Transhumant Pastoralism, Climate Change and Conflict in Africa

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Abstract: We consider the effects of climate change on seasonally migrant populations that herd livestock—i.e., transhumant pastoralists—in Africa. Traditionally, transhumant pastoralists benefit from a cooperative relationship with sedentary agriculturalists whereby arable land is used for crop farming in the wet season and animal grazing in the dry season. Rainfall scarcity can disrupt this arrangement by inducing pastoral groups to migrate to agricultural lands before the harvest, causing conflict to emerge. We examine this hypothesis by combining ethnographic information on the traditional locations of transhumant pastoralists and sedentary agriculturalists with high-resolution data on the location and timing of rainfall and violent conflict events in Africa from 1989–2018. We find that reduced rainfall in the territory of transhumant pastoralists leads to conflict in neighboring areas. Consistent with the proposed mechanism, the conflicts are concentrated in agricultural areas; they occur during the wet season and not the dry season; and they are due to rainfall's impact on plant biomass growth. Since pastoralists tend to be Muslim and agriculturalists Christian, this mechanism accounts for a sizable proportion of the rapid rise in religious conflict observed in recent decades. Regarding policy responses, we find that development aid projects tend not to mitigate the effects that we document. By contrast, the effects are reduced when transhumant pastoralists have greater power in national government, suggesting that more equal political representation is conducive to peace.

Key words: Transhumant pastoralism, sedentary agriculture, seasonal migration, conflict, weather.

JEL classification: N10; Q54; Z1.

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1. Introduction

Climate change is one of the most important challenges facing society. A fundamental concern is that more frequent extreme weather events may lead to violent conflict and political instability in fragile parts of the world. Many African countries are believed to be especially vulnerable to this threat, due in part to low economic development, weak state capacity, and a high reliance on crop agriculture. In this paper, we study a particularly important characteristic of African economic and cultural life that is susceptible to the deleterious effects of climate change. It is estimated that 22% of Africa's population obtains the majority of its income from animal husbandry and 43% of the continent's land mass is used to support pastoral activities (FAO, 2018). Many of Africa's pastoral ethnic groups engage in the practice of *transhumance*, which is the seasonal movement of grazing animals. Transhumance creates interdependent relationships that are potentially sensitive to the increased frequency of droughts brought on by climate change in Africa.

In typical years, neighboring transhumant pastoral and sedentary agricultural groups coexist in a symbiotic relationship that is characterized by seasonal migration. In the wet season, agriculturalists cultivate crops on more productive lands while transhumant pastoralists exploit more marginal lands that produce sufficient plant biomass (or *phytomass*) for their livestock. After the final harvest, transhumant pastoralists migrate along well-established corridors to arrive at the agricultural farmlands for the dry season, where they benefit from the year-round availability of phytomass while providing organic fertilizer in exchange.

In low precipitation years, there may be insufficient phytomass produced on the marginal grazing lands to sustain pastoralists' livestock. This shortage forces pastoralists to migrate to agricultural farmlands before the dry season begins. If the animals arrive before the final harvest, tensions can arise due to damaged crops and competition for resources, such as water and pasture. The issue is well-known, with many documented examples (Moritz, 2010, Kitchell, Turner and McPeak, 2014, Brottem, 2016).

Whether this mechanism results systematically in violent conflict is an empirical question. On the one hand, neighboring groups may avoid conflict if they believe droughts to be sufficiently rare events. In this case, the symbiotic relationship is worth preserving. On the other hand, groups may have updated their expectations about the frequency of droughts due to climate change. In this case, the symbiotic relationship is unsustainable, and frictions may emerge in the form of conflict events.

A related question concerns the recent rise of extremist-religious violence in Africa. Given that transhumant pastoral groups tend to be Muslim and sedentary agriculturalists tend to be Christian, it is possible that this mechanism also affects violence involving self-styled religious groups.

Our study examines these empirical questions. We measure the incidence of conflict using geocoded conflict data from the Uppsala Conflict Data Program (UCDP) and the Armed Conflict Location & Event Data Project (ACLED). We construct ethnicity-level measures of transhumant pastoralism by combining information, taken from the *Ethnographic Atlas*, on the historical importance of animal herding with information on historical mobility.

We begin with a descriptive account of the extent to which violence is more prevalent in land outside of the territory of groups that are transhumant pastoral. We examine variation across 0.5-degree grid cells. For each cell, we identify its *nearest neighbor*, which is the ethnic group, among all ethnic groups that border a cell's own ethnic group, that is geographically closest to the cell. We find that grid cells that have a transhumant pastoral nearest neighbor experience more conflict. When we distinguish between types of conflict, we find that the effect is present for conflicts that involve state actors, such as the police or military, as well as for smaller-scale conflicts that only involve non-state actors. The relationship with civil conflicts is consistent with accounts of agricultural landowners being aided by state forces against transhumant pastoral ethnic groups, who are coded non-state combatants.

We then turn to the central question of the analysis, which is whether reduced rainfall in the territories of transhumant pastoralists leads to conflict in nearby agricultural lands. Examining variation across grid cells and years, we estimate a specification that includes grid-cell fixed effects and country-year fixed effects. The variable of interest is an interaction between the measure of transhumant pastoralism of a grid cell's nearest neighbor and the average amount of rain in the nearest neighbor's territory in a year. The coefficient estimate tells us whether the incidence of conflict in a cell is influenced by rainfall in the nearest neighboring ethnic territory when the nearest neighbor is transhumant pastoral.

We find that, consistent with the hypothesis, less precipitation in a cell's nearest neighboring ethnic group increases conflict in the cell, but only if the neighbor is transhumant pastoral. The estimated effects are sizable and significant. We find that a one standard deviation decline in rainfall experienced by the median transhumant pastoral ethnic group raises the risk of conflict in a nearby grid cell by around 24%, or 0.8 percentage points (from a mean of 3.5% to 4.3%). The same shock experienced by a non-transhumant pastoral group has a negligible and statistically insignificant effect (around 2%, or 0.08 percentage points).

The specifications that we estimate also allow for direct effects of rainfall experienced in the grid cell itself and for any *intra*-ethnic effects of rainfall occurring in the same ethnic territory as the grid cell. They also allow for the possibility that these effects might differ if the cell's own ethnic group is transhumant pastoral. We find that these estimated effects are small and statistically insignificant. Thus, while we estimate sizable adverse spillover effects from reduced rainfall experienced by neighboring transhumant pastoral groups, we find no evidence of effects due to reduced rainfall in a cell or in the cell's own ethnic group.

The estimates are consistent with the hypothesis that low rainfall induces transhumant pastoralists to migrate early—that is, before the end of the growing season—to agricultural farmlands, resulting in damaged crops, competition for resources, and conflict. This interpretation has a number of falsifiable predictions that we take to the data. First, we check that the estimated effects are due to nearest neighbors being transhumant pastoral; namely, the combination of being both mobile and pastoral. We show that there are no significant effects arising from nearest neighbors who are either mobile but not pastoral or pastoral but not mobile. Second, we check that conflicts arising due to adverse rainfall in neighboring transhumant pastoral territories tend to be located on agricultural land. Third, we obtain very similar estimates when we examine the spillover effects due to phytomass growth rather than rainfall, suggesting that the effects are due to the reduced availability of plant matter for animal grazing. Fourth, we check that there is no spillover effect when we substitute precipitation with temperature. This is informative, since in the tropical and subtropical climates of the African continent, rainfall is more important for plant growth than temperature. Fifth, we examine the timing of the spillover effects within the year and find that they are concentrated during the growing season, when crops are being cultivated, but not during the dry season, when the land is left fallow. This is consistent with our hypothesis that conflict occurs when pastoral groups are forced to use farmland before harvest.

We then turn to additional questions of interest, starting with whether our findings are able to explain part of the rise in religious conflict involving jihadist groups in Africa in the past decades. Since transhumant pastoral groups tend to be Muslim and sedentary agricultural groups are generally Christian, conflicts between the two groups may be viewed as—or evolve into—religious violence. To investigate this, we separate conflict events into ones that involve jihadist actors and ones that do not. We find that our mechanism affects the incidence of both jihadist and non-jihadist conflict similarly. However, since jihadist conflicts were very rare prior to 2000, these similar marginal effects imply a much larger rate of growth for jihadist conflicts in the past two decades. Importantly, we also control for the religious composition of the nearest neighbor and find that transhumant pastoralism is considerably more important than religion in predicting the incidence of jihadist conflicts due to adverse rainfall in a cell's nearest neighbor.

We next consider the important question of what can be done to mitigate the effects that we find. We first examine the role of international aid projects, focusing specifically on projects aimed at curbing the effects of environmental degradation, such as irrigation, forestry, conservation, land improvement, and other agricultural projects. To test for the effects of such aid projects, we allow our main estimated effect to vary by the cumulative presence of foreign aid projects in a country and year starting in 1947. We find suggestive evidence that our documented effects are independent of these aid projects.

We also consider the effects of state-protected conservation areas, which aim to prevent environmental degradation and promote decarbonization. While these conservation projects may attenuate the effects of climate change, some have argued that they can exacerbate transhumant pastoral conflict by limiting the movements of herds and contributing to the scarcity of grazing pastures. To test this, we allow our main estimated effect to vary by the share of land in a country that is designated as conservation land at each point in time. We find that our estimated effects are greater in magnitude when countries have more land that has protected conservation status. This result suggests that conservation areas, while potentially beneficial in other ways, may exacerbate conflict stemming from adverse rainfall shocks in transhumant pastoral territories.

The last factor we consider is political power. In the absence of political power-sharing, minority groups may have strong incentives to fight (Mueller and Rohner, 2018). Greater representation of pastoral groups in national government may therefore mitigate conflict arising from low rainfall in pastoral territories. We test this using the Ethnic Power Relations dataset. We calculate, for each year and country, the power held by transhumant pastoral groups in national politics, and we allow our estimated effects to vary depending on this measure. We find that the estimated effects approach zero as transhumant pastoral groups gain a higher share of national power. This suggests that when both sides have fair representation in government, a peaceful resolution between pastoral groups and farmers is more likely.

Our analysis uncovers how relations between transhumant pastoral and sedentary agricultural groups are undermined by episodes of low rainfall, which are becoming more frequent in Africa due to climate change. The mechanisms that underlie the analysis are informed by the rich ethnographic literature on the nature of transhumance and its implications for seasonal interactions between sedentary farmers and herders in Africa (Lewis, 1961, Jacobs, 1965, Konczacki, 1978, Dyson-Hudson and Dyson-Hudson, 1980). Our findings add to this descriptive literature and to more recent studies that document how adverse climate shocks have affected African pastoral groups (Little, Smith, Cellarius, Coppock and Barrett, 2001, McPeak and Barrett, 2001, Maystadt and Ecker, 2004, Bollig, 2006) and in particular how they affect relations between pastoral and agricultural groups (Benjaminsen, Alinon, Buhaug and Buseth, 2012).

Our focus on transhumant pastoralism is complementary to studies that focus on either one of the two dimensions of this practice—either seasonal migration or pastoralism—and their connection to conflict and economic development. Various studies have shown the importance of seasonal migration for helping to alleviate poverty (Bryan and Mobarak, 2014, Morten, 2019). Others have examined the long-term consequences of animal husbandry on cultural traits associated with gender (Becker, 2019) and the importance placed on maintaining one's honor (Grosjean, 2014, Cao, Enke, Falk, Giuliano and Nunn, 2021). A number of studies have examined the long-term consequences that a noteworthy nomadic pastoral group, the Mongols, had on state development in China due to the threat of invasion, which was, in part, due to climate shocks (Bai and Kung, 2011, Ko, Koyama and Sng, 2018).

Our findings contribute to a better understanding of the salience of cross-ethnicity divisions and the conditions under which ethnic differences can lead to conflict. In particular, our findings provide insight into the recent finding in Depetris-Chauvin and Özak (2020) that conflict tends to occur near ethnic boundaries. Our findings suggest that one important mechanism underlying the relationship could be the disruption of the traditional symbiotic relationship between pastoralists and sedentary farmers. Eberle, Rohner and Thoenig (2020) also show that conflict at the boundaries between nomadic and non-nomadic groups is greater when temperatures are higher, consistent with existing studies showing that heat can increase violence through a variety of mechanisms, including psychological channels (Hsiang, Burke and Miguel, 2013, Hsiang and Burke, 2014, Baysan, Burke, González, Hsiang and Miguel, 2019). Our analysis indicates that the direct 'heat and hate' thermal stress effect on conflict documented in Eberle et al. (2020) is distinct from the inter-ethnic spillover effect of rainfall and phytomass documented here, which is due to the disrupted seasonal migration of transhumant groups.

We contribute directly to the literature on climate and conflict by providing new evidence that documents a precise mechanism through which climate change affects inter-group violence (see Miguel, Satyanath and Sergenti, 2004, Solow, 2013, Hsiang and Burke, 2014, Burke, Hsiang and Miguel, 2015). We also contribute to the wider literature on the determinants of conflict within Africa, including studies that explore the importance of historical factors (e.g., Besley and

Reynal-Querol, 2014, Depetris-Chauvin, 2015, Michalopoulos and Papaioannou, 2016, Moscona, Nunn and Robinson, 2020); ethnic or social factors (Montalvo and Reynal-Querol, 2005, Esteban, Mayoral and Ray, 2012, Rohner, Thoenig and Zilibotti, 2013, Arbatli, Ashraf, Galor and Klemp, 2020); and economic factors, especially shocks to the opportunity cost of conflict, which can be challenging to distinguish empirically from shocks that affect other drivers of conflict (Dube and Vargas, 2013, McGuirk and Burke, 2020).

One important aspect of our study is the spillover nature of the effect we identify—rainfall in one location (transhumant pastoral territories) affects conflict in another (sedentary agricultural territories). Our approach can be interpreted as recovering the exact structure of one mechanism behind the spatial spillovers observed in the existing climate-conflict literature (e.g., Guariso and Rogall, 2017, Harari and La Ferrara, 2018). While prior studies take a more empirical approach towards characterizing the nature of spillovers, our analysis starts with a specific mechanism that is motivated by the ethnographic literature. We then build our estimator to capture this mechanism while accounting for other, more general forms of spillover. In this way, our strategy is similar to other studies that also specify a particular spillover mechanism ex-ante that is then brought to the data (e.g. König, Rohner, Thoenig and Zilibotti, 2017).

The paper is organized as follows. In Section 2, we provide a description of the traditional symbiotic relationship between transhumant pastoralists and sedentary farmers in Africa. We also discuss recent changes in climate on the continent and how this has affected the nature of the herder-farmer relationship. In Section 3, we describe the data used in the main analysis. In Section 4, we examine the cross-sectional relationship between transhumant pastoralism and conflict in neighboring areas. In Section 5, we estimate the effect of lower rainfall in transhumant pastoral territory on conflict in neighboring locations. In Section 6, we present a series of auxiliary tests of causal mechanisms. In Section 7, we turn to the implications of our findings, including an examination of extremist-religious conflict and factors that may mitigate the effects that we estimate. Section 8 concludes.

2. Background and Context

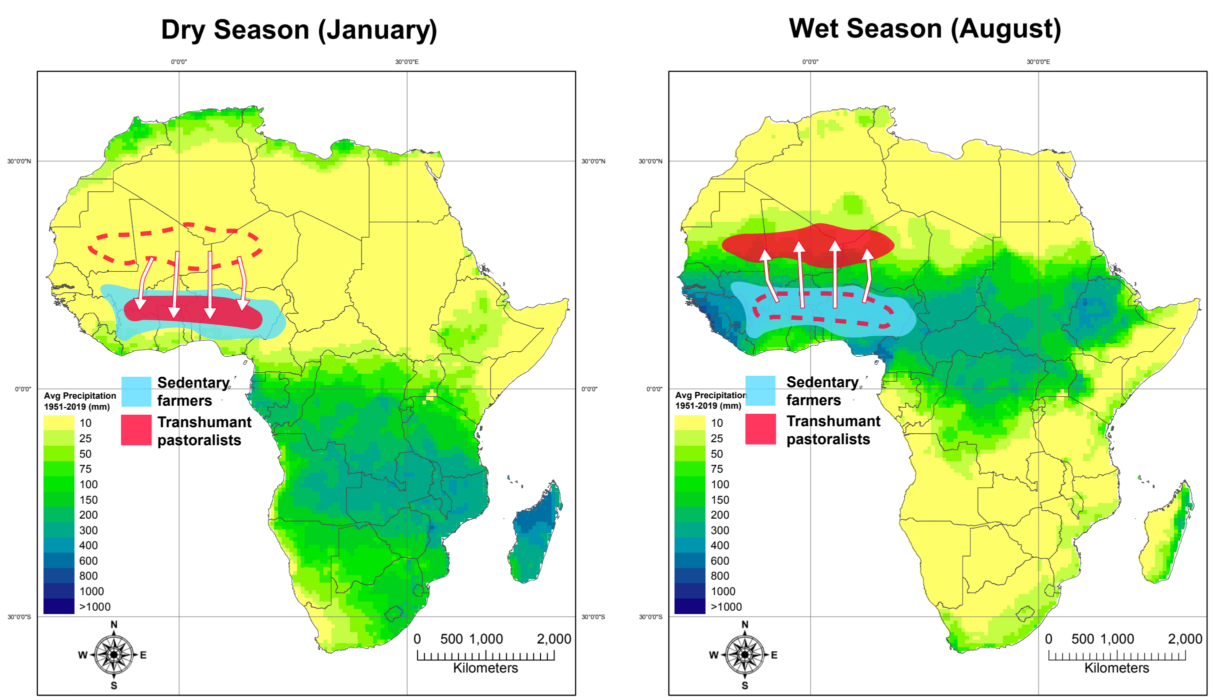
A. Transhumant Pastoralism

A defining feature of transhumant pastoralism is that it results in regular seasonal interactions with sedentary agricultural groups. Neighboring herders and farmers develop a symbiotic relationship that allows both groups to share resources in an efficient and mutually beneficial manner.

In most of Africa, seasons are determined primarily by precipitation rather than temperature, a fact highlighted by the typical description of the seasons as either the wet (i.e., growing) or dry (i.e., fallow) season. The time of year when seasons occur depends on where one is on the continent, particularly whether one is north or south of the equator. The seasonal variation is shown in Figure 1, which reports rainfall across the continent in two months, January and August. January, shown in Figure 1b, is a dry-season month for most of the continent that lies north of the equator and a wet-season month for areas south of the equator. By contrast, in August, which is shown in Figure 1b, the north experiences a wet season and the south a dry season.

The figure also provides a stylized illustration of transhumant migrations that occur in West Africa. Hypothetical sedentary agricultural groups are shown in blue and transhumant pastoral groups in red. During the wet season, when crops are cultivated, pastoralists keep their livestock on marginal grazing land that is not suitable for agriculture but supports the growth of wild grasses that provide sustenance to animals. During the dry season, this growth no longer occurs. As a result, herds are moved to the more fertile farmlands that are used for agriculture during the wet season but are left fallow during the dry season. This movement is shown by the arrows in Figure 1a. Animal herds are allowed to graze on the farmland during this period. This arrangement benefits both the pastoralists, who enjoy the dry-season production of animal feed, and the farmers, whose land is improved by the animals' manure, a form of nitrogen-rich organic fertilizer. At the end of the dry season, herds are moved from the agricultural lands and return to the more marginal grazing lands. This is shown by the arrows in Figure 1b.

Due to the seasonal movements of herds, both sedentary farmers and transhumant pastoralists are able to exploit the land efficiently and cooperatively. Stenning (1959, p. 6), in his study of the pastoral Fulani, describes the symbiotic relationship between them and their agricultural neighbors, the Uda'en: "Pastoral life is pursued not in isolation, but in some degree of symbiosis with sedentary agricultural communities…there have existed, possibly for many centuries, arrangements for pasturing cattle on land returning to fallow, and for guaranteeing cattle tracks



(a) Rainfall and migration during the dry season.

(b) Rainfall and migration during the wet season.

Figure 1: Rainfall and seasonal migration in Africa.

and the use of water supplies. Pastoral Fulani did not, and do not, merely graze at will, but obtained rights to the facilities they required from the acknowledged owners of the land."

As a consequence of these traditional relationships, extensive transhumance is common in the parts of Africa with ecological zones that have these features, the largest region being the Sahel. Except in a few cases, with very small samples, information about the exact routes remains undocumented. From these studies, which are summarized in Appendix Table A1, one can see many aspects that are relevant for our analysis. The distance between the origin and destination varies considerably, ranging from tens of kilometers to hundreds of kilometers. Although the routes are meandering, they often have a north-south orientation, although many routes follow an east-west orientation, especially near the west-facing coastal areas. Routes commonly cross ethnic boundaries and sometimes national boundaries.

B. Effects of Climate Change

For much of the African continent, particularly the Sahel region, the most salient consequence of climate change has been rainfall that is persistently below the long-run average. Increasing temperatures, particularly outside of Africa, tend to reduce precipitation on the continent. For example, increased Atlantic sea-surface warming causes lower rainfall and more droughts in the Western part of the continent (Shanahan, Overpeck, Anchukaitis, Beck, Cole, Dettman, Peck, Scholz and King, 2009), while warming in the Middle East, South Asia, and particularly the Indian Ocean affects precipitation in Eastern Africa (Cook and Vizy, 2013).

The recent effects of global warming on precipitation within the continent can be seen in Figure 2, which shows annual wet-season rainfall from 1901–2017 for the Sahel, a region that is particularly relevant for our analysis. It is clear that since the late 1960s, there has been a reduction in annual precipitation (Nicholson, Fink and Funk, 2018). Between 1970 and 2017, annual average rainfall was below the long-run (1900–2017) mean in 36 of the 47 years (Schneider, Becker, Finger, Rustemeier and Ziese, 2020). Although there is some slight attenuation in recent years, it is clear that global warming is associated with reduced rainfall (Biasutti, 2018, Herrmann and Mohr, 2012).

During this same time, the region has seen an increase in the frequency and severity of conflicts between sedentary agriculturalists and transhumant pastoralists. According to numerous accounts, the new climate regime has led to more variation in the timing and location of transhumance movements, causing migrations that are earlier in the season and deeper into agricultural lands (Ayantunde, Asse, Said and Fall, 2014). A plausible explanation for the concurrent trends is the reduction in living organic plant matter, known as *phytomass*, which provides sustenance for grazing herds. Rainfall is the primary determinant of living organic plant matter on the continent (Hein, 2006). While temperature is also a factor, its importance for plant growth is primarily due to its indirect effect on rainfall (Biasutti, 2018). This contrasts with the situation in more temperate regions outside of Africa, such as North America or Europe, where temperature is more important for plant growth than precipitation (Moles et al., 2014). While temperature is the primary constraint for plant growth in temperate climates, rainfall is the primary constraint in tropical climates. Our own calculations, which we describe in detail

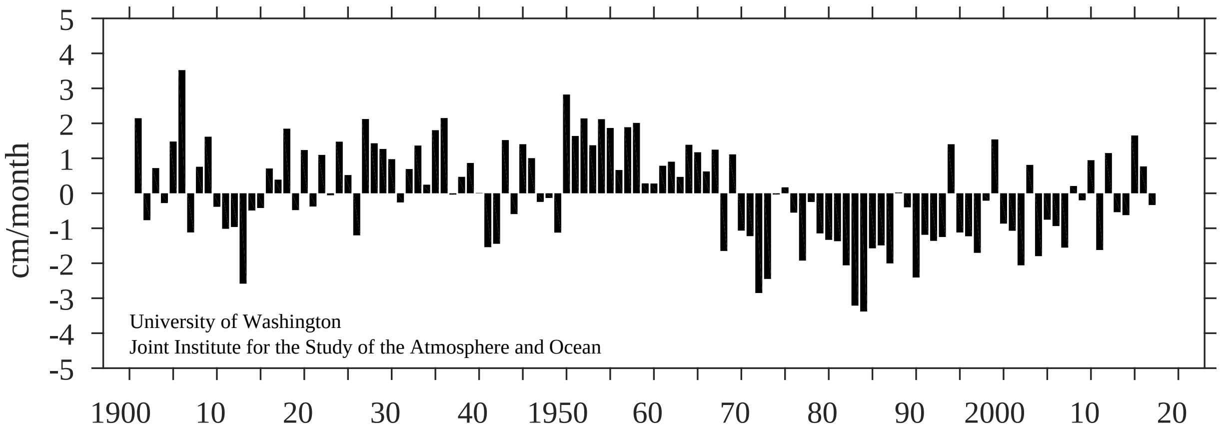


Figure 2: Climate change and historical precipitation in the Sahel. *Source*: Sahel Precipitation Index. University of Washington. June through October averages over 20-10^{o}N, 20^{o}W-10^{o}E. 1900–2017. `http://research.jisao.washington.edu/data/sahel/`

below, show that within our sample, annual variation in rainfall explains about six times more of the variation in phytomass than temperature. Given the importance of rainfall for phytomass growth on the African continent, our analysis focuses on the consequences of rainfall scarcity.

3. Data

A. Description, Sources, and Validation

Our analysis examines the relationship between conflict, rainfall (or phytomass), and transhumant pastoralism. Below, we describe the data and the measurement of each variable.[1]

Conflict Our baseline set of conflict variables are from two sources of geocoded data: the Uppsala Conflict Data Program (UCDP) (Sundberg and Melander, 2013), which covers 1989–2018, and the Armed Conflict Location & Event Data project (ACLED) (Raleigh, Linke, Hegre and Karlsen, 2010), which covers 1997–2019. We use both sources throughout our analysis since they each have strengths and weaknesses. While the UCDP data has longer temporal coverage, the ACLED data has broader coverage of smaller-scale conflicts.

To be included in the UCDP database, a conflict event must have at least one fatality and the pair of actors involved in the event (i.e., the conflict dyad) must have produced at least 25 fatalities in at least one calendar year throughout the series. Additionally, at least one of the actors involved in the event must be an "organized actor," such as the state or a politically organized rebel group or militia. The ACLED data have weaker criteria for inclusion. There is no requirement for a certain number of fatalities in a calendar year or a conflict event. Thus, the ACLED data are better equipped to capture small-scale, localized conflict events.

Using the reported locations of conflict events, we create measures of the presence of conflict in 0.5-degree (approx. 55km × 55km) grid cells during a calendar year. Our primary measures

[1] For more detail on data sources, see Appendix A.

are indicator variables that equal one if each of the following types of conflict occurs: *All* conflicts; *State* conflicts, where the state is involved as a participant in the event; and *Non-State* conflicts, where only non-state actors are involved.[2]

Summary statistics for the conflict measures are reported in Appendix Table A3. The unconditional probability of ACLED conflict incidence is much higher than that of UCDP incidence. As expected, the difference is largest for non-state conflicts: 8% for ACLED versus 2% for UCDP. Thus, we place particular importance on the ACLED data in our analysis of non-state conflicts.

Transhumant Pastoralism To identify transhumant pastoral societies, we use information from the *Ethnographic Atlas* (*EA*), a database of 1,265 ethnic groups assembled in Murdock (1967). We construct a composite index that captures the two key aspects of transhumant pastoralism.

The first is that the group moves seasonally; namely, that they are mobile. There is extensive information in the *EA* on the mobility of ethnic groups traditionally. Variable v30 of the database codes groups as falling within one of the following categories that describe the nature of settlement: (1) Nomadic or fully migratory; (2) Seminomadic; (3) Semisedentary; (4) Compact but impermanent settlements; (5) Neighborhoods of dispersed family homes; (6) Separated hamlets; (7) Compact and relatively permanent; and (8) Complex settlements.

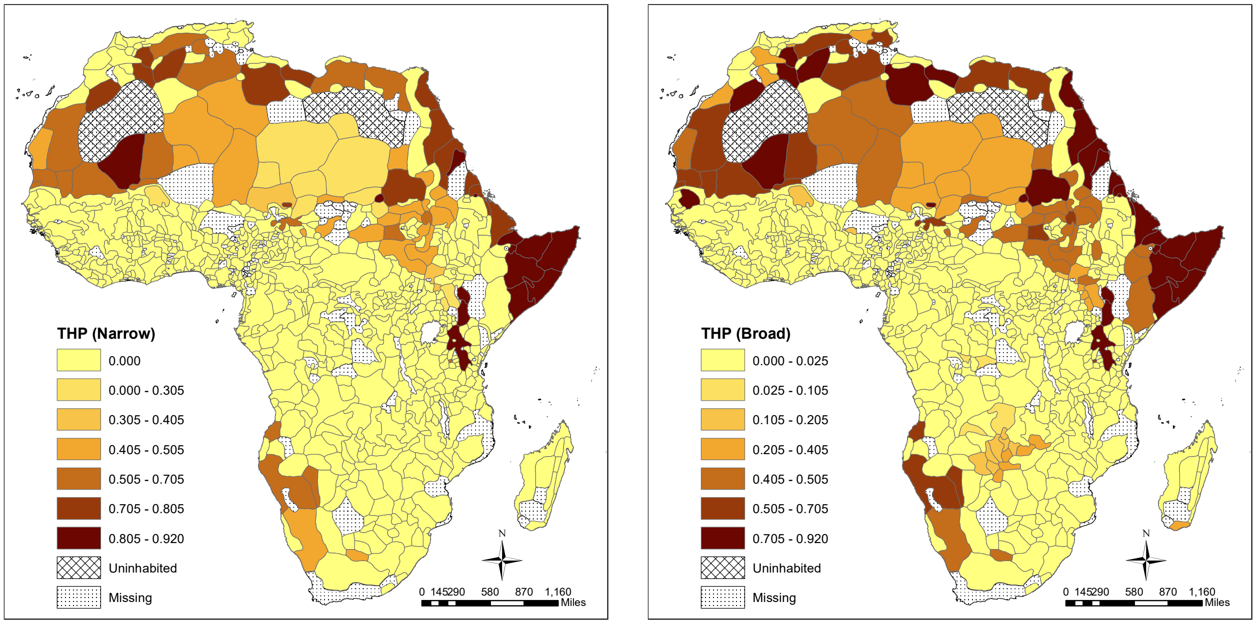
Although transhumance is not measured explicitly, nearly all forms of movement today are seasonal. Nomadic activity that is not seasonal is now rare. Thus, we take being traditionally nomadic as a proxy for being seasonally mobile. We create two indicator variables that allow for two definitions of transhumance: a 'narrow' definition that includes only groups that are 'nomadic or fully migratory' or 'seminomadic' and a 'broad' definition that also includes groups that are 'semisedentary' or have 'compact but impermanent settlements.' The variants differ in whether groups that are semi-mobile are coded as being transhumant or not. We denote the variable $Transhumant_e$, where e indexes ethnic groups in our sample.

The second key aspect of transhumant pastoralism is the herding of animals. To capture this dimension, we build on a measure developed in Becker (2019), which combines information on the fraction of subsistence that is from animal husbandry (measured on a 0-1 scale, from variable v4 in the *EA*) with an indicator variable that equals one if the primary large animal is suitable for herding (from variable v40). Animals that require herding include sheep, goats, equine animals, camels, and bovine animals, but not pigs, for example. Becker's measure is constructed as the interaction between these two measures. It ranges from 0 to 1 and it proxies for the fraction of an ethnic group's subsistence that is from herded animals. We denote this variable $Pastoral_e$.

We construct a measure of 'transhumant pastoralism' by interacting the two components: $Transhumant_e \times Pastoral_e$. The resulting variable, which we denote $TranshumantPastoral_e$, measures the fraction of a group's subsistence that is from transhumant pastoralism.

Since our measure is based on traditional practices from ethnographic sources rather than current practices from contemporary surveys, it is predetermined and unaffected by the episodes of conflict that we explain empirically. Reassuringly, the measure is still predictive of con-

[2]When constructing the ACLED measures, we focus on "battles" and "violence against civilians," which are analogous to the two- and one-sided events that comprise the UCDP data.



(a) Narrow definition

(b) Broad definition

Figure 3: Cross-ethnicity spatial variation in transhumant pastoralism.

temporary pastoralism. This can be seen in Appendix Figure A1, which shows the positive relationship between the contemporary ownership of animals, measured in DHS surveys, and the transhumant pastoralism of the ethnic group of the respondent.

To assign the variable to spatial units, we match each society from the *EA* to the ethnic territories mapped by Murdock (1959). Using a variety of sources, documented in Kincaide, McGuirk and Nunn (2020), we match around 96% of the ethnic territories in the map to an ethnic group in the *EA*.

Figure 3 shows the spatial distribution of the transhumant pastoralism measure. The intensity of transhumant pastoralism is consistent with expectations based on the location of land most suitable for animal grazing rather than agriculture. This can be seen in Appendix Figure A2, which shows the spatial distribution of land suitable for transhumant pastoralism and sedentary agriculture, taken from Beck and Sieber (2010), and the boundaries of ethnic groups with some form of traditional mobility. It is clear that the ecological environment is a key determinant of transhumant pastoralism.

Rainfall and Phytomass Pastoral groups rely on rain to produce the phytomass needed to sustain their livestock. Our rainfall variable measures average monthly precipitation during a calendar year in a 0.5 degree cell. The data are from the Global Precipitation Climatology Centre and are based on interpolated land-surface precipitation data from approximately 85,000 rain gauges across the globe (Schneider et al., 2020). The variable, which covers the full duration of our conflict series (1989–2019), is measured in centimeters per month.

We verify the importance of rainfall for plant growth using satellite data on dry matter vegetation (i.e., phytomass). The phytomass data is derived from satellite images provided by the Copernicus Global Land Service and is available at the 1km pixel level weekly from 1999-2019 (Copernicus, n.d.). We aggregate the data to the 0.5 degree cell-year level and measure the final variable in average kilograms of plant growth per hectare per day.

We estimate the determinants of phytomass growth at the cell-year level, modeling phytomass as a function of average annual precipitation and temperature, while conditioning on cell fixed effects and country-by-year fixed effects. The estimates, reported in Appendix Table A2, confirm the importance of precipitation for vegetation growth. Consistent with the environmental science literature (e.g., Waha, Müller and Rolinski, 2013, D'Onofrio, Sweeney, von Hardenberg and Baudena, 2019), we find that rainfall is a significant determinant of phytomass growth and is a more important factor than temperature. After accounting for the fixed effects, rainfall explains 3.6% of the residual variation while temperature explains 0.6%.

Given that rainfall is the main driver of phytomass growth on the African continent, we use this as our primary climate variable. We use rainfall rather than phytomass as our baseline measure since it is available for a much longer time series. In sensitivity checks, we show that the estimates are nearly identical when we use either phytomass or phytomass predicted by rainfall.

B. Summary of the Data

The descriptive statistics for the variables used in the analysis are reported in Appendix Table A3. In separate panels, we report variables that vary at the cell-year, cell, ethnic-group-year, and ethnic group levels. At the cell-year level, the incidence of any conflict is 3% when using the UCDP data and 8% when using the ACLED data. The average precipitation is 5.65 centimeters per month and the average temperature is 24.5 degrees Celsius. The average of the ethnicity-level measure of transhumant pastoralism is 0.08 when the narrow measure is used and 0.09 when the broad measure is used.

In Appendix Table A4, we report summary statistics for groups that are transhumant pastoral (column 1), groups that are not (column 2) and their difference (column 3). We find that transhumant pastoralism is associated with less conflict, less precipitation, less phytomass, higher temperatures, land that is less suitable for agriculture, and land that is more suitable for transhumant pastoralism. It is also associated with lower population, fewer nighttime lights, less national political power, a higher share of Muslim people, and a lower share of Christian people today. Looking at historical ethnographic traits, we see that transhumant pastoral groups, not surprisingly, practiced less agriculture and were more developed politically (as measured by levels of political authority beyond the local community).

These comparisons make clear that transhumant pastoralism is not randomly allocated across the continent. The practice is determined, in part, by ecological conditions and is associated with various other factors. This highlights the importance of our auxiliary analyses which look for evidence of our specific mechanism of interest, test for the importance of other ethnicity-level traits, and examine the importance of contemporary political power.

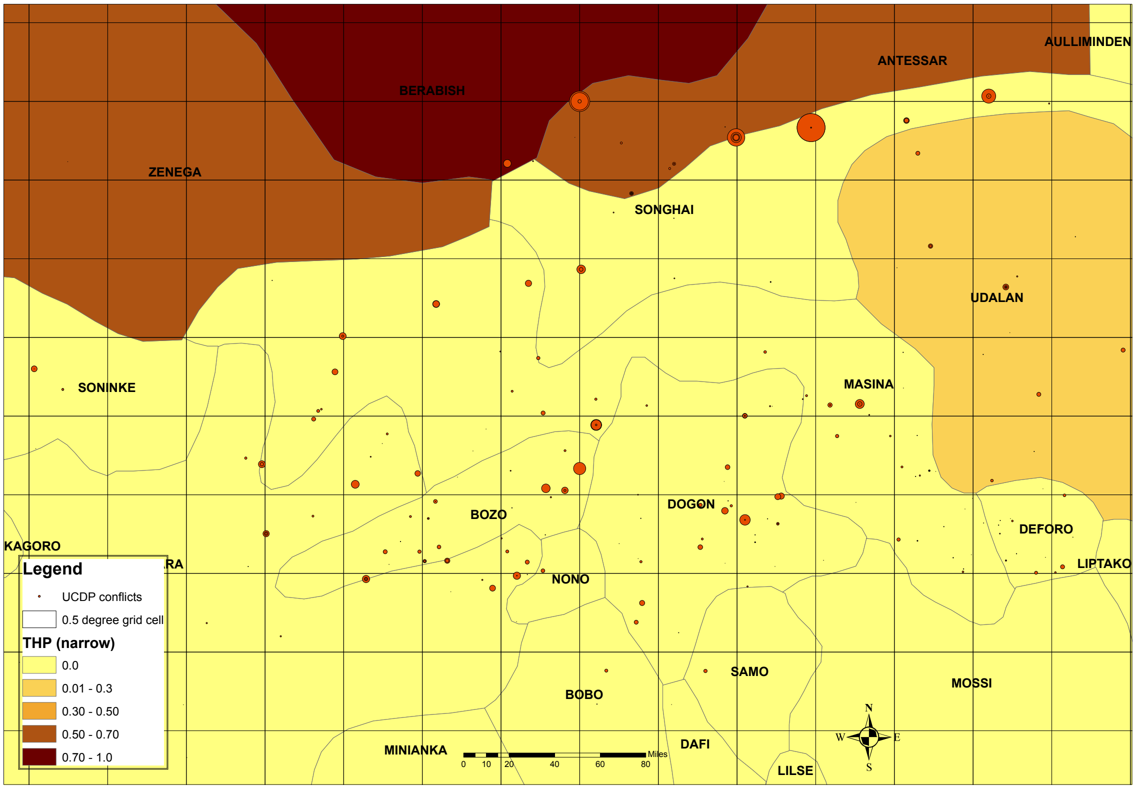


Figure 4: Structure of Data and Analysis. The figures shows 0.5-degree cells, along with the boundaries of the ethnic groups, their names, and their measure of transhumant pastoralism (THP) using the narrow definition of transhumant.

4. Cross-Sectional Patterns

We begin our analysis by estimating the relationship between being near transhumant pastoral groups and conflict across 0.5-degree grid cells. The sample comprises 9,691 cells nested in 780 ethnic territories across the African continent. These are shown in Figure 4 for a region in Mali that is traditionally inhabited by the Masina, Dogon, Zenega, Songhai, and others. The map also shows the location of UCDP conflicts from 1989–2018.

For each cell, we identify the neighboring ethnic group that is most relevant for that cell. As illustrated by Figure 4, cells within an ethnic territory can have different neighbors that are relevant. For example, consider cells located within the Masina ethnic territory. The relevant neighboring ethnic group varies depending on where a given cell is located in the territory. For the cells in the northwestern portion of the Masina territory, the relevant neighbor is the Zenega; for those in the eastern portion, the relevant neighbor is Udalan; and for cells in the southeastern portion, the relevant neighbor is the Dogon, Mossi, or Deforo. This generates rich variation in nearest neighbor characteristics even when holding constant the characteristics of one's own ethnic group. We identify each cell's 'nearest neighbor' (or 'neighbor' for short) as the ethnic group that is geographically closest to a cell's centroid among all ethnic groups that are

Table 1: Cross-Sectional Evidence of Conflict Spillover from Nearest Neighboring THP Territory: Cell Level

	Indicator for the presence of conflict					
	UCDP			ACLED		
	(1) I(Any)	(2) I(State)	(3) I(Nonstate)	(4) I(Any)	(5) I(State)	(6) I(Nonstate)
Panel A: Transhumant definition includes only groups that are migratory or nomadic (narrow definition)						
Neighbor Transhumant Pastoral [γ_1]	0.0273***	0.0253***	0.0057**	0.0702***	0.0534***	0.0698***
	(0.0054)	(0.0049)	(0.0025)	(0.0095)	(0.0077)	(0.0095)
Transhumant Pastoral [γ_2]	0.0081	0.0063	0.0017	0.0208**	0.0134*	0.0200**
	(0.0057)	(0.0046)	(0.0028)	(0.0097)	(0.0077)	(0.0097)
Panel B: Transhumant definition includes all groups without fully permanent settlements (broad definition)						
Neighbor Transhumant Pastoral [γ_1]	0.0301***	0.0288***	0.0050**	0.0671***	0.0534***	0.0667***
	(0.0053)	(0.0049)	(0.0023)	(0.0089)	(0.0074)	(0.0089)
Transhumant Pastoral [γ_2]	0.0076	0.0058	0.0012	0.0188**	0.0126*	0.0181*
	(0.0054)	(0.0044)	(0.0026)	(0.0093)	(0.0074)	(0.0093)
Dep. Var. Mean	0.035	0.025	0.016	0.085	0.055	0.085
Year FE & ln Population	Yes	Yes	Yes	Yes	Yes	Yes
Climate-Zone-Year Clusters	420	420	420	336	336	336
Cell Clusters	7,690	7,690	7,690	7,690	7,690	7,690
Observations	230,700	230,700	230,700	184,560	184,560	184,560

Note: All outcome variables measure conflict incidence at the level of a cell-year. "I(Any)" is an indicator variable that equals one if at least one violent conflict occurs in a cell and year. "I(State)" is an indicator variable that equals one if at least one conflict event involving the state occurs in a cell and year; "I(Non-State)" is an indicator variable that equals one if at least one conflict event not involving the state occurs in a cell and year. All specifications include a control for the natural log of the population of a grid-cell in 1990. Standard errors, which are reported in parentheses, are adjusted for clustering at the level of a grid-cell and a climate zone-year. * p < 0.1, ** p < 0.05, *** p < 0.01.

contiguous to the ethnic group in which the cell is located.[3]

With this data structure, we then estimate the following equation:

$$y_{iet} = \gamma_1\, \textit{TranshumantPastoral}_i^{\textit{Neighbor}} + \gamma_2\, \textit{TranshumantPastoral}_e^{\textit{OwnGroup}} + \gamma_3 \ln(pop_i) + \alpha_t + \eta_{iet}, \quad (1)$$

where i indexes 0.5-degree grid cells, e ethnic groups, and t years (1989–2018 or 1997–2019). The dependent variable, y_{iet}, is conflict incidence in cell i, which lies within the territory of ethnicity e, and in year t. The variable $\textit{TranshumantPastoral}_i^{\textit{Neighbor}}$ is the measure of transhumant pastoralism of the nearest neighboring ethnic group to cell i. The variable $\textit{TranshumantPastoral}_e^{\textit{OwnGroup}}$ measures the transhumant pastoralism of the ethnic group in which the cell is located. Lastly, $\ln(pop_i)$ is the natural log of the population of cell i, measured in 1990. The parameter of interest is γ_1, which represents the effect of the nearest neighboring ethnic group's transhumant pastoralism on conflict in a cell. Standard errors are adjusted for two-way clustering at the level of a cell and a climate zone-year.

Estimates of equation (1) are reported in Table 1. Panel A reports estimates using the narrow definition of transhumance, while panel B reports estimates using the broad measure. Each column reports estimates using a different measure of conflict as the dependent variable: total

[3]For cells that lie within multiple ethnic territories, we determine the ethnic group of a cell by the location of its centroid.

conflicts, state-involved conflicts, and non-state conflicts, each measured using either the UCDP (columns 1–3) or ACLED (columns 4–6) data.

In all specifications, we find that having a nearest neighbor that is transhumant pastoral is associated with significantly more conflict. While this relationship is present for all conflict measures, it is much smaller for non-state conflicts measured using the UCDP data. This is not surprising given that the UCDP data has more restrictive inclusion criteria that lower its coverage of smaller-scale conflicts not involving the state.

5. Rainfall Scarcity and Agro-Pastoral Conflict

We now turn to our baseline equation which estimates whether adverse rainfall in transhumant pastoral territories results in conflict in neighboring lands.

Estimating Equation We estimate a variant of equation (1) that traces the effect of rainfall in a neighboring transhumant pastoral territory on conflict in a cell. The equation is given by:

$$\begin{aligned} y_{iet} = {} & \gamma_0^s \, Rain_{it}^{Neighbor} + \gamma_1^s \, Rain_{it}^{Neighbor} \times TranshumantPastoral_i^{Neighbor} \\ & + \gamma_2^s \, Rain_{et}^{OwnGroup} + \gamma_3^s \, Rain_{et}^{OwnGroup} \times TranshumantPastoral_e^{OwnGroup} \\ & + \gamma_4^s \, Rain_{it}^{OwnCell} + \gamma_5^s \, Rain_{it}^{OwnCell} \times TranshumantPastoral_e^{OwnGroup} \\ & + X_{iet}'\Gamma + \alpha_i^s + \alpha_{c(i)t}^s + \eta_{iet}^s, \end{aligned} \tag{2}$$

where y_{iet} is an indicator for the incidence of conflict in cell i, located in ethnic territory e, and in year t; $Rain_{it}^{Neighbor}$ measures average precipitation in the nearest neighboring ethnic group to cell i in year t; $TranshumantPastoral_i^{Neighbor}$ is the transhumant pastoralism measure for the neighboring ethnic group; $Rain_{et}^{OwnGroup}$ measures precipitation in group e in year t; $TranshumantPastoral_e^{OwnGroup}$ is the transhumant pastoralism measure for ethnicity e; and $Rain_{it}^{OwnCell}$ measures precipitation in cell i in year t. The vector X_{iet}' includes additional covariates used in auxiliary robustness and sensitivity checks; α_i denotes cell fixed effects, which capture time-invariant differences across grid cells; and $\alpha_{c(i)t}$ denotes country-year fixed effects, which capture any variation across time that is common to all grid cells in a country. To account for serial and spatial dependence, our standard errors are two-way clustered at both the cell and climate zone-year levels.

The parameter γ_1^s represents the differential effect of rainfall in a neighboring ethnic territory on conflict in cell i when the neighboring ethnicity is transhumant pastoral relative to when it is not transhumant pastoral. A negative estimate of γ_1^s indicates that, consistent with our hypothesis, dry weather in pastoral territories causes additional conflict in neighboring cells.

It is important to note that this specification accounts flexibly for many factors that have been previously studied in the conflict literature. The cell fixed effects α_i^s capture all time-invariant determinants of conflict, such as geography, national boundaries, historical factors, and ethnic traits (e.g., Besley and Reynal-Querol, 2014, Michalopoulos and Papaioannou, 2016, Moscona et al., 2020). The country-year fixed effects $\alpha_{c(i)t}^s$ capture time-varying national-level factors such as changes in country GDP, national political or legal institutions, country-level ethnic fractionalization and polarization, resource endowments, and international geo-political characteristics, all of which have been prominent in the cross-country literature on conflict (e.g., Collier and Hoeffler, 1998, 2004, Fearon and Laitin, 2003, Ross, 2004, Esteban et al., 2012). The control for rainfall in a cell, $\gamma_4^s Rain_{it}^{OwnCell}$, captures the direct effects of rainfall on the opportunity costs or logistics of fighting (e.g., Miguel et al., 2004, Jia, 2014, Burke et al., 2015, Harari and La Ferrara, 2018). The control for rainfall in the territory of a cell's ethnic group, $\gamma_2^s Rain_{et}^{OwnGroup}$, captures intra-ethnic spatial spillover effects, which are also potentially important determinants of conflict in a location (Harari and La Ferrara, 2018). Our specification also allows for differential effects of the rainfall controls by the transhumant pastoralism of the cell or ethnic group.

Results Estimates equation (2) are reported in Table 2 for the narrow definition of transhumant pastoralism and in Appendix Table A5 for the broad definition. Each column reports estimates for one of our six conflict measures. The first set of coefficients, reported under the heading 'Nearest Neighboring Ethnic Group,' are for the effect of variables that measure rainfall experienced by the nearest neighboring ethnic group, γ_0^s, and its interaction with the neighbor's transhumant pastoralism measure, γ_1^s.

We find that less rainfall in a cell's nearest neighboring ethnic group leads to more conflict in the cell, but only if the neighbor is transhumant pastoral. While the estimated effects for non-transhumant pastoral groups are never statistically different from zero, the differential effects for transhumant pastoral neighbors are always negative and, in all columns but one, are statistically significant. Consistent with prior findings, the estimates for non-state conflict using the high-threshold UCDP data are much smaller in magnitude and imprecisely estimated.

To assess the magnitude of the estimates, in the second panel, we report the predicted effect (expressed as a percentage of the dependent variable mean) of a one-standard-deviation reduction in rainfall. According to the estimates, this adverse rainfall shock causes an increase in conflict that is equal to 37.5% of the mean of total UCDP conflict (column 1); for the ACLED measure of conflict, which has a higher mean, the equivalent figure is 13.6% (column 4).

If we take into account the deficiency of the UCDP non-state conflict measure, the evidence suggests that rainfall in the territory of transhumant pastoral nearest neighbors affects both state and non-state conflict. This implies that herder-farmer conflicts can involve state agents such as police, conservation officers, or the military, or they can occur absent government involvement.

The tables also report the coefficients for $\gamma_2^s \ldots \gamma_5^s$, which are the estimated effects of rainfall in the cell's own ethnic group e and in cell i itself, and the differential effects of the rainfall measures when the ethnic group is transhumant pastoral. These are reported under the headings 'Own Ethnic Group' and 'Own Cell.' Each of the estimated coefficients is small in magnitude and almost never statistically different from zero. Only one of 24 coefficients is significant, and that is at the 10% level. Thus, while we find that less rainfall in the territory of the nearest neighboring transhumant pastoral groups leads to greater conflict, there is no evidence of effects for own-cell or own-group rainfall.

Robustness and Sensitivity Checks We now turn to the sensitivity of our estimates. We have shown that the estimates using the narrow and broad definitions of transhumant pastoralism are

Table 2: Effect of Rain Shock in Nearest Neighboring THP Territory on Conflict in a Cell: Narrow Definition of Transhumance

	Indicator for the presence of conflict					
	UCDP			ACLED		
	(1) I(Any)	(2) I(State)	(3) I(Nonstate)	(4) I(Any)	(5) I(State)	(6) I(Nonstate)
Nearest Neighboring Ethnic Group						
Rain [γ_0^s]	-0.0005	0.0001	-0.0005	-0.0007	0.0004	-0.0008
	(0.0006)	(0.0006)	(0.0005)	(0.0011)	(0.0009)	(0.0011)
Rain × Transhumant Pastoral [γ_1^s]	-0.0110***	-0.0121***	-0.0012	-0.0096**	-0.0092***	-0.0096**
	(0.0033)	(0.0031)	(0.0021)	(0.0038)	(0.0035)	(0.0038)
Own Ethnic Group						
Rain [γ_2^s]	0.0001	0.0014	-0.0002	0.0007	0.0014	0.0005
	(0.0010)	(0.0009)	(0.0007)	(0.0013)	(0.0010)	(0.0013)
Rain × Transhumant Pastoral [γ_3^s]	-0.0014	-0.0046	0.0017	-0.0011	-0.0079	0.0005
	(0.0047)	(0.0048)	(0.0038)	(0.0065)	(0.0062)	(0.0065)
Own Cell						
Rain [γ_4^s]	-0.0002	-0.0005	-0.0001	-0.0004	-0.0007	-0.0002
	(0.0007)	(0.0006)	(0.0005)	(0.0010)	(0.0009)	(0.0010)
Rain × Transhumant Pastoral [γ_5^s]	0.0041	0.0056*	-0.0008	0.0046	0.0052	0.0032
	(0.0035)	(0.0032)	(0.0024)	(0.0051)	(0.0039)	(0.0051)
Nearest Neighboring Ethnic Group: Additional Calculations						
Effect of 1 Std. Dev. Rain Shock as % of Dep. Var. Mean:						
Rain	-1.88	0.57	-3.51	-0.95	0.83	-1.13
p-value	[0.40]	[0.83]	[0.36]	[0.53]	[0.67]	[0.46]
Rain × Transhumant Pastoral	-37.51	-57.26	-8.68	-13.60	-20.12	-13.64
p-value	[0.00]	[0.00]	[0.58]	[0.01]	[0.01]	[0.01]
Rain + Rain × Transhumant Pastoral	-39.39	-56.68	-12.19	-14.55	-19.29	-14.76
p-value	[0.00]	[0.00]	[0.43]	[0.01]	[0.01]	[0.00]
Dep. Var. Mean	0.035	0.025	0.016	0.085	0.055	0.084
Cell FE	Yes	Yes	Yes	Yes	Yes	Yes
Country × Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Climate-Zone-Year Clusters	420	420	420	322	322	322
Cell Clusters	7,722	7,722	7,722	7,722	7,722	7,722
Observations	231,660	231,660	231,660	177,606	177,606	177,606

Note: The unit of observation is a 0.5-degree grid-cell and year. "I(Any)" is an indicator variable that equals one if at least one violent conflict occurs in a cell and year. "I(State)" is an indicator variable that equals one if at least one conflict event involving the state occurs in a cell and year; "I(Non-State)" is an indicator variable that equals one if at least one conflict event not involving the state occurs in a cell and year. *Nearest Neighboring Ethnic Group* refers to the nearest neighboring ethnic territory to cell i. *Own Ethnic Group* refers to the ethnic territory that contains cell i. Standard errors, which are reported in parentheses, are adjusted for clustering at the level of a grid-cell and a climate zone-year. * p < 0.1, ** p < 0.05, *** p < 0.01.

qualitatively identical. Thus, for the remainder of the paper, we use the narrower definition as our baseline measure. In addition, we limit our focus to four baseline outcome variables. We retain both measures of overall conflict, but use the UCDP measure of state conflict (because of the longer time series) and the ACLED measure of non-state conflict (because of the better coverage of smaller-scale conflicts due to the lower threshold for inclusion).

A potential concern is that transhumant pastoralists might also have other characteristics that are important for mediating the relationship between adverse rainfall and nearby conflict. Given this, we check the sensitivity of our findings to accounting for other potentially important characteristics of neighboring ethnic groups; namely, pre-colonial political centralization, the presence of segmentary lineage organization, and a traditional belief in a religion with a moralizing high god.[4] We re-estimate a variant of equation (2) controlling for each additional characteristic of a cell's nearest neighbor interacted with the neighbor's rainfall. The estimates, which we report in Appendix Table A6, show that our findings remain robust to the inclusion of these additional controls.

Another potential concern is that transhumant pastoral groups tend to live in locations where rainfall is more scarce. Thus, our findings might be biased by the differential spillover effects for nearest neighbors that experience less rainfall in general. We check for this by estimating our baseline equation while controlling for the rainfall of the nearest neighbor (normalized to lie between 0 and 1) interacted with the group's average rainfall during the period of our analysis, 1989–2019. As shown in Appendix Table A7, the estimates of interest are nearly identical with the inclusion of this control.

It is possible that our measure of rainfall is correlated with other time-varying macro-level factors that differentially affect the presence of conflict adjacent to transhumant pastoral groups. Rainfall could be capturing the effects of other factors that are also trending over time, such as the availability of firearms, population density, better communication technologies, and so forth (Acemoglu, Fergusson and Johnson, 2020, Manacorda and Tesei, 2020). To account for this, we include a control for a linear time trend interacted with each cell's nearest neighbor's measure of transhumant pastoralism. While this control captures factors trending linearly over time, other factors exhibiting more irregular movements may also be important for conflict, such as commodity prices (Berman, Couttenier, Rohner and Thoenig, 2017, McGuirk and Burke, 2020). To account for this, we also interact the measure of a cell's nearest neighbor's transhumant pastoralism with numerous aggregate price indices that may affect conflict differently across space. These include price indices for energy (coal, crude oil, and natural gas), metals and minerals (aluminum, copper, iron ore, lead, nickel, steel, tin, and zinc), and precious metals (gold, platinum, and silver), as well as a price index for agricultural products (oils and meals, grains, and other food such as bananas, meat, and sugar).[5] The estimates with these additional covariates, reported in Appendix Table A8, are similar in magnitude and remain highly significant.

Our final check examines the robustness of our conclusions to various methods of calculating standard errors, including clustering by country; clustering by country and climate-zone; and allowing for spatial correlation within 1,000 kilometers of a cell. As we report in Appendix Table A9, the precision of our estimates is similar in each case.

[4]Pre-colonial political centralization, which is measured by the levels of jurisdictional hierarchies beyond the local community, has been shown to be an important determinant of public goods provision and economic development (Gennaioli and Rainer, 2007, Michalopoulos and Papaioannou, 2013), both of which are relevant for conflict. Segmentary lineage organization has been shown to be associated with conflict (Moscona et al., 2020). The presence of a moralizing high god is believed to be an important factor for cooperation, conflict, and long-term economic growth (Norenzayan, 2013).

[5]The data are from the World Bank's "Pink Sheet" commodity price index dataset (World Bank, 2021). All indices are based on real prices.

6. Testing for Specific Mechanisms

Our findings are consistent with adverse rainfall shocks inducing transhumant pastoral groups to migrate to nearby agricultural lands before the harvest, resulting in conflict with sedentary farmers. This explanation yields a number of additional testable predictions that we now take to the data. These are: (1) the effects are due to the combination of mobility and pastoralism (i.e., transhumant pastoralism) rather than either mobility or pastoralism alone; (2) transhumant pastoral rainfall should primarily affect conflict on agricultural lands; (3) since rainfall matters because it affects plant growth, we should observe similar patterns if we use phytomass rather than rainfall; (4) we should not observe the same patterns if we examine other climatic traits, like temperature, that are less important for plant growth in Africa; and (5) transhumant pastoral rainfall should primarily affect conflict during the wet season (when groups are competing for resources) and not the dry season (when they are not).

Test 1: Importance of transhumant pastoralism rather than mobility or pastoralism alone. Our mechanism of interest suggests that both aspects of transhumant pastoralism are necessary; namely, that groups move seasonally and they engage in animal herding. If an ethnic group is characterized by only one of the two—they move without animals or they have animals but do not move—then we do not expect to observe the same effects.

To test for this, we estimate a version of equation (2) that also includes each component of the transhumant pastoralism measure—the mobility indicator and the pastoralism index—interacted with rainfall. By including each component interaction, we are accounting separately for the role of mobility and for the role of pastoralism. This is particularly important given the recent findings in Eberle et al. (2020), which show the importance of mobility for mediating the effects of temperature on conflict. This also addresses potential concerns arising due to factors associated with pastoralism, such as the presence of a "culture of honor" and revenge-taking (Nisbett and Cohen, 1996, Grosjean, 2014, Cao et al., 2021), which may be more acute in the absence of rainfall. These effects are captured by the inclusion of the pastoralism measure (along with relevant interactions) in the equation directly.

The estimates from the equation including the component interactions are reported in Table 3. We find that our estimates of interest are robust to these additional controls and that the coefficients for the controls themselves are small and insignificant. This suggests that it is the seasonal movement of migrating herd animals that is important for our findings and not either mobility or the presence of herd animals alone.

Test 2: Concentration of conflict on agricultural land. The second testable prediction that arises from our interpretation is that conflict due to adverse rainfall shocks in the territory of transhumant pastoral groups should be concentrated in land that is agricultural. Using information from variable v5 of the *Ethnographic Atlas*, we split the sample between cells that are located within the territory of ethnic groups whose traditional reliance on agriculture for subsistence exceeded 35%

Table 3: Robustness to Controlling for the Components of Transhumant Pastoralism

	Indicator for the presence of conflict			
	(1)	(2)	(3)	(4)
	UCDP I(Any)	UCDP I(State)	ACLED I(Any)	ACLED I(Nonstate)
Nearest Neighboring Ethnic Group				
Rain	-0.0014	0.0005	-0.0020	-0.0021
	(0.0011)	(0.0008)	(0.0015)	(0.0015)
Rain × Pastoral	0.0043	-0.0022	0.0069	0.0067
	(0.0044)	(0.0035)	(0.0061)	(0.0061)
Rain × Transhumant	0.0040	0.0020	0.0029	0.0031
	(0.0025)	(0.0018)	(0.0039)	(0.0039)
Rain × Transhumant Pastoral	-0.0191***	-0.0128**	-0.0186**	-0.0187**
	(0.0069)	(0.0057)	(0.0088)	(0.0088)
Dep. Var. Mean	0.0351	0.0253	0.0845	0.0842
Cell FE	Yes	Yes	Yes	Yes
Country × Year FE	Yes	Yes	Yes	Yes
Climate-Zone-Year Clusters	420	420	322	322
Cell Clusters	7,722	7,722	7,722	7,722
Observations	231,660	231,660	177,606	177,606

Note: The unit of observation is a 0.5-degree grid-cell and year. "I(Any)" is an indicator variable that equals one if at least one violent conflict occurs in a cell and year. "I(State)" is an indicator variable that equals one if at least one conflict event involving the state occurs in a cell and year; "I(Non-State)" is an indicator variable that equals one if at least one conflict event not involving the state occurs in a cell and year. *Nearest Neighboring Ethnic Group* refers to the nearest neighboring ethnic territory to cell i. This regression controls for the corresponding variables at the *Own Ethnic Group* level and the *Own Cell* level. Standard errors, which are reported in parentheses, are adjusted for clustering at the level of a grid-cell and a climate zone-year. * p < 0.1, ** p < 0.05, *** p < 0.01.

and those whose reliance was between 0-35%. We then re-estimate equation (2) separately for agricultural and non-agricultural cells.

The estimates, reported in Table 4, show that our main effects are driven primarily by conflict in agricultural cells. While the estimated coefficient for the interaction of interest, γ_1^s, is large in magnitude and statistically significant for agricultural cells, it is much smaller in magnitude, varies in sign, and is never statistically different from zero in non-agricultural cells. Thus, consistent with our interpretation, it is agricultural grid cells that are primarily responsible for the effects reported in Table 2.[6]

Test 3: Similar effects for phytomass. Our hypothesis implies that a lack of rainfall in the territory of transhumant pastoral groups leads to conflict because it reduces the amount of vegetation available for herd animals, which are moved to more fertile agricultural lands as a consequence. If this is the case, we should find that adverse phytomass growth in the territory of neighboring transhumant pastoral groups should be associated with increased conflict in precisely the same manner as adverse rainfall.

[6]We find similar results when we split cells into three groups: the effects are greatest in absolute magnitude for cells in the highest agriculture category, defined as 66-100% reliance.

Table 4: Effect of Rain in Nearest Neighboring THP Territory on Conflict in Agricultural and Non-Agricultural Cells

	Conflict in Agricultural Cells				Conflict in Non-Agricultural Cells			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	UCDP	UCDP	ACLED	ACLED	UCDP	UCDP	ACLED	ACLED
	I(Any)	I(State)	I(Any)	I(Nonstate)	I(Any)	I(State)	I(Any)	I(Nonstate)
Nearest Neighboring Ethnic Group								
Rain [γ_0^s]	-0.0006	0.0002	-0.0002	-0.0004	0.0000	-0.0001	-0.0105***	-0.0103***
	(0.0007)	(0.0006)	(0.0011)	(0.0011)	(0.0026)	(0.0024)	(0.0036)	(0.0036)
Rain × Transhumant Pastoral [γ_1^s]	-0.0119**	-0.0121***	-0.0172***	-0.0180***	-0.0053	-0.0062	0.0052	0.0056
	(0.0047)	(0.0039)	(0.0056)	(0.0057)	(0.0056)	(0.0051)	(0.0064)	(0.0064)
Dep. Var. Mean	0.039	0.028	0.097	0.096	0.025	0.019	0.055	0.055
Cell FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country × Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Climate-Zone-Year Clusters	390	390	299	299	390	390	299	299
Cell Clusters	5,482	5,482	5,482	5,482	2,240	2,240	2,240	2,240
Observations	164,460	164,460	126,086	126,086	67,200	67,200	51,520	51,520

Note: The unit of observation is a 0.5-degree grid-cell and year. "I(Any)" is an indicator variable that equals one if at least one violent conflict occurs in a cell and year. "I(State)" is an indicator variable that equals one if at least one conflict event involving the state occurs in a cell and year; "I(Non-State)" is an indicator variable that equals one if at least one conflict event not involving the state occurs in a cell and year. *Nearest Neighboring Ethnic Group* refers to the nearest neighboring ethnic territory to cell i. *Own Ethnic Group* and *Own Cell* covariates are included in the regressions but not reported. Standard errors, which are reported in parentheses, are adjusted for clustering at the level of a grid-cell and a climate zone-year. * p < 0.1, ** p < 0.05, *** p < 0.01.

We test for this by re-estimating equation (2) using the measures of phytomass in place of rainfall. The estimates, reported in Panel A of Table 5, are very similar for UCDP and even larger in magnitude for ACLED. For example, looking at overall conflict, we find that a one standard deviation decrease in phytomass in the territory of a neighboring transhumant pastoral group increases conflict by 37.95% of the mean incidence when the UCDP measure is used (column 1) and by 32.09% when the ACLED measure is used (column 3). The equivalent effects of rainfall are 37.5% and 13.6%.[7]

Unlike rainfall, one might be concerned that our satellite measure of phytomass growth is itself endogenous to both conflict and the location of grazing animals. To address this concern, we create a *Phytomass Suitability Index*, which is phytomass predicted by rainfall at the level of a cell and a year. Aggregating this measure to the level of an ethnic group and the level of a nearest neighbor for each year, we then estimate a version of equation (2) where the six rainfall variables are replaced by six corresponding Phytomass Suitability Indices. Estimates using the indices are reported in Appendix Tables A10 and A11, where Table A10 uses a phytomass suitability index predicted by a linear function of rainfall and Table A11 uses a measure that is predicted by a quadratic function (i.e., rainfall and rainfall squared). The estimates are similar in both magnitude and precision to our baseline estimates.

Test 4: No effects for temperature. According to our interpretation, we should not find the same effects for temperature as we do for rainfall or phytomass since it is not as important for plant growth in Africa. While it is well documented that temperature is linked to conflict through many potential channels, we do not expect temperature to matter for conflict through our specific interaction of interest.

[7]The robustness of our findings to the use of the phytomass measure alleviates the concern that imprecision in the gridded rainfall data might be important for our estimates. While the underlying rainfall data are based on a dense set of weather gauges, the gridded measure does rely on interpolation. By contrast, the phytomass measure is based on satellite images measured weekly at the 1km pixel level.

Table 5: Estimates Using Phytomass and Temperature Rather than Rainfall

	Indicator for the presence of conflict			
	(1) UCDP I(Any)	(2) UCDP I(State)	(3) ACLED I(Any)	(4) ACLED I(Nonstate)
	Panel A: Effect of Phytomass			
Nearest Neighboring Ethnic Group				
Phytomass	0.0001	0.0001	0.0003	0.0004
	(0.0005)	(0.0004)	(0.0006)	(0.0006)
Phytomass × Transhumant Pastoral	-0.0043**	-0.0041**	-0.0085***	-0.0086***
	(0.0018)	(0.0016)	(0.0018)	(0.0018)
Effect of 1 Std. Dev. Phytomass Shock as % of Dep. Var. Mean:				
Phytomass × Transhumant Pastoral	-37.95	-50.73	-32.09	-32.70
p-value	[0.02]	[0.01]	[0.00]	[0.00]
Dep. Var. Mean	0.037	0.027	0.087	0.087
Climate-Zone-Year Clusters	280	280	294	294
Cell Clusters	7,722	7,722	7,722	7,722
Observations	154,440	154,440	162,162	162,162
	Panel B: Effect of Temperature			
Nearest Neighboring Ethnic Group				
Temperature	0.0019	0.0028**	0.0027	0.0026
	(0.0016)	(0.0013)	(0.0027)	(0.0027)
Temperature × Transhumant Pastoral	0.0022	0.0047	0.0030	0.0029
	(0.0037)	(0.0035)	(0.0045)	(0.0045)
Effect of 1 Std. Dev. Temp. Shock as % of Dep. Var. Mean:				
Temp. × Transhumant Pastoral	5.55	15.89	3.48	3.42
p-value	[0.54]	[0.18]	[0.52]	[0.52]
Dep. Var. Mean	0.032	0.024	0.068	0.068
Climate-Zone-Year Clusters	364	364	252	252
Cell Clusters	7,722	7,722	7,722	7,722
Observations	200,728	200,728	138,968	138,968
Cell FE	Yes	Yes	Yes	Yes
Country × Year FE	Yes	Yes	Yes	Yes

Note: The unit of observation is a 0.5-degree grid-cell and year. "I(Any)" is an indicator variable that equals one if at least one violent conflict occurs in a cell and year. "I(State)" is an indicator variable that equals one if at least one conflict event involving the state occurs in a cell and year; "I(Non-State)" is an indicator variable that equals one if at least one conflict event not involving the state occurs in a cell and year. *Nearest Neighboring Ethnic Group* refers to the nearest neighboring ethnic territory to cell i. *Own Ethnic Group* and *Own Cell* covariates are controlled for but not reported. Standard errors, which are reported in parentheses, are adjusted for clustering at the level of a grid-cell and a climate zone-year. * p < 0.1, ** p < 0.05, *** p < 0.01.

We test for this by re-estimating equation (2) using temperature in place of rainfall. The findings, reported in Panel B of Table 5, reveal that the same patterns are not present in the data when we use temperature. We estimate a fairly precise zero coefficient for the interaction between the temperature of a cell's nearest neighbor and the neighbor's measure of transhumant pastoralism. This is consistent with our observation that, unlike rainfall, temperature is not a first-order determinant of phytomass growth.[8]

Overall, the estimates indicate that the established mechanisms linking temperature to conflict

[8]Interestingly, we find evidence of a direct relationship between temperature and conflict, as in the existing literature. Specifically, we estimate that, in general, higher temperatures experienced by the ethnic group of a cell result in more conflict in that cell.

in the literature cannot account for the effects we find here.[9] This is particularly important given the recent evidence that higher temperatures at the border between nomadic and sedentary populations increase conflict. These null effects provide added assurance that our mechanism is distinct from the 'heat and hate' effects documented in Eberle et al. (2020).

Test 5: Concentration of conflict during the wet season. The fourth test focuses on the timing of conflict within a year. Our mechanism of interest implies that adverse rainfall in transhumant pastoral territories only generates conflict in nearby farmland during the wet season. A lack of rain during the wet season forces transhumant pastoral groups to migrate early to neighboring farmlands, when land is still being used for cultivation, which generates conflict. By contrast, during the dry season, there is no tension since land is fallow and animal grazing benefits both groups.

We verify this prediction using a number of tests. In the first, we estimate a variant of equation (2) where the dependent variable is a measure of conflict that is specific to each of the two seasons. Because the length of the seasons differ across locations, we transform the dependent variable to be a monthly average, either: (1) the fraction of months that have at least one conflict incident, or (2) the average number of conflict incidents per month.

To separate wet-season conflicts from dry-season conflicts, we use data from the MIRCA2000 global dataset (Portmann, Siebert and Döll, 2010), which provides information on the beginning and end of the growing season as of the year 2000 at a 5 arc minute (9.2 km at equator) resolution. We use the starting and final months of the growing season for the 'main crop' of a cell, defined as the crop with the greatest harvested area in the cell. Our sample is therefore restricted to cells that contain some harvested cropland and experience both seasons. Among these cells, the average duration of the main crop's wet season is 5.75 months.

To ensure that we capture all conflict events due to the joint use of resources, we define wet-season conflict as conflict events that begin during either the main crop's growing season or within a month after it ends. This allows for conflict events that coincide with the harvesting period, which may extend beyond the estimated final month of the main crop's growing season according to the MIRCA2000 data. Dry-season conflicts are events that begin at any point during the rest of the year.[10]

The estimates are reported in Panel A of Table 6. We find that our baseline effects are primarily due to conflict events that occur in the wet season. The estimated effects on wet-season conflict are about twice the magnitude and much more precisely estimated than the effects on dry-season conflict. This is particularly striking because, without understanding the nature of conflict that arises from transhumant pastoralism, one might expect rainfall to have the largest effect on conflict during the dry season, when fresh water is more scarce.

[9] As reported in Appendix Table A12, if we include both rainfall and temperature, our estimated rainfall spillover effects from transhumant pastoral neighbors remain large and statistically significant, while we observe no equivalent spillover effect from temperature shocks.

[10] When dating conflicts, we use the earliest date indicated when multiple dates or a time interval is reported. Thus, we focus on the first incident within a conflict event—which is our object of interest—rather than other incidents that are more likely to be a continuation of previous clashes.

Table 6: Effects of Neighbor's Rainfall on Conflict during the Wet and Dry Seasons

	Wet Season UCDP Conflict		Dry Season UCDP Conflict	
	(1)	(2)	(3)	(4)
	Incidence Year Equiv.	No. Events Year Equiv.	Incidence Year Equiv.	No. Events Year Equiv.
	Panel A. Annual Rainfall and Conflict by Seasons			
Nearest Neighboring Ethnic Group				
Annual Rain	0.0008	0.0039	-0.0022	-0.0017
	(0.0023)	(0.0048)	(0.0032)	(0.0113)
Annual Rain × Transhumant Pastoral	-0.0346***	-0.1294**	-0.0152	-0.0669
	(0.0128)	(0.0613)	(0.0116)	(0.0444)
Effect of 1 Std. Dev. Rain Shock as % of Dep. Var. Mean:				
Annual Rain × Transhumant Pastoral	-46.32	-94.31	-18.60	-44.40
p-value	[0.01]	[0.04]	[0.19]	[0.13]
	Panel B. Seasonal Rainfall and Conflict by Seasons			
Nearest Neighboring Ethnic Group				
Seasonal Rain	0.0013	0.0037	-0.0015	0.0008
	(0.0016)	(0.0041)	(0.0022)	(0.0073)
Seasonal Rain × Transhumant Pastoral	-0.0184*	-0.0834*	-0.0043	-0.0103
	(0.0104)	(0.0486)	(0.0103)	(0.0214)
Effect of 1 Std. Dev. Rain Shock as % of Dep. Var. Mean:				
Seasonal Rain × Transhumant Pastoral	-41.73	-102.80	-6.75	-8.69
p-value	[0.08]	[0.09]	[0.68]	[0.63]
Dep. Var. Mean	0.090	0.165	0.098	0.181
Cell FE	Yes	Yes	Yes	Yes
Country × Year FE	Yes	Yes	Yes	Yes
Climate-Zone-Year Clusters	420	420	420	420
Cell Clusters	4,632	4,632	4,632	4,632
Observations	138,960	138,960	138,960	138,960

Note: The unit of observation is a 0.5-degree grid-cell and year. "Incidence" is per-month UCDP conflict incidence in either the wet season or the dry season as defined in the main text. "Number" is per-month number of UCDP conflict events. *Nearest Neighboring Ethnic Group* refers to the nearest neighboring ethnic territory to cell i. *Own Ethnic Group* and *Own Cell* covariates are included in the regressions but not reported. Standard errors, which are reported in parentheses, are adjusted for clustering at the level of a grid-cell and a climate zone-year. * p < 0.1, ** p < 0.05, *** p < 0.01.

The second test that we implement also measures season-specific rainfall. Thus, we estimate the relationship between rainfall in a season and conflict in that season, and we do this separately for both wet and dry seasons. The estimates, reported in Panel B of Table 6, show a similar pattern. Our baseline finding is driven by adverse rainfall in the wet season causing conflict in the wet season rather than adverse rainfall in the dry season causing conflict in the dry season.

Test 6: Combinations of predictions. The last exercise that we undertake is to combine the prediction about the timing of the effects (wet season rather than dry season) with the importance of phytomass and the location of conflict events (agricultural land). Appendix Table A13 reproduces the estimates from Table 6, but using phytomass growth rather than rainfall. As shown, the same pattern emerges in the data. It is during the wet season that we see the effects of phytomass growth on conflict.

We next incorporate the prediction about the location of conflicts by re-estimating the specifications reported in Table 6 and Appendix Table A13, but for agricultural cells and non-agricultural cells separately. The estimates, reported in Appendix Tables A14 and A15 respectively, show that the seasonal patterns we identify (for both rainfall and phytomass) are strongly present in agricultural cells but much less so in non-agricultural cells.

These specific patterns—on the timing of the effects during the year, the location of the effects across groups, and the centrality of plant growth—are precisely what one would expect according to our hypothesis: reduced rainfall in transhumant pastoral territories induces herders to move to agricultural lands prior to the harvest, generating competition for resources that ultimately results in conflict.

7. Learning from the Estimates

The estimates reported to this point provide evidence consistent with first-hand accounts of the effects of climate change on conflict between transhumant pastoral groups and farmers. In this section, we examine how this finding relates to extremist-religious conflict and whether or not it is moderated by government policies or by the distribution of political power across ethnic groups.

A. Examining Religious Extremism

We begin with the question of whether our estimated relationship can help to explain the rise in religious conflict in Africa in the past two decades. This trend is shown in Figure 5, which reports the average conflict incidence across cells in our UCDP data between 1989 and 2018 for events that involve at least one actor that is labeled as being a jihadist group and for those events that do not.[11] Jihadist conflicts have increased significantly since 2000, while non-jihadist conflicts have remained relatively stable.

One apparent explanation for this is a rise in religious grievances or tensions between Islamic and Christian groups. However, our findings raise the possibility that this trend is instead (or also) due to the increased frequency of adverse rainfall shocks in transhumant pastoral territories. In our data, groups with a value of transhumant pastoralism that is non-zero are 56.5% Muslim and 27.8% Christian, whereas groups with a value of transhumant pastoralism equal to zero are 24.6% Muslim and 48.4% Christian (see Appendix Table A4). Since the conflicts that we study often involve a largely Muslim group on one side and a largely Christian group on the other, they may take the appearance of—or soon develop into—religious conflict. Tensions between farmers and herders have also been known to generate support for jihadist groups, which facilitates recruitment (Benjaminsen and Ba, 2019). Jihadist groups may therefore become involved in conflicts between farmers and herders that arise due to reduced rainfall.

We test for this possibility by estimating our baseline specification—equation (2)—separately for jihadist and non-jihadist conflicts. The estimates are reported in columns 1 and 2 of Table 7. We find statistically significant and quantitatively similar estimates for the coefficient on our interaction term for both types of conflict. This suggests that our mechanism applies equally to

[11]We identify jihadist conflict events as those for which (i) the word "jihad" is present in either the actor's name or in the source headline or (ii) the word "Islam-" appears in the source headline and one of the actors is explicitly jihadist. The list of groups is in Appendix A.

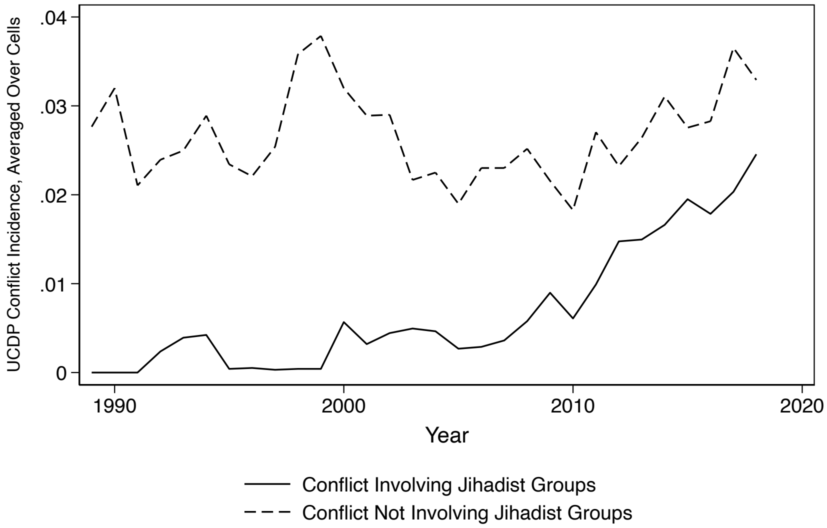


Figure 5: Total Jihadist and non-Jihadist Conflicts over Time in Africa

both jihadist and non-jihadist conflict. The predicted effects of a one-standard-deviation rainfall shock in terms of the mean of the dependent variable, reported in the second panel of the table, are about three times greater for jihadist conflicts (82%) than non-jihadist conflicts (27%). This is because our measure of jihadist conflict has a lower mean incidence, which can be seen in Figure 5, particularly prior to 2000.

In columns 3 and 4, we check whether our findings are simply because transhumant pastoral groups are more likely to be Islamic, which may be correlated with other factors—such as low educational mobility, as in Alesina, Hohmann, Michalopoulos and Papaioannou (2023)—that interact with low rainfall in a manner that results in conflict spillovers. To account for the importance of religion, we include the proportion of each ethnic group that is Christian and Muslim (as of 2020) interacted with each of our three rainfall measures (own cell, own ethnic group, and nearest neighboring ethnic group) as controls in equation (2).[12] The estimated effects are nearly identical in magnitude and significance after accounting for contemporary religion.

Our findings suggest that extremist-religious violence responds to adverse rainfall in almost the same manner as other types of violence. This is consistent with atavistic grievances not being the sole determinant of religious conflict.

B. Policy Responses: Development Aid Projects and Protected Conservation Areas

Development Aid Projects In recent decades, many development organizations have designed interventions to combat the adverse effects of climate change. Examples include projects that aim to enhance agricultural productivity, improve irrigation infrastructure, or expand protected conservation areas. A potential solution to the effects that we document is to implement more

[12]The data are constructed using information from the *World Religion Database*, which reports information on the populations of 18 religions for each language group in the world (Johnson and Grim, 2021). The data are reported with Ethnologue identifiers which we match to our *Ethnographic Atlas*. Since multiple *Ethnologue* groups often match to one *Ethnographic Atlas* group, we create *Ethnographic Atlas* level measures by taking population-weighted averages across all *Ethnologue* groups that match to a *Ethnographic Atlas* group.

Table 7: Jihadist Violence

	Indicator for the presence of conflict			
	(1) I(Jihadist)	(2) I(Non-Jihadist)	(3) I(Jihadist)	(4) I(Non-Jihadist)
Nearest Neighboring Ethnic Group				
Rain	-0.0000	-0.0006	0.0006	0.0002
	(0.0003)	(0.0006)	(0.0005)	(0.0020)
Rain × Transhumant Pastoral	-0.0051**	-0.0063**	-0.0056**	-0.0056*
	(0.0022)	(0.0026)	(0.0025)	(0.0030)
Rain × Share Muslim			-0.0020	-0.0016
			(0.0015)	(0.0025)
Rain × Share Christian			-0.0003	-0.0007
			(0.0006)	(0.0028)
Nearest Neighboring Ethnic Group: Additional Calculations				
Effect of 1 Std. Dev. Rain Shock as % of Dep. Var. Mean:				
Rain × Transhumant Pastoral	-82.03	-27.05	-82.42	-21.41
p-value	[0.02]	[0.01]	[0.03]	[0.06]
Dep. Var. Mean	0.007	0.028	0.008	0.032
Cell FE	Yes	Yes	Yes	Yes
Country × Year FE	Yes	Yes	Yes	Yes
Climate-Zone-Year Clusters	420	420	420	420
Cell Clusters	7,722	7,722	6,507	6,507
Observations	231,660	231,660	195,210	195,210

Note: The unit of observation is a 0.5-degree grid-cell and year. "Jihadist" is an indicator variable that equals one if at least one UCDP conflict event occurs in a cell-year involving a self-styled jihadist group, as defined in the main text. "Non-Jihadist" is an indicator variable that equals one if at least one UCDP conflict event occurs in a cell-year that does not involve a self-styled jihadist group. *Nearest Neighboring Ethnic Group* refers to the nearest neighboring ethnic territory to cell i. *Own Ethnic Group* and *Own Cell* covariates are included in the regressions but not reported. In columns 3 and 4, the covariates also include own ethnic group rainfall interacted with the share muslim and the share christian, as well as own cell rainfall interacted with the same two variables. Standard errors, which are reported in parentheses, are adjusted for clustering at the level of a grid-cell and a climate zone-year. * p < 0.1, ** p < 0.05, *** p < 0.01.

of these interventions. However, given the specifics of the mechanism that we uncover, it is not clear whether these policies will help. The effects that we identify are due to adverse rainfall causing pastoral groups to migrate to nearby farmlands before harvest. Improving the agricultural productivity of farmland does not solve this underlying problem. Moreover, irrigation projects potentially facilitate the conversion of marginal lands to farmland, thus reducing the land available for grazing. Land privatization and the creation of protected conservation lands that ban animal grazing likely have the same effect. In general, any policy that constrains the land available to pastoralists in response to adverse rainfall can potentially increase the likelihood that they come into conflict with farmers during the growing season.

Against this backdrop, we examine whether our documented effects are stronger or weaker in the presence of such projects. To do this, we allow our effects of interest to differ depending on the stock of aid projects present in a country and year. We measure the presence of aid projects in a country over time using the *Aid Data* repository, which reports detailed information on all bilateral and multilateral foreign aid projects from 1947-2013.[13] We measure the cumulative number of project locations that have been implemented in each country prior to that year (since 1947) and

[13]See AidData (2017) and Tierney, Nielson, Hawkins, Roberts, Findley, Powers, Parks, Wilson and Hicks (2011).

normalize this by the number of cells in a country.[14] We denote this variable $ForeignAid_{ct}$.[15]

We then estimate the following equation, which allows our effect of interest to vary by the prevalence of foreign aid projects in a country:

$$\begin{aligned}
y_{iet} \quad = \quad & \psi_0^s \, Rain_{it}^{Neighbor} + \psi_1^s \, Rain_{it}^{Neighbor} \times TranshumantPastoral_i^{Neighbor} \\
& + \psi_2^s \, Rain_{it}^{Neighbor} \times TranshumantPastoral_i^{Neighbor} \times ForeignAid_{ct-1} \\
& + \psi_3^s Rain_{it}^{Neighbor} \times ForeignAid_{ct-1} + \psi_4^s TranshumantPastoral_i^{Neighbor} \times ForeignAid_{ct-1} \\
& + \psi_5^s \, Rain_{et}^{OwnGroup} + \psi_6^s \, Rain_{et}^{OwnGroup} \times TranshumantPastoral_e^{OwnGroup} \\
& + \psi_7^s \, Rain_{it}^{OwnCell} + \psi_8^s \, Rain_{it}^{OwnCell} \times TranshumantPastoral_e^{OwnGroup} \\
& + \alpha_i^s + \alpha_{c(i)t}^s + \xi_{iet}^s, \qquad (3)
\end{aligned}$$

where $ForeignAid_{ct}$ is as described above and all indices and other variables are as defined in equation (2). The estimates of interest are ψ_1^s, which is our main spillover effect when transhumant pastoral groups are in a country with no previous foreign aid, and ψ_2^s, which shows how our effect of interest differs depending on the amount of past foreign aid projects in a country.

The first analysis that we undertake divides foreign aid projects into two categories: those that are agricultural and those that are not. We identify agricultural projects as those for which the reported sector code is "Agriculture" and non-agricultural projects as all others. We allow our estimated effects of interest to differ depending on the cumulative presence of both types of projects in a country and year. The estimates, which are reported in Table 8, show no evidence that agricultural aid reduces the effects of rainfall in transhumant pastoral territories on conflict in nearby cells. While the point estimates are imprecise, their sign and magnitudes suggest that agricultural aid may actually exacerbate the effects of interest.

To investigate whether the estimates mask heterogeneous effects, we create even finer categories of aid projects, distinguishing between irrigation projects, forestry projects, conservation projects, land projects, other agricultural projects, and other non-agricultural projects.[16] The estimates, which are reported in Appendix Table A17, do not indicate that any of these types of aid alleviate the effects of adverse rainfall shocks in transhumant pastoral areas on conflict.

Finally, because $ForeignAid_{ct}$ varies over time as well as between countries, we estimate a version of (3) that additionally controls for $Rain_{it}^{Neighbor} \times TranshumantPastoral_i^{Neighbor} \times \alpha_c^s$ and $Rain_{it}^{Neighbor} \times TranshumantPastoral_i^{Neighbor} \times \alpha_t^s$; that is, our double interaction of interest interacted with country fixed effects and with year fixed effects. By including these interactions, we only exploit variation in foreign aid that is over time and within-country rather than across countries. In effect, this implies that our triple-interaction effect of interest, ψ_2^s, is identified using a difference-in-differences style estimator rather than a cross-country estimator. The results of

[14]For example, if one umbrella program is implemented in ten locations in a country with twenty cells, it is measured with a value of 10/20 = 0.5.

[15]Descriptive statistics for all country-year level variables employed in this section are presented in Appendix Table A16.

[16]We measure these variables by searching for relevant keywords in the set of variables that contain the project descriptions or sectors. The keywords are, respectively, "irrigat" for irrigation; "forest" for forestry; "conserv" for conservation; and "land", "tenure" or "titling" for land. We define the residual projects as agricultural or non-agricultural as in the first analysis.

Table 8: Heterogeneity by the Presence of International Aid Projects

	Indicator for the presence of conflict			
	(1) UCDP I(Any)	(2) UCDP I(State)	(3) ACLED I(Any)	(4) ACLED I(Non-State)
Nearest Neighboring Ethnic Group				
Rain × Transhumant Pastoral	-0.0129***	-0.0122***	-0.0038	-0.0036
	(0.0038)	(0.0035)	(0.0039)	(0.0039)
Rain × Transhumant Pastoral × Total Agriculture Aid	-0.0059	-0.0068	-0.0113	-0.0117
	(0.0064)	(0.0055)	(0.0074)	(0.0075)
Rain × Transhumant Pastoral × Total Non-Agriculture Aid	0.0004	0.0004	0.0005	0.0005
	(0.0004)	(0.0004)	(0.0005)	(0.0005)
Dep. Var. Mean	0.032	0.024	0.068	0.068
Cell FE	Yes	Yes	Yes	Yes
Country × Year FE	Yes	Yes	Yes	Yes
Climate-Zone-Year Clusters	364	364	252	252
Cell Clusters	7,722	7,722	7,722	7,722
Observations	200,772	200,772	138,996	138,996

Note: The unit of observation is a 0.5-degree grid-cell and year. "I(Any)" is an indicator variable that equals one if at least one violent conflict occurs in a cell and year. "I(State)" is an indicator variable that equals one if at least one conflict event involving the state occurs in a cell and year; "I(Non-State)" is an indicator variable that equals one if at least one conflict event not involving the state occurs in a cell and year. *Nearest Neighboring Ethnic Group* refers to the nearest neighboring ethnic territory to cell i. This regression controls for the corresponding variables at the *Own Ethnic Group* level and the *Own Cell* level. Standard errors, which are reported in parentheses, are adjusted for clustering at the level of a grid-cell and a climate zone-year. * p < 0.1, ** p < 0.05, *** p < 0.01.

this procedure are presented in Panels A and B of Appendix Table A18. The results again suggest that, if anything, agricultural projects may exacerbate the main effects that we document.[17]

Conservation Areas The next analysis that we undertake looks specifically at the role of protected conservation lands in a country at a point in time. While conservation is an important tool for environmental protection, it can also be disruptive for pastoral groups. Lands that are converted into conservation areas may contain transhumant pastoral corridors or grazing pastures. Since conservation areas typically forbid the use of protected lands for grazing or impose regulations or fees when use is allowed, their expansion may disrupt existing transhumant migration routes and cooperative arrangements with farmers (Bergius, Benjaminsen, Manganga and Buhaug, 2020, Cavanagh, Weldemichel and Benjaminsen, 2020).

We measure the presence of conservation lands in each country and year using data from *Protected Planet*, a global database of protected areas and other conservation measures,[18] and compile panel data that measures the share of a country's total area that is under protection each year. We then estimate a variant of equation (3) that uses this measure rather than foreign aid. The estimates, reported in Table 9, suggest that conservation lands may exacerbate the effects of adverse rainfall experienced by transhumant pastoral groups. To illustrate this, in the second panel of the table, we report the predicted effect (relative to the mean of the dependent

[17] We do not present coefficients for $Rain_{it}^{Neighbor} \times TranshumantPastoral_i^{Neighbor}$ since they are relevant only for the omitted country and year.

[18] See UNEP-WCMC and IUCN (2021). The database was accessed via the URL `protectedplanet.net` on May 16, 2021.

Table 9: Heterogeneity by the Share of Conservation Lands in a Country

	Indicator for presence of conflict			
	(1) UCDP I(Any)	(2) UCDP I(State)	(3) ACLED I(Any)	(4) ACLED I(Nonstate)
Nearest Neighboring Ethnic Group				
Rain × Transhumant Pastoral	-0.0082	-0.0073	-0.0005	-0.0003
	(0.0050)	(0.0047)	(0.0055)	(0.0055)
Rain × Transhumant Pastoral × Share Protected Area in Country	-0.0248	-0.0390	-0.0626**	-0.0638**
	(0.0259)	(0.0258)	(0.0260)	(0.0262)
Nearest Neighboring Ethnic Group: Additional Calculations				
Effect of 1 Std. Dev. Rain Shock as % of Dep. Var. Mean:				
Rain × Transhumant Pastoral when Protected Area at 10th pctile	-28.6	-35.6	-1.1	-0.9
p-value	[0.09]	[0.10]	[0.88]	[0.91]
Rain × Transhumant Pastoral when Protected Area at 90th pctile	-52.2	-87.0	-25.9	-26.2
p-value	[0.00]	[0.00]	[0.00]	[0.00]
Dep. Var. Mean	0.035	0.025	0.085	0.084
Cell FE	Yes	Yes	Yes	Yes
Country × Year FE	Yes	Yes	Yes	Yes
Climate-Zone-Year Clusters	420	420	322	322
Cell Clusters	7,718	7,718	7,718	7,718
Observations	231,540	231,540	177,514	177,514

Note: The unit of observation is a 0.5-degree grid-cell and year. "I(Any)" is an indicator variable that equals one if at least one violent conflict occurs in a cell and year. "I(State)" is an indicator variable that equals one if at least one conflict event involving the state occurs in a cell and year; "I(Non-State)" is an indicator variable that equals one if at least one conflict event not involving the state occurs in a cell and year. *Nearest Neighboring Ethnic Group* refers to the nearest neighboring ethnic territory to cell i. Relevant covariates at the *Own Ethnic Group* and *Own Cell* levels are controlled for but not reported. Standard errors, which are reported in parentheses, are adjusted for clustering at the level of a grid-cell and a climate zone-year. * p < 0.1, ** p < 0.05, *** p < 0.01.

variable) of a one-standard-deviation change in rainfall for different values of the conservation land variable. We find that, in countries with a large share of protected conservation land (i.e., at the 90th percentile of the sample), lower rainfall in a neighboring transhumant pastoral territory significantly increases conflict by 26–87%, depending on the outcome variable. In countries with minimal conservation (i.e., at the 10th percentile), the effects are only marginally significant and range from 1–36%.

To explore these effects further, we disaggregate the country-level conservation measure into two subnational measures: one for ethnicity e (that lies in country c) and one for its complement, i.e., the rest of country c. This is motivated by observations that grazing bans in certain parts of a country can displace conflict into neighboring locations (e.g., Avuwadah, 2021). We allow for such spillover effects by estimating heterogeneous effects by both measures. The estimates, reported in Appendix Table A19, reveal clear evidence that the exacerbating effect of conservation is driven entirely by the presence of conservation areas located *elsewhere*; namely, within the country but outside of a cell's ethnic territory. By contrast, the presence of conservation areas in a cell's own ethnic territory appears to reduce the effects of adverse rainfall in pastoral territories on conflict. Thus, while conservation areas appear to reduce these violent events locally, this comes at a cost of increasing violence elsewhere. The net effect, as documented in Table 9, is an aggregate increase in the effect of interest.[19]

Overall, the results of this exercise are consistent with conservation areas leading to more constraints faced by herders, resulting in a larger effect of adverse rainfall in pastoral territories on nearby conflict. The effects appear to be due to a spillover mechanism, whereby conservation areas deflect conflict towards other parts of a country.

C. Rainfall Scarcity, Pastoral Representation in Government, and Conflict

These estimates suggest that conflict induced by adverse rainfall in transhumant pastoral territories may be exacerbated by government policies such as the expansion of conservation areas. This raises the broader question of whether national political economy forces play an important role in either moderating or amplifying the main relationship that we document. Here, we test whether the same spillover effects are present when pastoral groups have more political power.

The motivation for the test comes from the fact that pastoral groups are less likely to be afforded grazing rights when they are excluded from national politics. In this scenario, state forces will serve to protect the property rights of landowning farmers via restrictions or outright bans on grazing, which have recently been implemented in a number of countries (Avuwadah, 2021). Another less obvious example are land titling programs, which weaken the legitimacy of customary use rights that are important to pastoral groups (Boone, 2019).

Numerous studies have documented cases of policy bias against pastoral groups. Often, this stance is explicit, with transhumant pastoralism being viewed as inefficient and outdated. For example, the president of Tanzania, Jakaya Kikwete, in his 2005 inaugural speech to Parliament, argued: "Our people must change from being nomadic cattle herders to being modern livestock keepers." A year later, during a press conference, he asserted: "We are producing little milk, export very little beef, and our livestock keepers roam throughout the country with their animals in search for grazing grounds. We have to do away with archaic ways of livestock farming." (Mattee and Shem, 2006, p. 4).

We measure the extent to which political power in a country is held by transhumant pastoral groups using information from the Ethnic Power Relations (EPR) Dataset, which documents the nature of political power held by ethnic groups (Cederman, Wimmer and Min, 2010). We use this information to construct a measure of the total amount of political power held by an ethnic group e in country c in year t, which we denote by $Power_{ect}$. The categories, and their numerical values, are given by: (0) Fully excluded from politics (self exclusion or discrimination); (1) Powerless; (2) Junior partner in government; (3) Senior partner in government; (4) Dominant power; and (5) Monopoly power.

Our interest is in the share of total political power in a country that is held by transhumant pastoral groups. We measure the amount of political power in country c in year t by aggregating the power held by all ethnic groups e: $\sum_e Power_{ect}$. We measure the amount of power held by transhumant pastoral groups by: $\sum_e TranshumantPastoral_e \times Power_{ect}$. The share of power held by

[19]Since variation in conservation land is likely endogenous to many relevant factors, in Panels C and D of Appendix Table A18 we again include controls for $Rain_{it}^{Neighbor} \times TranshumantPastoral_i^{Neighbor} \times \alpha_c^s$ and $Rain_{it}^{Neighbor} \times TranshumantPastoral_i^{Neighbor} \times \alpha_t^s$, finding similar effects to those reported above.

transhumant pastoral groups in a country and year is then:

$$Power^{THP}_{ct} = \frac{\sum_e TranshumantPastoral_e \times Power_{ect}}{\sum_e Power_{ect}}.$$

The distribution of the measure across countries and years is shown in Appendix Figure A3. It is clear that the amount of political power held by pastoral groups is limited. The median value of $Power^{THP}_{ct}$ is 0.09, and a third of the observations have a measure that is equal to zero, indicating transhumant pastoral groups do not hold any political power. The highest value of the measure is 0.61, which is for Mauritania from 1989–2017, when the Delim, Trarza, Regeibat, Zenega, Tajakant, and Berabish pastoral groups were represented as junior partners in government.

Using the transhumant political power measure, we estimate a variant of equation (2) that allows our effect of interest to differ depending on the extent to which transhumant pastoral groups hold political power in that country in year $t-1$, $Power^{THP}_{ct-1}$. We use a lagged measure, which helps to address the potential for reverse causality—that is, conflict in year t affecting a change in power in year t. The estimating equation is:

$$\begin{aligned} y_{iet} \;=\;& \phi^s_0\, Rain^{Neighbor}_{it} + \phi^s_1\, Rain^{Neighbor}_{it} \times TranshumantPastoral^{Neighbor}_{i} \\ &+\phi^s_2\, Rain^{Neighbor}_{it} \times TranshumantPastoral^{Neighbor}_{i} \times Power^{THP}_{c(i)t-1} \\ &+\phi^s_3 Rain^{Neighbor}_{it} \times Power^{THP}_{c(i)t-1} + \phi^s_4 TranshumantPastoral^{Neighbor}_{i} \times Power^{THP}_{c(i)t-1} \\ &+\phi^s_5\, Rain^{OwnGroup}_{et} + \phi^s_6\, Rain^{OwnGroup}_{et} \times TranshumantPastoral^{OwnGroup}_{e} \\ &+\phi^s_7\, Rain^{OwnCell}_{it} + \phi^s_8\, Rain^{OwnCell}_{it} \times TranshumantPastoral^{OwnGroup}_{e} \\ &+\alpha^s_i + \alpha^s_{c(i)t} + \xi^s_{iet}, \end{aligned} \tag{4}$$

where all indices and variables are as in equation (2). The estimates of interest are ϕ^s_1, which is our main spillover effect when transhumant pastoral groups have no political power, and ϕ^s_2, which tells us how much the estimated spillover effect changes as transhumant pastoral groups gain more political power.

Estimates of equation (4) are reported in Table 10. We find that the estimated coefficient for the interaction between a nearest neighbor's rainfall and that neighbor's measure of transhumant pastoralism, $\hat{\phi}^s_1$, is negative and statistically significant for all four measures. This is the estimated effect for a country where the share of power held by transhumant pastoral groups is zero. The estimated coefficient for the triple interaction, $\hat{\phi}^s_2$, is positive and generally significant, indicating that the effect of rainfall in the territory of a neighboring transhumant pastoral group on conflict is closer to zero when transhumant pastoral groups have more national political power.

To assess the importance of the estimated heterogeneity, in the bottom panel of each table we calculate the predicted effect and statistical significance of $Rain^{Neighbor}_{it} \times TranshumantPastoral^{Neighbor}_{i}$ at different values of $Power^{THP}_{c(i)t-1}$. The first predicted effect that we report is for a value of $Power^{THP}_{c(i)t-1}$ that is equal to the 10th percentile of its distribution, which is zero. Below this, we report the same statistic calculated at the 90th percentile (0.303). We find that for country-years in which no transhumant pastoral groups share political power, the estimated spillover effect is large. For example, a one-standard-deviation decrease in rainfall is associated with an increase of conflict of 58% for all conflicts using the UCDP measure and 82% for all conflicts using the

Table 10: Heterogeneity by Share of Political Power Held by Transhumant Pastoral Groups

	Indicator for the presence of conflict			
	(1) UCDP I(Any)	(2) UCDP I(State)	(3) ACLED I(Any)	(4) ACLED I(Nonstate)
Nearest Neighboring Ethnic Group				
Rain × Transhumant Pastoral	-0.0158**	-0.0151***	-0.0513***	-0.0513***
	(0.0062)	(0.0054)	(0.0091)	(0.0091)
Rain × Transhumant Pastoral × THP Power Share	0.0458**	0.0367*	0.1834***	0.1824***
	(0.0231)	(0.0211)	(0.0392)	(0.0393)
Nearest Neighboring Ethnic Group: Additional Calculations				
Effect of 1 Std. Dev. Rain Shock as % of Dep. Var. Mean:				
Rain × Transhumant Pastoral when THP Power at 10th pctile	-58.1	-74.0	-81.7	-82.1
p-value	[0.01]	[0.01]	[0.00]	[0.00]
Rain × Transhumant Pastoral when THP Power at 90th pctile	-7.2	-19.4	6.8	6.3
p-value	[0.64]	[0.32]	[0.52]	[0.56]
Dep. Var. Mean	0.033	0.024	0.075	0.075
Cell FE	Yes	Yes	Yes	Yes
Country × Year FE	Yes	Yes	Yes	Yes
Climate-Zone-Years	406	406	308	308
Cells	7,018	7,018	7,015	7,015
Observations	195,975	195,975	149,290	149,290

Note: The unit of observation is a 0.5-degree grid-cell and year. "I(Any)" is an indicator variable that equals one if at least one violent conflict occurs in a cell and year. "I(State)" is an indicator variable that equals one if at least one conflict event involving the state occurs in a cell and year; "I(Non-State)" is an indicator variable that equals one if at least one conflict event not involving the state occurs in a cell and year. *Nearest Neighboring Ethnic Group* refers to the nearest neighboring ethnic territory to cell i. This regression controls for the corresponding variables at the *Own Ethnic Group* level and the *Own Cell* level. Standard errors, which are reported in parentheses, are adjusted for clustering at the level of a grid-cell and a climate zone-year. * p < 0.1, ** p < 0.05, *** p < 0.01.

ACLED measure. When a country is at the 90th percentile of transhumant pastoral political power, these effects are not statistically different from zero. In addition, they are very small: 7% for UCDP and 7% for ACLED.[20]

While the estimates reported here are merely correlational, they are consistent with political power playing an important role in determining whether episodes of low rainfall in pastoral areas lead to conflict. They align with prior evidence showing that, in the absence of political power-sharing, minority groups have stronger incentives to fight (Mueller and Rohner, 2018).

8. Conclusions

We have studied the question of whether climate change is responsible for disrupting longstanding relationships between transhumant pastoralists and neighboring sedentary agriculturalists in Africa. Traditionally, transhumant pastoralists benefit from a cooperative relationship with

[20] Again, in Panel E of Appendix Table A18, we report estimates from a specification that also includes controls for $Rain_{it}^{Neighbor} \times TranshumantPastoral_{i}^{Neighbor} \times \alpha_c^s$ and $Rain_{it}^{Neighbor} \times TranshumantPastoral_{i}^{Neighbor} \times \alpha_t^s$. The country fixed effects interacted with our double interaction of interest ensures that we use only within-country variation in $Power_{c(i)t-1}^{THP}$ to produce our estimates of interest. As reported, we again find positive and significant estimates.

sedentary agriculturalists whereby arable land is used for farming in the wet season and grazing in the dry season. Our findings confirm anecdotal accounts that decreased rainfall in transhumant pastoral territories is forcing herders to migrate to neighboring agricultural territories before the harvest, resulting in competition for resources and the emergence of conflict.

The core of our analysis documented a relationship between adverse rainfall in the territories of transhumant pastoralists and conflict in the territory of neighboring ethnic groups. To test for the mechanism of interest—disruption to the seasonal migrations of transhumant pastoralists—we confirmed the effects through a series of falsification exercises. We found that the conflicts induced by rainfall scarcity are concentrated in nearby agricultural lands and tend to occur during the wet season, which is when land is still used for cultivation, and not during the dry season, when land is left fallow and available for grazing. We also found that the effect of rainfall operates through its influence on phytomass growth, which grazing animals require for sustenance.

Our estimates also shed light on a specific form of conflict that has become more pervasive in Africa in recent decades, namely religious violence. Transhumant pastoral groups tend to be Islamic, while sedentary agriculturalists tend to be Christian. Our estimates indicate that a large proportion of extremist-religious violence involving jihadist groups is due to the mechanism we document rather than primordial grievances alone. Our counterfactual exercise implies that if rainfall were one standard deviation higher during our study period, jihadist conflict would be lower by 31%.

Our analysis also generates important policy implications. We examined whether policies that are commonly used to combat the effects of environmental degradation can alleviate the destructive effects that we identify in this article. We found no evidence that implementing agricultural development aid projects or expanding protected conservation areas contributes to the reduction of conflict that occurs due to lower rainfall in transhumant pastoral locations. The findings suggest that such projects do not address the root cause of the conflict and may even be counterproductive.

By contrast, we did find evidence that political economy factors are important. The estimated effects are closer to zero when pastoral ethnic groups have a greater share of national political power. Since transhumant pastoral groups are typically under-represented in national politics, this suggests that a more equitable distribution of political power could have significant dividends in the form of peace. Indeed, if taken literally, our estimates imply that more equitable politics could fully eliminate the effects of adverse rainfall on conflict that we document.

Finally, our findings highlight the importance of understanding the ethnic and cultural context when studying conflict and climate change. In particular, they illustrate the value of understanding pastoral populations and their way of life, which remains understudied and underappreciated in development economics despite comprising perhaps more than a fifth of Africa's population.

Data Availability Statement

The data and code underlying this research are available on Zenodo at `https://dx.doi.org/10.5281/zenodo.10543632`.

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