administrative unit similar to a county) and another 9 percent were at the greater Division level. Due to incomplete place name information in the reports, only four cases could be plotted at the broadest District level, which was too broad for our purposes, and these cases were therefore omitted from the dataset. We then overlaid a grid of 345 quadrants measuring 0.25x0.25 decimal degrees, which contained data on monthly rainfall data from 1998 to 2009, obtained from the United States National Atmospheric and Space Administration's global precipitation records (http://precip.gsfc.nasa.gov). In this study, the number of incidents and the number of deaths (by Turkana as attacker or attacked) were summarized across each quadrant.

Mapping Topographical Features

Topographical features were mapped using two data sources. Landform and standing water data came from the GeoNames database, while rivers and smaller watercourses came from the United States Geological Service's (USGS) HydroSHEDS database (http://hydrosheds.cr.usgs.gov/index.php). The GeoNames database included 42 types of topographical features. Because of the relatively small sample size, the topographical features were consolidated into eight types and assigned to quadrants. These features, explained further in Appendix B, are: Mesa Plat, Valley Gorge, Mountain Features, Hill Cliff, Standing Water, Intermittent Standing Water, Flowing Water, and Intermittent Flowing Water. We used selected features to compile custom feature classes based on the types of landforms of interest in Kenya and Uganda, and added counts of these features to each quadrant in the rainfall grid. We converted the line features of flowing water to points in the geographic information system and added counts of intermittent and flowing water points to each quadrant in the rainfall grid as a proxy for length of flowing water. With this information, violent incidents could be analyzed in relation to rainfall quadrants, elevation, and hydrological and topographical features.

Spatial Variability of Rainfall

The Turkana ecosystem, like other arid and semi-arid areas of East Africa, is characterized by patchy rainfall distribution and concomitant patchy vegetation productivity (Little, et al. 1999). The herders' preferred strategy for utilizing these patches requires mobility across different micro-ecological zones at different times of the year. One assumes that much of the livestock-related violence would have to do with competition over accessing and controlling pockets of more productive or highly productive rangelands, as researchers noted elsewhere in the region (McPeak, et al. 2011). Presumably some of these highly desired patches would be located in blocks with better rainfall. The latter suggests that such blocks would be “hotspots” of violence, especially during long dry-seasons and drought years when scarcity of forage and water threatens the survival of the herds.

As noted above, we had two measures in each of the quadrants of the spatial variation in rainfall across the entire 12-year study period. The two measures are mean annual rainfall per quadrant and the coefficient of variation for annual rainfall. These two measures generally are related ($p < .001$; $r = .749$). Higher rainfall areas generally are more predictable; i.e., have lower coefficients of variation. Much of Turkanaland is quite dry and unpredictable, particularly in the northeastern part of Turkana District. This is apparent in Figures 1 and 2, which group quadrants into quintiles of the coefficient of variation—the darkest area is the most unpredictable.

RESULTS

Our general hypothesis is that livestock-related violence should be greater in relatively more predictable rainfall areas since the Turkana head for better places in difficult times. We differentiate between the livestock-related incidents when the Turkana were the attackers vs. when they were attacked by others. Figure 1 visually suggests that when the Turkana are the attackers, the frequency and intensity of livestock raids follow the rainfall gradients of the district. Both the number of raids and the ferocity of the outcomes increase as one moves from the more arid blocks in the center to the relatively wetter blocks on the plateaus and high rising ridges along the southern and western borders of the district.

Figure 2 shows that the spatial pattern would be slightly different when the raids were against the Turkana by one of the neighboring ethnic groups. In the south and west, when attackers came from Pokot and/or Karamoja districts, the worst violence occurred inside the administrative boundaries of Turkana district in semi-arid blocks along the foothills. From the Pokot or Karamojong point of view, these regions are more unpredictable; from the Turkana point of view, these regions are more predictable.

Figure 2 also shows what appears to be anomalous to the broad pattern just discussed. In the north, attackers cross into Kenya from Ethiopia (Nyangatom and Dassenech), South Sudan (Toposa and Nyangatom), or

Uganda (Dodos and Karamojong). There, the “hotspot” blocks seem to be within the high variability rainfall zone. This pattern is not explained by rainfall, but rather by the presence of two major dry-season reserves (Coghenour 2008). One is the lower Omo Delta, at the mouth of Omo River, which consists of seasonally flooded plains, pans, and swamps. The other consists of pockets of rarely used pastures along the Tarach River and the Lokwanamoru and Lorionetom mountains in a poorly defined border area long associated with land-use disputes. Both areas are generally avoided by the Turkana, but herders may find the risk necessary when times are bad.

Table 1 (see Appendix C) shows the mean number of incidents and mean number of deaths—separately by Turkana as attacker and Turkana as attacked—by quintile of coefficient of variation for annual rainfall within Turkanaland. A one-way analysis of variance (ANOVA) is significant in the last two columns and marginally significant in the first. Notice that in the last two columns when the Turkana are attacked, the highest numbers (bolded) are in the most predictable quadrants (these tend to be inside Turkana District along the border to the south and west). This pattern is consistent with the Turkana trying to reach areas with more predictable rainfall. The broader region shown in Figures 1 and 2 suggests a curvilinear relationship, probably because there are logistical reasons the Turkana cannot readily attack far into Pokot or Karamojong territory. Not only will these areas be more densely populated, but it would be difficult to get back home alive and with captured herds intact.

There are nonetheless some significant linear relationships between yearly mean rain, as well as the coefficient of variation, and the number of livestock-related incidents, both when Turkana are attacked by others and when they are attacking others (see Table 2). Table 2 shows the Pearson’s r between yearly mean rainfall and yearly coefficient of variation inside Turkana district, where most of the incidents take place. The results are significant for the number of incidents. Quadrants with higher rainfall are more likely to have livestock-related incidents when the Turkana are attackers or attacked. There are also significantly more deaths associated with Turkana attacks where the yearly coefficient of variation is lower. And the result regarding deaths when Turkana are attacked is marginally significant in quadrants where the yearly coefficient of variation is lower. The correlations may be relatively small because there appears to be an additional pattern not considered in this analysis—namely, the livestock-related violence along the northern disputed border appears unrelated to rainfall. We recognize that anytime a model is incompletely specified, correlations will be lower than expected.

Effects of Variations in Topography and Landscape

McCabe (2004) recorded that on November 22, 1980, Angorot relocated his main camp to the edges of Nadikam gravel plains near the foothills of a dry-season mountain range. One late afternoon five days later, about ten Pokot raiders, unexpectedly sneaking through from the nearby mountains, attacked his herd of small stock while the animals were being herded back to the main camp. Armed with spears and non-automatic rifles, the raiders killed two herd-boys and drove off with about 350 milking goats and sheep (McCabe 2004:133–34). About a year later, in December 1981, Pokot raiders attacked the herds of another Turkana man, Lorimet, who lost all of his small animals and some cattle. This raid occurred on a plain called Naroo, one day after Lorimet arrived to join other herders en route to pockets of dry-season pastures along the southern borders of the district (Dyson-Hudson and McCabe 1985:255).

These examples suggest that topographic and landscape features may be relevant to understanding the spatial component of livestock-related violence involving the Turkana. The most salient geophysical features seem to be plains near mountainous areas and mountainous areas at higher elevation—areas that are likely to have more rainfall due to topographic effects.

Figures 3 and 4 depict elevation and mountain features along with incidents of violence (circles) and the number of deaths in each incident (hue). Note that the patterns of livestock-related violence look roughly similar to what we found for rainfall variability. After testing for relationships with mountains and elevation, we explored correlations with other land forms and water features.

Keep in mind that the unit of analysis is the 30x30 km quadrant, so the correlation is between the presence or absence of a feature (such as a plain) in the quadrant and the number of incidents or average number of livestock-related deaths in the quadrant.

Plains are ordinarily imaged as broad stretches of land, such as the Great Plains of North America, but “plains” in the GeoNames database refers to an extensive area of comparatively level to gently undulating land with relatively regular surface and typically adjacent to an area of higher elevation. This depiction corresponds to the plains in Turkanaland. In the ethnographic accounts, we noted only one additional feature associated with violence: Turkana plains are often broken by small lava hills and basement-complex outcrops that rise to 100 meters (300 ft.) above the landscape (Dyson-Hudson and McCabe 1985:37). These dots often function as entry points or narrow passes to different sections of broken plains, which makes them strategically useful for launching raids on a moving herd.

Our count of "mountain feature" for Turkanaland includes a composite measure of several highland forms used in GIS maps. Specifically, the composite measure of mountains includes plateaus (highly dissected but gently sloped landforms with useable escarpments and flat tops), mountains (elevations rising above plateaus), ridges (mountain chains often encircling plains or plateaus), and peaks (pointed elevations dominating the skylines).

The correlations between livestock-related violence and these elevation features are fairly weak, but the relationship between the presence of a plain and the number of incidents in which Turkana attack others inside Turkanaland is indeed significant: $r = .24$, $p < .05$ (see Table 3, row 1). There is also a marginally significant relationship between plains and being attacked. This is consistent with the ethnographic reports of raids while herders camp on plains en route to dry-season ranges along high-plateau areas. This is considered in the discussion section.

Variation in Hydrological Features

Unlike pastures, which are communally shared by all members of a territorial section, Turkana wells are privately owned since they are dug by individuals. However, when the water is readily available from open sources such as flowing rivers, pools, or springs, all herders enjoy unrestricted rights (Dyson-Hudson and McCabe 1985:38). The ethnographic accounts emphasize this distinction in water rights and its implications for linking water more with resource use conflicts than with opportune livestock raids. For example, Dyson-Hudson and McCabe (1985) reported an altercation at Kaariwo waterhole in February 1981 when the owner of the well threatened with sticks to beat someone who was taking water from his well (Dyson-Hudson and McCabe 1985:43).

By contrast, the GIS data show a clear pattern in which many of the livestock related conflicts occurred around communally used water sources. The two drainage maps (Figures 5 and 6), for example, show two major waterforms as hotspots. One is the area along sections of major rivers, especially the Kerio, Turkwell, Kibish, and Sugata. A second centers near the mouth of River Omo where fresh grass grows when the delta is seasonally flooded. This suggests that violence is significantly higher in quadrants where water is drawn from open sources such as rivers (when flowing), permanent pools, and springs. The pattern is the same whether the Turkana are the attacker or the attacked.

Table 4 shows some waterform variables that are significant or close to significant in predicting violence. In general, there are more significant or marginally significant relationships with waterform variables than with landform variables. We performed t-tests on those variables that were binary, comparing quadrants with and without each waterform. Some of the relationships are significant by t-test that were not significant using correlations. These are identified with footnotes to Table 4. Most of the relationships are positive, suggesting that more water relates to more livestock violence as shown in the drainage (see Figures 5 and 6). The only negative relationships, albeit marginally significant, are with standing water and the length of intermittent rivers when Turkana are attackers. Perhaps because the river is intermittent with no water-bearing beds, pastoralists must rely on private wells. In the absence of established use-rights to privately maintained wells, herders are less likely to risk going to those quadrants, as McCabe's study shows (McCabe 1990:91). Unfortunately, we don't know whether particular incidents were about water per se or access to water because we do not have sufficient accompanying ethnographic detail from newspaper reports. We do know from ethnographic accounts that violence is significantly more likely when water is drawn from common sources (in the form of flowing rivers or river beds with accessible water-bearing stretch) than from privately maintained wells. And yet, these findings are provocative, suggesting that commonly shared water sources are more dangerous areas, perhaps because pastoralists and their animals are more visible, or the access points are more limited and findable, or because groups are more likely to encounter each other at these junctures. By contrast, private wells may be located on sites that provide better protection and defense in case of attack.

DISCUSSION

One purpose of this study was to explore how the ethnographic data on the Turkana and the data in GIS could help to better understand where livestock-related violence occurs. With regard to spatial distribution, the data converge best with regard to two broad patterns. First, much of the raiding on Turkana appears to occur while the herds are on transitional moves—splitting from, and coalescing at, dry-season main camps. These camps are typically strategically located on the margins of expansive plains but close to both water sources and forage needed by the five primary species of livestock.

Why should the likelihood of raids on Turkana and their herds increase while on plains? The main reason may have to do with the place of plains as landscapes of strategic importance in Turkana herding strategies. Plains serve not only as key rangelands but also as important staging grounds for herd splitting and coalescing in response to changing resource conditions. The strategic value of plains is especially revealed during long dry-seasons and drought years when herders have to cope with severe forage and water scarcity. At the end of the 1980–1981 drought, for example, Dyson-Hudson and McCabe (1985) reported that Angorot's livestock were separated in five different camps scattered around the edges of the major Toma and Naroo plains. The major camp, together with the milking camels and the milking small stock, was on the slopes of a mountain near the southern edges of Toma plains. The strong non-milking goats browsed on the mountain above the main camp. The weak non-milking smallstock were near a small river below the main camp. The cattle moved to the southern portion of Naroo plains, while the non-milking camels foraged on the lower slopes of a mountain not far from there (Dyson-Hudson and McCabe 1985:208).

While useful for meeting the species-specific dietary needs of livestock, this strategy of splitting and coalescing the herd involves a series of transitional moves in and out of plains. Ethnographic accounts also suggest that pastoral families are more vulnerable while on the move and/or immediately after relocating to a new place. As noted in the beginning of this section, both Angorot and Lorimet suffered from raids within days after their arrival on the plains.

The presence of mountain features in a quadrant has no significant relationship to incidents or deaths from livestock raids (see row 2 of Table 3). Perhaps this is because most of the mountains tend to be high rising hills, with no easy entry points and too far from water sources for herders to use. However, some mountain areas do provide dry-season fodder especially for small stocks well adapted to climbing on rocky escarpments. These herds would be relatively protected because the location is too inaccessible for attackers to enter or leave safely.

A second spatial pattern suggests that much of the raiding by the Turkana occurs in blocks along the administrative boundaries of the district, which also mark boundaries between ethnic groups. These blocks are located on higher elevations where the rainfall pattern is generally more reliable. This suggests that raids by the Turkana are essentially motivated by drought conditions when the survival of the herd depends on temporary access to pastures in danger areas.

While exploring risks of livestock raids across the study quadrants, we noted that the evidence from GIS data, while suggestive, was fairly weak. But why? A principal reason for this may have to do with the fact that we do not know precisely where an incident took place within a quadrant. Even though our 30x30 km units are relatively small, they are often probably not small enough. There may be a river running through the quadrant, but that does not mean that the livestock-related incident took place when animals were being watered or herders were approaching a watering place. Additionally, the water may run right next to a quadrant with violence, but correlations at the quadrant level would not be able to pick up such associations. Vector graphics, instead of polygon graphics, might be one solution for achieving more fine-grained associations of violence with landforms or waterforms.

Other measurement and conceptual issues may matter. Studies show that landscape-level features commonly used in geographic information systems, notably indicators relating to land-use/land-cover dynamics, range productivity/carrying capacity, rainfall regimes, and water forms, were developed by researchers more familiar with weather pattern and resource conditions in temperate zones where stability is the natural order (Little 2003). These indicators are built on specific models that assume a great deal of similarity across different zones of a relatively stable ecosystem. When applied to arid and semi-arid areas like Turkana, where spatial and temporal instability and disturbance are the norm, these indicators fail to capture the extreme variability. For example, our GIS measures suggest that there are permanent flowing rivers. However, from the perspective of the Turkana, ethnographers tell us, there are no rivers that flow throughout the year (Dyson-Hudson and McCabe 1985:40). Instead, the Turkana only see some stretches of sandy riverbeds with varying potentials for water-bearing across seasons.

Range ecologists also noted that pasture and water resources seldom reoccur from year to year. Rather, their distribution seems to be characterized by randomness and variability. To this effect, one finds in the district, as in other arid lands elsewhere, patches of high ecological value alongside large expanses of marginal range and shrub lands (Behnke and Scoones 1993). The Turkana recognize this variability and disturbances in implementing their herding strategies. They rely on mobility. Also, herding unit managers like Angorot do not attribute some degree of equilibrium or carrying capacity to the different sections of the rangelands they cover in their seasonal migration. They know that a block that appears unusually rich in pasture productivity one season can turn to barren land by the next.

Ethnography suggests that the Turkana do not move to a particular landscape for its physical features (be that plains, mountains, flooded delta, or river bed). Neither do they appear to view the rainfall condition in terms of the district-wide gradients and annual variation we used for analysis. Their resource-use practices appear to be informed by deep familiarity with weather conditions and real-time information on day-to-day events. They use this information and experience to find water and forage that meets the dietary needs of their livestock. For this reason, an experienced herder will often camp at a site where he hopes to find all these resources interspersed within a manageable grazing radius. Thus, commonly used geographic indicators may be somewhat limited in explaining the values of such highly variable resources.

Yet, there appear to be spatial patterns that are not readily apparent in ethnography. We may think of these spatial patterns as probabilities rather than determinants. They include: (1) livestock-related violence is more frequent in more predictable rainfall areas (while the Turkana may not know exactly where to find water and pasture in drought conditions, they must know at some level where they are more likely to be available); and (2) livestock-related violence is more likely where there is flowing water or longer rivers. If these patterns do not show up in ethnography, this does not mean that they are not relevant. More directed interviewing may be needed to understand whether the digital spatial data help to find meaningful patterns.

SUMMARY AND CONCLUSION

Turkana herders pursue a pragmatic land-use strategy that shows a great deal of familiarity with local spatial conditions that may help predict likelihoods of livestock raids. They seek to move to safer areas while avoiding places where they scouted raider movements. This study demonstrates how information from both ethnographic accounts and a geographic information system can be used to explore where livestock raids occur.

Our analysis broadly replicates a longstanding land-use dilemma well documented in ethnographic accounts. Much of the raiding on Turkana occurs while the herds are on the move, splitting from and coalescing at transitional camps en route to dry-season ranges. These camps are typically located on the outer flanks of relatively safer wet-season pastures at the center of the district. By contrast, much of the raiding by the Turkana appears to occur in blocks along the administrative boundaries of the district. These blocks are located on higher elevations where the temperature is cool and the rainfall pattern generally reliable. This suggests that raids by the Turkana are motivated by drought conditions when the survival of the herd depends on temporary access to pastures in dangerous areas. We also note a suggestive link between violence and commonly shared water sources. More violence appears to occur in quadrants with flowing water and longer rivers than in blocks with privately owned wells.

These spatial patterns, we believe, will be relevant for mitigating livestock violence through early warning and localized policy intervention. The results also inform the ethnographic literature, which tends to lack quantitative foundation for supporting its otherwise rich description of the many causes, courses, and consequences of livestock violence among East African pastoral communities.

NOTES

1. This research was supported by the Office of Naval Research Multidisciplinary University Research Initiative under grant no. N00014-08-1-0921 to George Mason University, with a sub-award to the Human Relations Area Files (PI: Claudio Cioffi-Revilla; co-PIs: Carol R. Ember, Sean Luke, and Kenneth De Jong). The opinions, findings, and results are those of the investigators and do not reflect the views of the sponsors. We thank Sophie Skoggard and Brittany Burke for collecting and summarizing violent episodes from LexisNexis, Kate Cummings for entering the preliminary data into a database, and Atesmachew Hailegiorgis and Chenna Cotla Redda for performing the necessary steps to make the weather data available.
2. The data on violence are the same used by Ember and colleagues in their study on rainfall and violent conflict. For a more detailed description of the data collection methods see Ember, et al. 2012:182–86.
3. The absence of information on intra-Turkana cattle raids was also noted in a recent study of co-operation in warfare (Mathew and Boyd 2011).
4. See Gufu Oba, Ecological Factors in Land Use Conflicts, Land Administration, and Food Insecurity in Turkana, Kenya, Pastoral Development Network Papers. http://www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/5389.pdf.
5. The results are not significant within 100 km outside of Turkana district, perhaps because there are many quadrants with no Turkana attacks. Limiting the quadrants to at least one attack of some kind shows Turkana significantly more likely to attack in quadrants where the yearly rain is higher ($r = .40$; $p < .005$; $n = 48$) and the yearly coefficient of variation is lower ($r = -.32$, $p = .028$).

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APPENDIX A

Figure 1

Yearly Coefficient of Variation in Rainfall and Yearly Livestock-Related Deaths for all Parties when Turkana are Attackers, 1998–2009

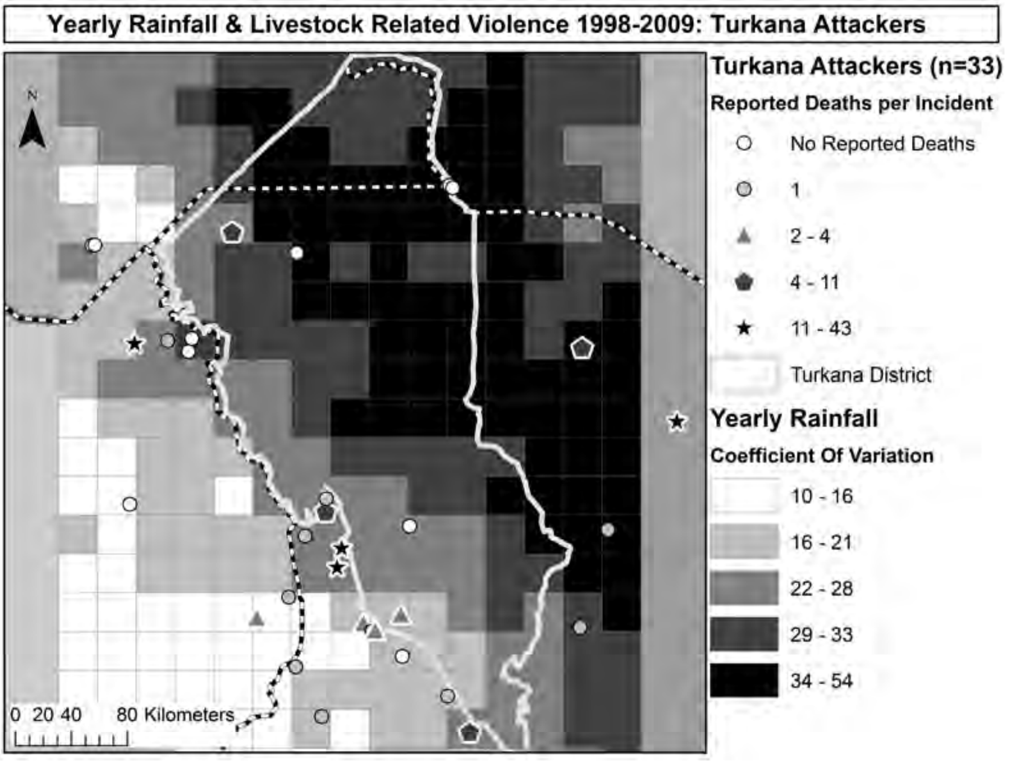


Figure 2

Yearly Coefficient of Variation in Rainfall and Yearly Livestock-Related Deaths for All Parties when Turkana are Attacked, 1998–2009

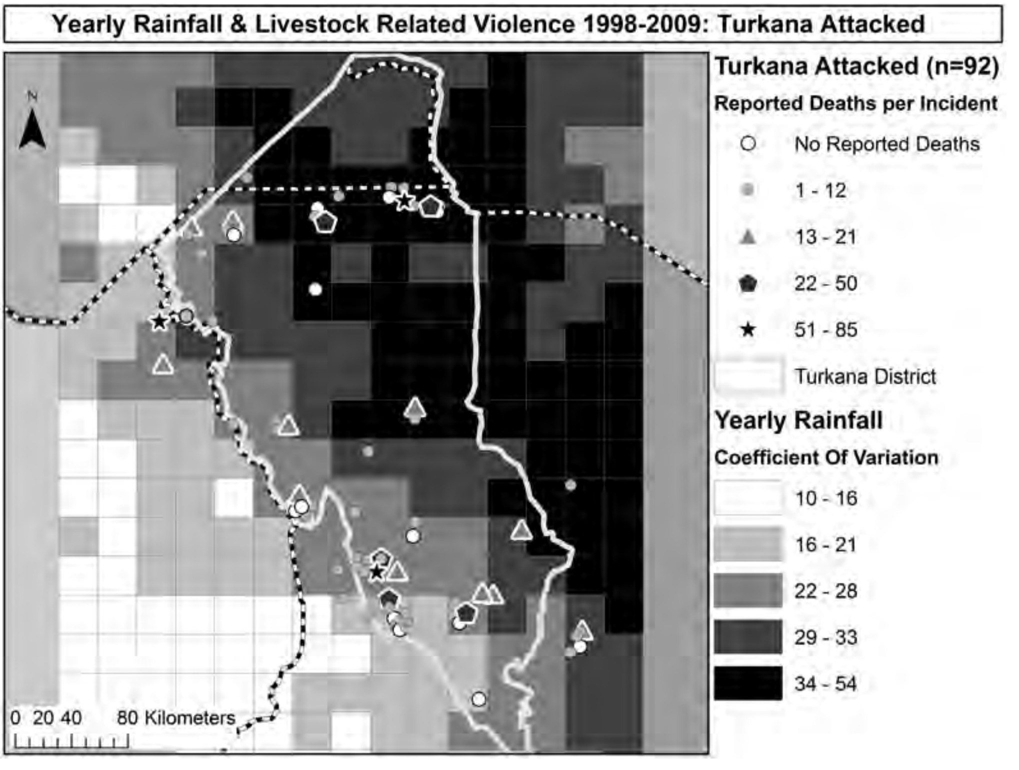


Figure 3

Digital Elevation Model for Turkanaland and Deaths of All Parties for Each Livestock-Related Attack by the Turkana, 1998–2009

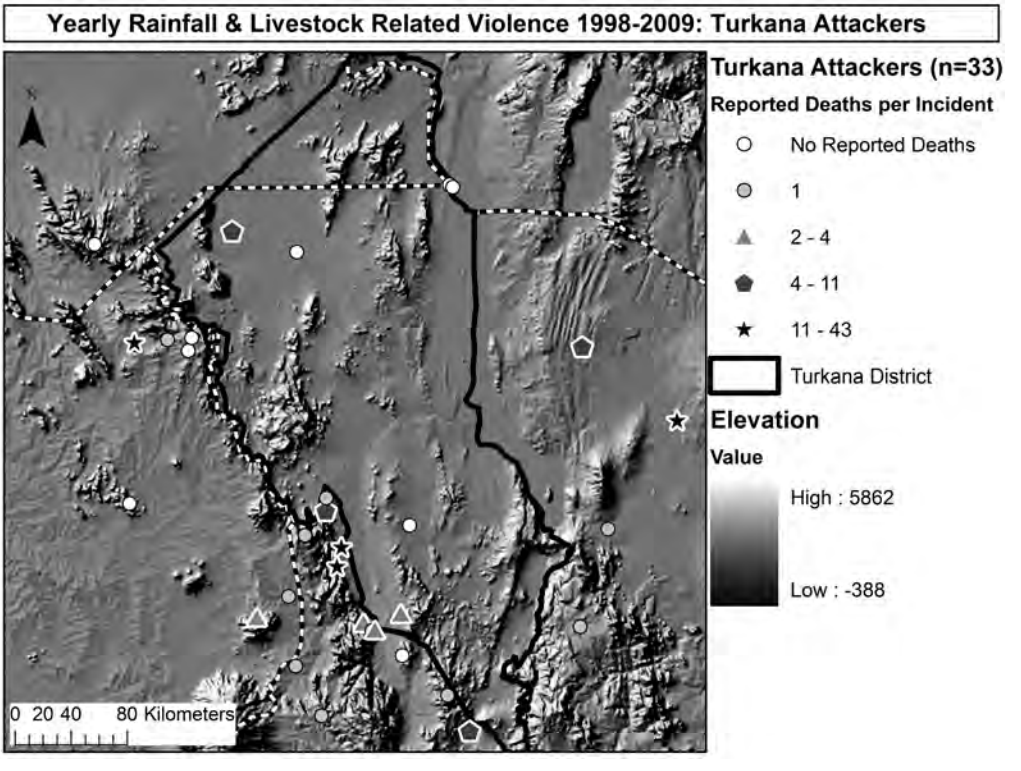


Figure 4

Digital Elevation model for Turkanaland and Deaths of All Parties for Each Livestock-Related Attack on the Turkana

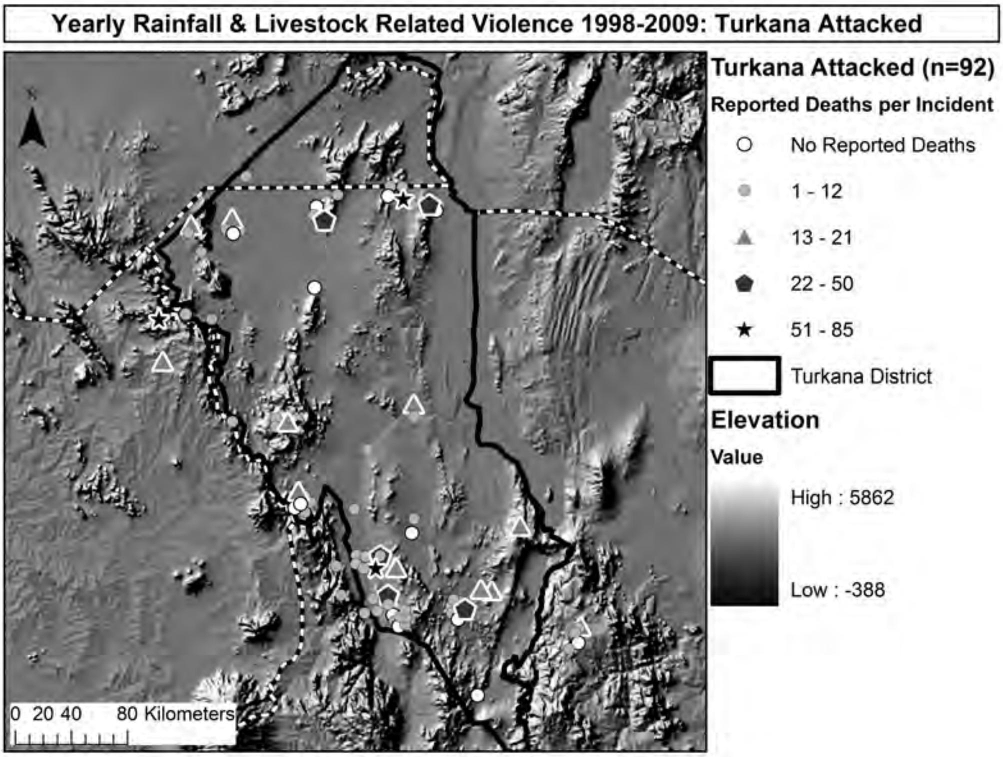


Figure 5

Deaths of All Parties for Each Livestock-Related Attack *by the Turkana*, 1998-2009, as Related to Nearby Bodies of Water

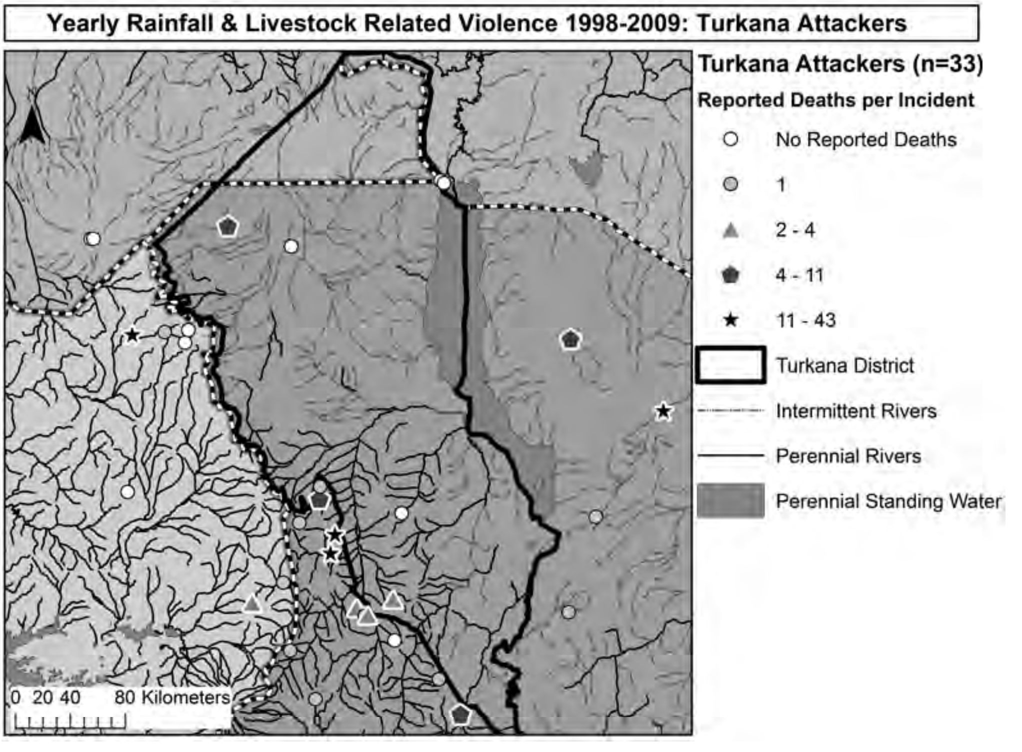
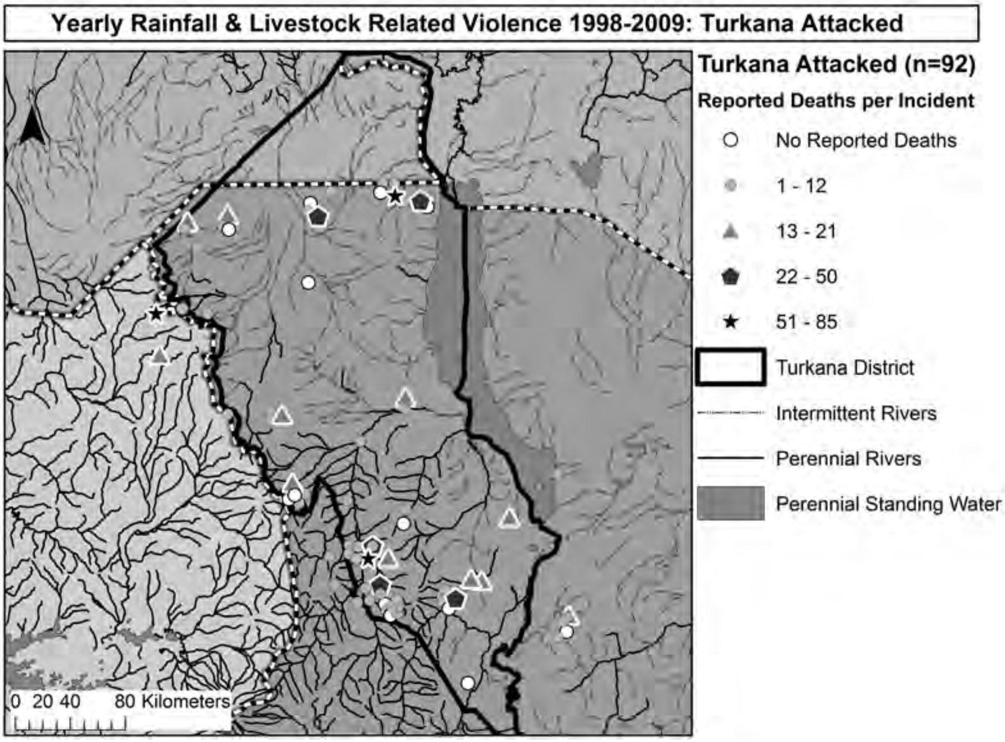


Figure 6

Deaths of All Parties for Each Livestock-Related Attack on the Turkana, 1998–2009, as Related to Nearby Bodies of Water



APPENDIX B

Landforms and Water Features

VARIABLE	GeoNames Features Included in Variable
Mesa Plat	Mesa(s)—flat-topped, isolated elevation with steep slopes on all sides; less extensive than a plateau Plateau—elevated plain with steep slopes on one or more sides, and often with incised streams
Desert	Desert—large area with little or no vegetation due to extreme environmental conditions
Valley Gorge	Gorge(s)—short, narrow, steep-sided section of a stream valley; a break in a mountain range or other high obstruction, used for transportation from one side to the other Saddle—broad, open pass crossing a ridge or between hills or mountains Valley—elongated depression usually traversed by a stream
Mountain Features	Mountain(s)—elevation standing high above the surrounding area with small summit area, steep slopes and local relief of 300 meters or more Peak—pointed elevation atop a mountain, ridge, or other hypsographic feature Ridge(s)—long narrow elevation with steep sides and a more or less continuous crest Escarpment—long line of cliffs or steep slopes separating level surfaces above and below
Hill Cliff	Cliff(s)—high, steep-to-perpendicular slope overlooking a waterbody or lower area Hill(s)—rounded elevation of limited extent rising above the surrounding land with local relief of less than 300 meters Rock(s)—conspicuous, isolated rocky mass
Wildlife Reserve	Wildlife reserve—tract of public land reserved for the preservation of wildlife
Plains	Plain(s)—extensive area of comparatively level to gently undulating land, lacking surface irregularities, and usually adjacent to a higher area

(continued)

Forest	Forest—area dominated by tree vegetation. Forest reserve—forested area set aside for preservation or controlled use
Intermittent Standing Water	Mud Flat(s)—relatively level area of mud either between high- and low-tide lines or subject to flooding Lake Bed(s)—dried up or drained area of a former lake; intermittent lake Salt Area—shallow basin or flat where salt accumulates after periodic inundation; intermittent wetland
Standing Water	Lake Channel—the part of a lake having water deep enough for navigation between islands, shoals, etc. Lake(s)—large inland body of standing water; crater lake; wetland dominated by grass-like vegetation Pond(s)—small standing waterbody Pool(s)—small and comparatively still, deep part of a larger body of water, such as a stream or harbor, or a small body of standing water. Reservoir—artificial pond or lake Swamp—wetland dominated by tree vegetation Well(s)—cylindrical hole, pit, or tunnel drilled or dug down to a depth from which water, oil, or gas can be pumped or brought to the surface Waterhole—natural hole, hollow, or small depression containing water, used by humans and animals, especially in arid areas

VARIABLE	HydroSHEDS Features Included in Variables
Perennial Flowing Water	Water flows that are relatively constant throughout the calendar year
Intermittent Flowing Water	Water flows that are seasonal or irregular

APPENDIX C

Table 1

Level of Violence by Quintiles in Coefficient of Variation for Yearly Rainfall
Using All Quadrants inside Turkanaland (n=95 Quadrants)

Quintiles of Coefficient of Variation in Yearly Rainfall	Avg. No. Raids when Turkana Are Attackers	Avg. No. Deaths when Turkana Are Attackers	Avg. No. Raids in which Turkana Are Attacked	Avg. No. Deaths in which Turkana Are Attacked
Lowest= 1 (n=19)	**.32**	1.11	**1.95**	**21.58**
2 (n=19)	.16	**1.53**	.79	5.32
3 (n=19)	.00	.00	.11	1.68
4 (n=19)	.23	.00	.21	4.68
Highest= 5 (n=20)	.00	.00	.60	6.75
ANOVA	p=.06	p=.39	p=.00	p=.00

Table 2

Rainfall Variation and Relationships to Number of Incidents and Deaths in Quadrants within Turkanaland (Pearson's r)

Measure of Rainfall Variability	No. Incidents when Turkana Are Attackers	No. Deaths when Turkana Are Attackers	No. Incidents when Turkana are Attacked	No. Deaths when Turkana Are Attacked
Yearly Mean Rainfall	.26*	.13	.22*	.18†
Yearly Coefficient of Variation in Rainfall	-.28**	-.21*	-.28**	-.19†

†<.10; *p<.05; **p<.01; ***p<.001 (all two-tailed); n = 95

Table 3

Selected Landforms and Relationships to Number of Incidents and Deaths in Quadrants within Turkanaland (Pearson's r)

Geographic Feature	No. Incidents when Turkana Are Attackers	No. Deaths when Turkana Are Attackers	No. Incidents when Turkana Are Attacked	No. Deaths when Turkana Are Attacked
Plains (yes, no)	.24*	.05	.18†	.10
Mountains (yes, no)	-.03	.12	-.01	.02
Elevation	.11	.07	.18†	.12

†p<.10; *p<.05; **p<.01; ***p<.001 (all two-tailed); n=95

Table 4

Water Forms and Relationships to Livestock-related Incidents and Deaths within Quadrants in Turkanaland (Pearson's r); 95 Quadrants[a]

Water Form	No. Incidents when Turkana Are Attackers	No. Deaths when Turkana Are Attackers	No. Incidents when Turkana Are Attacked	No. Deaths when Turkana Are Attacked
Flowing Water (yes, no)	.29**[b]	.23*	.28**[c]	.24*[b]
Length of River	.28**	.36***	.18†	.14
Intermittent River (yes, no)	.12	.14[c]	.15[c]	.09
Length of Intermittent River	-.18†	-.16	.17†	-.14
Standing Water (yes, no)	-.15[a]	-.17[c]	.14	.25*[c]

†p<.10; *p<.05; ***p<.01; ***p<.001 (all two-tailed)

[a]Welch's t-tests were also performed on the water features comparing quadrants with each of the following present versus absent: flowing water, intermittent river, and standing water. Those with superscript "b" were marginally significant and in the same direction expressed by the Pearson's r. Those with superscript "c" were significant and in the same direction expressed by the Pearson's r.
[b]Marginally significant (p<.10) on Welch's t-test.
[c]Significant at p<.05 on Welch's t-test.