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. Droughts 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 droughts in the territory of transhumant pastoralists lead to conflict in neighboring areas. Consistent with the proposed mechanism, the effects 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. Turning to policy responses, we find that development aid projects tend not to mitigate the effects that we document. By contrast, the effects are closer to zero 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, p. 1). 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 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 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. These journeys can range from hundreds of meters to hundreds of kilometers. In low precipitation years, however, there may be insufficient phytomass produced on the marginal grazing lands to sustain pastoralists' livestock. When this happens, they are forced to migrate to agricultural farmlands before the dry season. 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 empirical 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 explains violence involving self-styled religious groups.

We investigate these questions in our analysis. The mechanism that we document above suggests the following testable hypothesis: droughts that occur in the territories of transhumant pastoralists lead to conflict in nearby agricultural lands.

We test for this hypothesis by examining the incidence of conflict using two sets of geocoded conflict measures, one collected by the Uppsala Conflict Data Program (UCDP) and another by the Armed Conflict Location & Event Data Project (ACLED).[1] To determine the identity of transhumant pastoral groups, we use data from the *Ethnographic Atlas* (Murdock, 1967), which contains information on the economic and cultural practices of pre-colonial ethnic societies worldwide. We construct two ethnicity-level measures of transhumant pastoralism. Both combine ethnographic information on the historical importance of animal herding in the society, as used by Becker (2019), with information on the historical mobility of an ethnicity. One variable defines transhumant groups as being those that are traditionally fully- or semi-nomadic. The other broadens the definition to also include groups that are traditionally semi-sedentary or live in impermanent settlements. We assign these characteristics to territories on a map using information on the traditional boundaries between ethnic groups in Africa from Murdock (1959).

We begin with a cross-sectional analysis to determine if violence is more prevalent in nearby land outside of the territory of groups that are transhumant pastoral. Using variation at the ethnicity level, we find that the incidence of conflict within a group's territory is higher if they are adjacent to ethnic groups that are transhumant pastoral. We then move to a more micro approach and study the relationship at the level of a 0.5-degree grid cell, which is around 55km $\times$ 55km at the equator. For each cell, we identify the 'nearest neighboring' ethnic group. This is the ethnic group, among all ethnic groups that are contiguous to the cell's own ethnic group, that is geographically closest to the cell. We find a similar relationship: grid-cells that have a transhumant pastoral nearest neighbor experience more conflict. The relationship is present whether we use the UCDP or ACLED data. 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 conflict events involving non-state actors. This is consistent with accounts wherein agricultural landowners are often represented by state forces while transhumant pastoral ethnic groups are identified as non-state forces.

We then turn to the central question of the paper, which is whether adverse rainfall shocks that occur in the territories of transhumant pastoralists lead to conflict in nearby agricultural lands. We undertake our analysis using a panel that varies by 0.5-degree grid-cell and year (1989–2018 when using the UCDP data and 1997–2019 when using the ACLED data). All specifications include grid-cell fixed effects, which account for time-invariant factors, and country-year fixed effects, which account for common macro-level shocks that vary by country and year.

We test whether the incidence of conflict in a cell is influenced by precipitation in the nearest neighboring ethnic territory. We are predominantly interested in whether there is a differential effect if the nearest neighboring ethnic group is transhumant pastoral. Thus, the coefficient of interest is for an interaction between the measure of transhumant pastoralism of a grid-cell's nearest neighboring ethnic group and the average amount of rain in that ethnic group's territory in a year. We find clear evidence in support of the hypothesis: higher precipitation in the nearest neighboring ethnic group reduces conflict in a given cell, but only if the neighbor is transhumant pastoral.

The estimated effects are sizable and significant. We find that a one standard deviation adverse precipitation shock in a transhumant pastoral society raises the risk of conflict in a nearby grid-cell

[1] See Sundberg and Melander (2013) and Raleigh, Linke, Hegre and Karlsen (2010) respectively.

by around 39%, or 1.33 percentage points (from a mean of 3.5% to 4.83%). For the same shock, a non-transhumant pastoral group is predicted to have a much smaller effect that is not statistically different from zero (around 2%, or 0.08 percentage points). The specifications also allow for a direct effect of rainfall that occurs in the grid-cell itself or in the territory of the ethnic group in which the grid-cell lies. We find that the estimated direct effects of precipitation are small and statistically insignificant. Thus, while we estimate sizable spillover effects due to the nearby presence of transhumant pastoralism, we find no evidence that rainfall in a cell directly affects conflict in the same cell.

The result is consistent with periods of low precipitation inducing transhumant pastoralists to migrate early—that is, during the growing season—to agricultural farmlands, resulting in damaged crops, competition for resources, and conflict. This interpretation lends itself to well-defined falsification tests. We conduct five such tests to pinpoint the mechanism driving the main reduced-form results.

First, the estimated spillover effects are primarily driven by conflict in agricultural territories rather than non-agricultural territories. The specific mechanism is therefore an adverse rainfall shock in a transhumant pastoral ethnic homeland causing conflict in a nearby agricultural ethnic homeland.

Second, we estimate strikingly similar results when we replace data on rainfall with data on phytomass growth, as measured by the European Union's *Copernicus* satellite program. This indicates that rainfall induces conflict because it affects the availability of plant matter for grazing. We also estimate the relationship using rainfall as an instrument for phytomass, again finding similar results.[2]

Third, we examine the timing of the conflict effects within the year using month-level conflict data. If adverse shocks induce pastoral groups to migrate before the harvest, resulting in damaged crops and competition for resources, then we should observe these conflict events during the wet season, when crops are being cultivated, and not during the dry season, when the land is left fallow. Consistent with this mechanism, we find that the effects are concentrated in the wet season. Again, the results are explained entirely by conflict in agricultural territories.

Fourth, we combine our predictions for phytomass and for the within-year timing of conflict effects and find the same patterns: low phytomass growth in pastoral territories leads to conflict during the wet season and not the dry season. Again, the effects are concentrated in agricultural territories. These results are not due to the existence of a season during which all conflict tends to occur. Indeed, the unconditional probability of conflict is slightly higher during the dry season compared to the wet season. Rather, they are consistent with environmental shocks upending the traditional relationship between neighboring herders and farmers by inducing competition for resources before the growing season has ended.

Finally, we find that there is no spillover effect when we replace our data on precipitation with data on temperature. This is informative for two reasons. First, in sub-Saharan Africa, the share of annual variation in phytomass that is explained by rainfall is around six times higher than the

[2]We do not use phytomass data for the main analysis because the series only begins in 1999, which is ten years later than our conflict and precipitation data.

share that is explained by temperature. This exercise, thus, serves as a placebo check. Second, many studies have shown that temperature is linked to conflict through a variety of mechanisms that are orthogonal to our hypothesis (Burke, Hsiang and Miguel, 2015). The absence of any effect indicates that these mechanisms do not explain our results.

We then turn to our auxiliary questions of interest, starting with whether this mechanism is able to explain the rise in extremist-religious conflict involving jihadist groups in Africa since 2000. Since transhumant pastoral groups are more likely to be Muslim and sedentary agricultural groups more likely to be 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 self-styled jihadist actors and ones that do not. We show that the effect of droughts through our documented mechanism affects both jihadist violence and non-jihadist violence similarly. This holds when we control for the religion of people inhabiting these areas today. Since jihadist conflicts were very rare prior to 2000, the similar marginal effect has resulted in a much larger rate of growth of jihadist conflicts in the past two decades. These findings indicate that extremist-religious violence responds to severe economic scarcity in almost exactly the same manner as other types of violence, implying that religious conflicts are not solely determined by atavistic grievances.

Next, we consider the question of what may help to mitigate the effects that we estimate. We first examine the role of international aid projects, focusing particularly on projects aimed at curbing the effects of climate change, namely agricultural development projects and environmental conservation projects. On the one hand, such projects may mitigate the effect of droughts on conflict by helping to improve land productivity. On the other hand, some have claimed that such projects can further exacerbate tensions by marginalizing pastoral groups. Agricultural irrigation projects may promote the use of marginal land for farming rather than grazing and conservation areas may disrupt the traditional routes of transhumance pastoral groups. 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 from 1947–2013. We find no significant heterogeneity—our estimated effects are not attenuated in the presence of any type of foreign aid. In fact, we find some evidence that projects aimed at improving the productivity of agriculture may exacerbate the effects slightly. We then test for different effects in the presence of state-controlled protected conservation areas, which have the intention of mitigating environmental degradation. These policies have been argued to exacerbate transhumant pastoral conflict by limiting the movements of herds and contributing to the scarcity of pasture for grazing. We find that our estimated effects are significantly greater in magnitude when a country converts more land to protected conservation status. This suggests that conservation areas exacerbate conflict by increasing competition for land between herders and farmers.

Finally, we examine whether the representation of transhumant pastoral groups in national government affects our estimates. We use the Ethnic Power Relations dataset and calculate, for each year and country, the extent to which transhumant pastoral groups hold power in national politics and allow our estimated effects to vary depending on this measure. We find that our spillover effect is reduced, and approaches zero, as transhumant pastoral groups gain a higher (and closer to representative) share of national power. The result is consistent with accounts of state forces responding with violence to incursions by pastoral groups when the latter are politically excluded. This pattern suggests that climate-induced conflict between farmers and herders can be mitigated with more equitable political representation.

Our analysis is informed by, and contributes to, the ethnographic literature on the nature of transhumance and its implications for seasonal interactions between sedentary farmers and herders in Africa, both historically and today (Lewis, 1961, Jacobs, 1965, Konczacki, 1978, Dyson-Hudson and Dyson-Hudson, 1980). It also adds 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 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—that is, 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). Other studies have examined the long-term consequences of animal husbandry for 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 particularly noteworthy nomadic pastoral group, the Mongols, had on state development in China due to the threat of invasion, which has been shown to have been driven, in part, by climate shocks (Bai and Kung, 2011, Ko, Koyama and Sng, 2018).

Our findings also shed light on the salience of cross-ethnicity divisions, contributing to a line of inquiry that tries to understand how certain events can heighten or alleviate intergroup hostilities (Hjort, 2014, Yanagizawa-Drott, 2014, Depetris-Chauvin, Durante and Campante, 2020). In particular, our findings provide complementary evidence to Lowe's (2021) experimental finding that the type of contact matters for intergroup relations. In our setting, regular contact between transhumant pastoral groups and local agricultural populations is not problematic—indeed, it is productive. However, when this contact occurs due to the early migration of pastoralists, the symbiotic relationship is replaced with a competitive one, resulting in hostility and conflict. Thus, the nature of the contact matters fundamentally.

Our analysis also provides insight into the recent finding in Depetris-Chauvin and Özak (2020) that conflict tends to occur near ethnic boundaries. Our analysis suggests that one important mechanism underlying the relationship is 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 many mechanisms (Hsiang, Burke and Miguel, 2013, Hsiang and Burke, 2014, Baysan, Burke, González, Hsiang and Miguel, 2019). Our analysis of temperature, rainfall, and phytomass suggests that the direct thermal stress 'heat and hate' effect documented in Eberle et al. (2020) is distinct from the spillover rainfall effects we find here.

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 et al., 2015, Mach, Kraan, Adger, Buhaug, Burke, Fearon, Field, Hendrix, Maystadt, O'Loughlin, Roessler, Scheffran, Schultz and von Uexkull, 2019). We contribute also 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). We overcome this issue with our spillover design, which traces the effect of an adverse economic shock that occurs in one ethnic territory on conflict that occurs in a neighboring ethnic territory, holding conditions there constant.

An important aspect of our study is the spillover nature of the effect that we document—rainfall in one location affects conflict in another. Thus, our findings recover the exact structure of one mechanism behind the spatial spillovers that have been identified in the existing climate-conflict literature (e.g., Guariso and Rogall, 2017, Harari and La Ferrara, 2018). While prior studies take a more purely empirical approach towards characterizing the nature of spillovers on average within Africa, our analysis starts with a particular theoretical mechanism in mind that is motivated by the ethnographic literature. We then build our estimator to capture this precise mechanism while accounting for other, more general forms of spillover. Our strategy is similar to other studies that also specify a particular spillover mechanism ex-ante that is then brought to the data. For example, König, Rohner, Thoenig and Zilibotti (2017) estimate the effects of weather shocks experienced by a military or rebel group's network of allies and enemies during the Second Congo War.

Lastly, our findings emphasize the important role of migration in understanding the broader relationship between climate change and conflict (Black, Bennett, Thomas and Beddington, 2011, Bosetti, Cattaneo and Peri, 2021). While the literature has tended to focus on climate change and permanent migration (e.g., Barrios, Bartinelli and Strobl, 2006, Marchiori, Maystadt and Schumacher, 2012, Cattaneo and Peri, 2016), our findings speak to the role of seasonal migration in mediating the relationship between climate change and conflict. Thus, our findings provide an interesting contrast to Bosetti et al.'s (2021) finding that permanent migrations reduce the adverse effects of climate change on conflict in origin countries and have no effect on receiving countries.

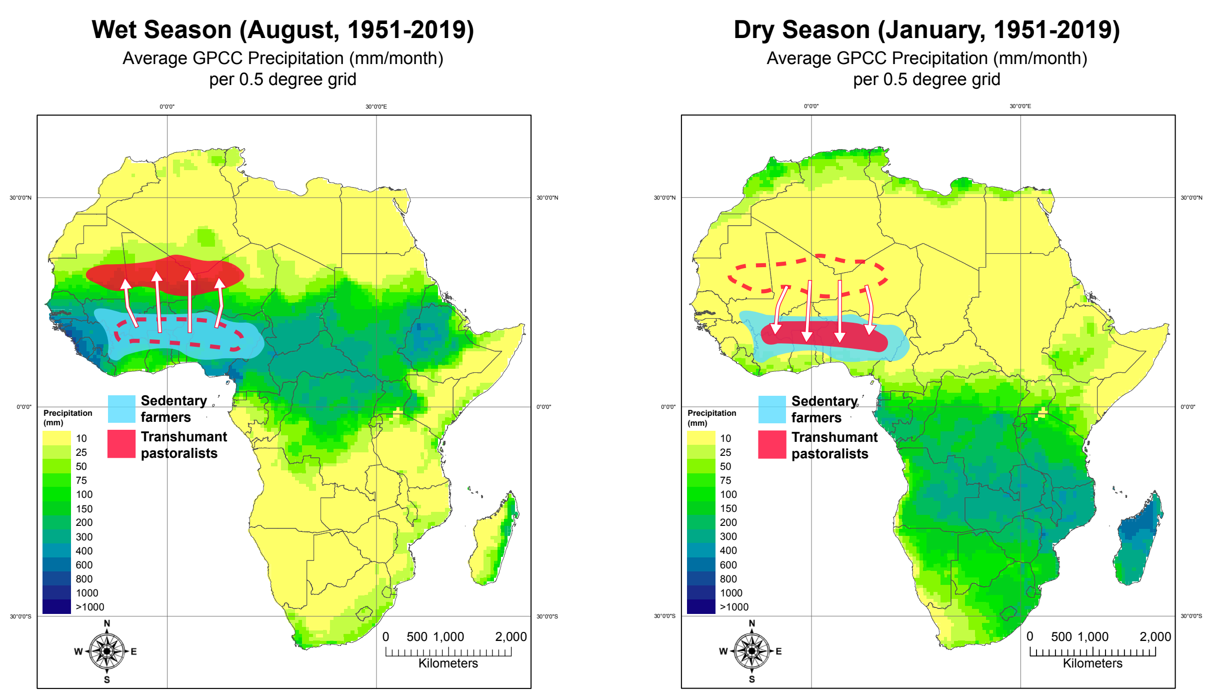
The paper is organized as follows. In Section 2, we provide a description of the traditional symbiotic relationship between transhumant pastoralists and sedentary farmers in Africa. We also discuss recent changes in climate on the continent and how this has affected the nature of the herder-farmer relationship. In Section 3, we describe the data used in the main analysis. In Section 4, we present quantitative cross-sectional evidence on the prevalence of conflict in these areas. In Section 5, we propose and test an econometric model that explicitly addresses the spillover effect of pastoral weather shocks at the cell-level. In Section 6, we present a series of analyses that test for causal mechanisms. In Section 7, we turn to the implications of our findings, including an examination of extremist-religious conflict and of factors that may mitigate the effects that we estimate.

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 for 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. Seasons are defined as periods of the year that are wet or dry. Exactly when these seasons occur depends on where one is on the continent, and 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, August and January. August, which is shown on the left, is a wet season month for most of the continent that lies north of the equator. For the continent south of the equator, the



(a) Gridded Historical average precipitation during a wet season month in the northern hemisphere (dry in the south).

(b) Gridded Historical average precipitation during a dry season month in the northern hemisphere (wet in the south).

Figure 1: Rainfall and seasonal migration in Africa.

month is part of the dry season. By contrast, in January, which is shown on the right, the north experiences a dry season and the south a wet 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 does support 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 the right map. Animal herds are permitted 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 the left map.

Thus, due to the seasonal movements of herds, both sedentary farmers and transhumant pastoralists are able to exploit the land efficiently and cooperatively. As an example, consider Stenning (1959), who, in his study of the pastoral Fulani, describes the symbiotic relationship between them and their agricultural neighbors, the Uda'en, as follows:

> In the dry season herds are dispersed southward in response to shortages of pasture and water and congregate again in the north to avoid tsetse fly in the wet season. A wide variation in the distance and impetus of these movements is found, depending on location variations in savannah habitat, but seasonal movement is a consistent feature of Fulani pastoralism throughout this zone... pastoral life is pursued not in isolation, but in some degree of symbiosis with sedentary agricultural communities. Alongside the continuous exchange of dairy products for grain and other goods, there have existed, possibly for many centuries, arrangements for pasturing cattle on land returning to fallow, and for guaranteeing cattle tracks 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. (pp. 4, 6)

The details of transhumant pastoralism and the timing and nature of the symbiotic relationship with farmers varies from region to region. For example, while most of the continent experiences one wet season and one dry season, some locations experience a "dual wet season," meaning a wet season, then a dry season, and then another wet season. Other locations are "bimodal," having one wet season, but within this, two clear peaks during the wet season. However, across the continent, the most common pattern is one wet season that has a unimodal distribution of rainfall. The second most common, which is present in parts of Kenya, Ethiopia, and Somalia, is for two distinct wet seasons, each of which has a unimodal distribution of rainfall (Herrmann and Mohr, 2012). However, in all cases, the logic of seasonal movements of grazing animals to fallow agricultural lands still holds.

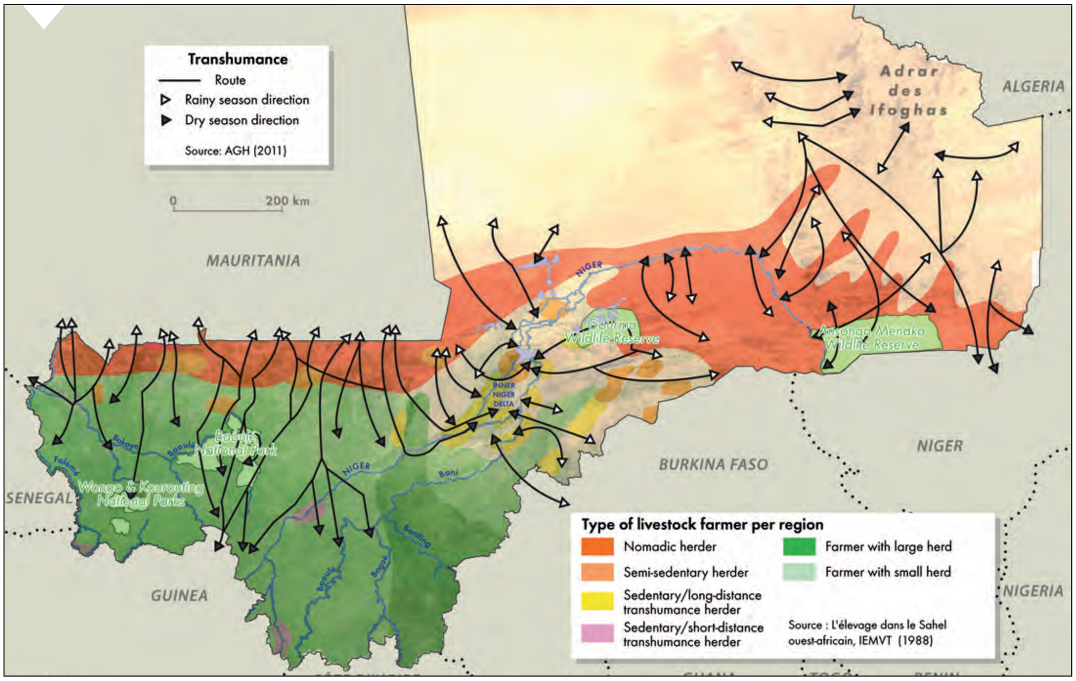


Figure 2: Seasonal transhumance routes of nomadic pastoralists in Mali

As a consequence of these traditional relationships, extensive transhumance routes exist in the parts of Africa with ecological zones that have these features, the largest region being the Sahel. The transhumance routes, examples of which are illustrated in Figure 2 for Mali, have a number of characteristics that are important for our empirical strategy. The routes vary in length, ranging from hundreds of meters to hundreds of kilometers. Although they tend to be predominantly in a north-south direction, they do vary in direction. They typically cross ethnic and national boundaries.

B. Effects of Climate Change

While the relationship between sedentary agriculturalists and transhumant pastoralists has frequently produced violence throughout history, recent decades appear to have witnessed a marked rise in conflict between the two groups, at least if measured by the prevalence of media coverage.[3] At this same time, the African continent as a whole, but particularly the Sahel region, has experienced rainfall that is persistently below average. Existing climatological research indicates that there was a noticeable change towards a weaker monsoon and drier conditions beginning in the late 1960s (Nicholson, Fink and Funk, 2018). Recent rainfall data show that within the Sahel region, between 1970 and 2017, annual average rainfall was below the long-run (1900–2017)

[3] Recent examples include: The Economist ("Fighting in the Sahel has forced 1.7m people from their homes," accessed July 2020 at `https://www.economist.com/graphic-detail/2020/06/20/fighting-in-the-sahel-has-forced-17m-people-from-their-homes`); Foreign Affairs ("The deadliest conflict you've never heard of," accessed July 2020 at `https://www.foreignaffairs.com/articles/nigeria/2019-01-23/deadliest-conflict-youve-never-heard`); and Reuters ("Sahel herders facing harshest dry season in years, aid agency warns," accessed July 2020 at `https://www.reuters.com/article/us-africa-herders/sahel-herders-facing-harshest-dry-season-in-years-aid-agency-warns-idUSKBN1CW1ZF`).

mean in 36 of the 47 years (Schneider, Becker, Finger, Meyer-Christoffer, Rudolf and Ziese, 2015). In recent years, there is some evidence that the rainfall shortage during the past decades may be attenuating. However, the evidence also indicates that important characteristics of the rainy season have also permanently changed (Biasutti, 2018, Herrmann and Mohr, 2012).

According to descriptive accounts, the new climate regime has led to more variation in the timing and location of transhumance movements. Over time, they tend to extend deeper into agricultural lands and to occur earlier in the season (Ayantunde, Asse, Said and Fall, 2014). These trends are explained by the climatology literature, which has established a strong correlation between rainfall and living organic plant matter, known as *phytomass* (Hein, 2006). While temperature is also a factor, its importance for plant growth is primarily due to the indirect effect that it has on rainfall (Biasutti, 2018). Thus, given the central importance of rainfall for phytomass growth, our analysis focuses on this characteristic of climate.

Moreover, because we aim to estimate precise spatial spillovers at a local level, our analysis requires variability in the determinants of plant growth at a fine geographic resolution. This is true for precipitation, but much less so for temperature (Thomas and Nigam, 2018).[4] The effect that temperature has on rainfall does not occur at a local level. Instead, the temperature in one macro-level region affects the rainfall patterns in another. For example, Shanahan, Overpeck, Anchukaitis, Beck, Cole, Dettman, Peck, Scholz and King (2009) examine paleohydrological data from the past three millennia and show that persistent drought in West Africa is caused by increased Atlantic sea surface temperatures. Cook and Vizy (2013) document the important effects that warming in the Middle East, South Asia, and particularly the Indian Ocean have on precipitation in Eastern Africa. In short, although temperature changes are important at a macro-level due to their effect on spatial and temporal rainfall patterns, the existing research indicates that, at a local level within Africa, temperature is not the primary determinant of phytomass.[5] Our own calculations are consistent with this conclusion, as we explain below. We find that, on average, the share of annual variation in phytomass that is explained by rainfall is around six times higher than the share that is explained by temperature.

3. Data

A. Description, Sources, and Validation

Conflict Our baseline set of geocoded conflict variables are from two sources: the Uppsala Conflict Data Program (UCDP) and the Armed Conflict Location & Event Data project (ACLED). We use both sources throughout our analysis since each has its own strengths and weaknesses. While the UCDP data has better temporal coverage, the ACLED data has better coverage of smaller-scale conflicts.

[4]See, in particular, their Figure C1.

[5]In more temperate regions outside of Africa, such as North America or Europe, studies find that temperature is positively associated with plant growth and its variation explains more of plant growth than variation in precipitation (Moles et al., 2014). This is consistent with temperature being the primary constraint for plant growth in temperate climates but rainfall being the primary constraint in tropical climates.

In the UCDP data, conflict events are two-sided battles or one-sided attacks. To be included, a conflict event must have at least one fatality and the pair of actors involved in the conflict (i.e., the conflict dyad) must have produced at least 25 fatalities in at least one calendar year throughout the series. Finally, 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. Geocoded conflict event data are available from 1989–2018.

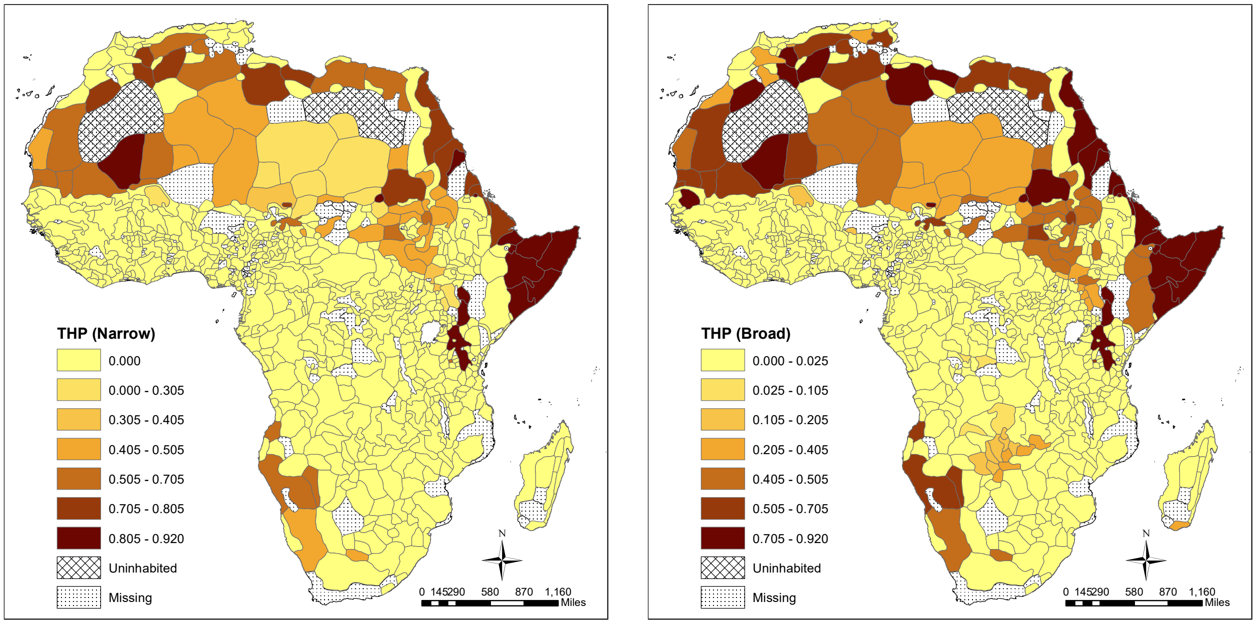
In contrast to the UCDP data, the ACLED data has weaker requirements for inclusion. There is no 25-person (in a calendar year) fatality threshold requirement, nor is there a requirement for at least one fatality during the conflict event. We focus on "battles" and "violence against civilians," which are analogous to the two- and one-sided events in the UCDP data (conditional on the exclusion threshold). We omit non-violent events such as protests and strategic developments. While the ACLED database is informative for smaller-scale incidents, it reports data only for the period 1997–2019.

For each of the two datasets, we create three measures of conflict: *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. Summary statistics for the conflict measures, at the cell-year level, are reported in Table 1. Consistent with the ACLED data having a more comprehensive set of conflict events, particularly those that are smaller in scale, we find that the unconditional probability of ACLED conflict incidence is much higher than for the UCDP data. As expected, the difference is largest for non-state conflicts: 8% for ACLED versus 2% for UCDP.

Transhumant Pastoralism To identify transhumant pastoral societies, we use information from the *Ethnographic Atlas*, a database of 1,265 ethnic groups assembled and published by Murdock from 1962–1980. We construct a composite index that captures the two key aspects of transhumant pastoralism.

The first key aspect is that the group moves seasonally; namely, that they are transhumant. There is extensive information in the *Ethnographic Atlas* 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—non-transhumant nomadism is now rare. Thus, we take being traditionally nomadic as a proxy for being transhumant. We create two indicator variables that allow for two definitions: our 'narrow' definition of transhumance includes only groups that are 'nomadic or fully migratory' or 'seminomadic'; while our 'broad' definition of transhumance additionally includes groups that are 'semisedentary' or that have 'compact but impermanent settlements.' The variants differ in whether groups that are semi-mobile are coded as being transhumant (second measure) or not (first measure). We denote this variable $Transhumant_e$.



(a) Narrow definition of transhumant pastoralism

(b) Broad definition of transhumant pastoralism

Figure 3: Cross-ethnicity measures of transhumant pastoralism.

The second key aspect of transhumant pastoralism is the herding of animals. To capture this dimension, we build on a measure developed by Becker (2019). Her variable combines information on the fraction of subsistence that is from animal husbandry (measured on a 0-1 scale, from variable v4 in the *Ethnographic Atlas*) 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. Becker's measure is constructed as the interaction between these two measures. Thus, it ranges from 0-1 and is a proxy for the fraction of an ethnic group's subsistence that is from herded animals. We denote this variable $Pastoral_e$.

Our measure of 'transhumant pastoralism' is constructed as the interaction between the two components: $Transhumant_e \times Pastoral_e$. The resulting variable, which we denote $TranshumantPastoral_e$, measures the fraction of a transhumant group's subsistence that is from pastoralism.

To assign these variables to spacial units, we match each society from the *Ethnographic Atlas* to ethnic territories in a digitized version of the map from George Peter Murdock's book, *Africa: Its Peoples and their Culture History*. Using a variety of sources, documented in Kincaide, McGuirk and Nunn (2020), we match around 96% of the ethnic territories in the map to corresponding ethnic groups in the *Ethnographic Atlas*. Figure 3 shows the distribution of the transhumant pastoralism indices across ethnic groups using this map.

The location and intensity of transhumant pastoralism is consistent with expectations and determined primarily by the locations of lands that are most suitable for animal grazing rather than agriculture. This can be seen in Appendix Figure A1, which shows the spatial distribution of land suitabile for transhumant pastoralism and sedentary agriculture, taken from Beck and

Sieber (2010),[6] as well as the boundaries of ethnic groups with some form of traditional mobility. From the figure, it is clear that the ecological environment is an important determinant of this characteristic.

Rainfall and Phytomass Pastoral groups rely on precipitation to produce the phytomass needed to sustain their livestock. Our main weather shock variable is a 0.5 degree cell-year measure of precipitation calculated by the Global Precipitation Climatology Centre (Schneider et al., 2015). It measures land-surface precipitation from rain gauges built on Global Telecommunications System (GTS)-based data, which is an international system for the dissemination of meteorological data from weather stations, satellites, and numerical weather prediction centers. This variable covers the full duration of our conflict series (1989–2018). It 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 data are at the level of a 1km pixel weekly from 1999–2018 and are taken from *Copernicus*, the European Union's Earth observation program. We aggregate the data to the 0.5 degree cell-year level and measure the final variable in average kilograms per hectare per month.

We estimate the determinants of phytomass at the cell-year level. We model phytomass as a function of average annual precipitation and temperature, while conditioning on cell fixed effects and country-by-year fixed effects.[7] The estimates, which are reported in Appendix Table A2, confirm the importance of precipitation for vegetation growth. We report estimates that include only rainfall, only temperature, and both together. 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. In addition, by various metrics, we find rainfall to be a much more important determinant than temperature. First, after accounting for the fixed effects, rainfall explains 3.6% of the residual variation while temperature explains 0.6%; second, the F-statistic for rainfall is 136, while for temperature it is 31; third, we estimate that a within-cell standard deviation rise in rainfall increases phytomass by 1.61% of the mean, while the equivalent rise in temperature decreases phytomass by 0.53%.[8]

Given that rainfall is the main driver of phytomass growth, we proceed using rainfall as our primary climate shock variable. We use rainfall, rather than phytomass, since it is available for a much longer time series. In sensitivity checks, we show that we obtain nearly identical estimates when phytomass is used.

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[6] Beck and Sieber (2010) use ecological niche modeling to derive spatial predictions of land use types based on climatic and soil input data. The database covers all of the African mainland at a 2.5 arc-minute (approx. 5km) resolution. In the database, transhumant pastoralism is called 'nomadic pastoralism.' Since nearly all nomadic activity today (i.e., movement of populations) is transhumant (i.e., seasonal), we refer to the measure as 'transhumant pastoralism.'

[7] This specification includes the same fixed effects as in our baseline estimating equations.

[8] These findings are consistent with a number of studies from the climate science literature. For example, Waha et al. (2013) study the importance of temperature, the length of the wet season, and precipitation during the wet season on maize growth across cells in Africa. They find precipitation to be a crucial factor, particularly in the parts of the continent that are most affected by climate change, such as the Sahel.

B. Summary of the Data

The descriptive statistics for our main variables (conflict, transhumant pastoralism, and rainfall), as well as all other covariates used in the analysis, are reported in Table 1. We present in separate panels variables that vary at the cell-year, cell, ethnic-group-year, and ethnic group levels. At the cell-year level, the incidence of 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. Looking at ethnicity characteristics, one can see that the average measure of transhumant pastoralism is 0.08 when the narrow measure is used and 0.10 when the broad measure is used.

In Table 2, we present summary statistics separately for groups that are transhumant pastoral and groups that are not. In column 1, we report averages for groups with a measure of transhumant pastoralism that is greater than zero; in column 2, we report averages for groups with a measure of transhumant pastoralism that is equal to zero; and in column 3, we estimate the difference in means. We find that transhumant pastoralism is associated with less conflict (for both UCDP and ACLED), less precipitation, less phytomass, higher temperatures, less land suitable for agriculture, and more land 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, practice 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. In addition, it is clear that transhumant pastoralism is associated with other factors, namely historical state development and political power today. These facts highlight the importance of our auxiliary analyses which look for evidence of our specific mechanism of interest, test for the importance of other traits like pre-colonial state centralization, and examine the importance of contemporary political power.

4. Cross-Sectional Relationships

We begin our analysis by presenting cross-sectional evidence on the relationship between being near transhumant pastoral groups and conflict. Motivated by our mechanism of interest, our empirical setup allows transhumant pastoralism to affect conflict in nearby territories. We begin by using variation across ethnic groups before moving to a finer analysis at the grid-cell level.

A. Ethnicity-level analysis

We test whether an ethnic group e experiences more conflict within their territory if they are adjacent to ethnic groups that are transhumant pastoral. We examine this with the following estimating equation:

$$y_{et} = \delta_1 TranshumantPastoral_e^{Neighbor} + \delta_2 TranshumantPastoral_e^{OwnGroup} + \delta_3 \ln(pop_e) + \alpha_t + \varepsilon_{et}, \quad (1)$$

Table 1: Descriptive Statistics

	Mean	SD	Count	Min	Median	Max
	Cell-Year Level Variables, 1989-2018					
UCDP: I(Any Conflict), 0/1	0.03	0.18	290,730	0.00	0.00	1.00
UCDP: I(State Conflict), 0/1	0.02	0.15	290,730	0.00	0.00	1.00
UCDP: I(Nonstate Conflict), 0/1	0.02	0.12	290,730	0.00	0.00	1.00
ACLED: I(Any Conflict), 0/1	0.08	0.27	213,202	0.00	0.00	1.00
ACLED: I(State Conflict), 0/1	0.05	0.22	213,202	0.00	0.00	1.00
ACLED: I(Nonstate Conflict), 0/1	0.08	0.27	213,202	0.00	0.00	1.00
Precipitation, cm/month	5.65	5.14	290,730	0.00	4.38	49.28
Phytomass, kg/ha	30.69	30.35	193,820	0.01	23.44	141.11
Temperature, $^{\circ}C$	24.50	3.95	251,922	7.51	24.75	39.53
Nighttime Lights, 0-1	0.04	0.03	203,511	0.00	0.03	0.96
	Cell Level Variables					
Nearest Neighbor Transhumant Pastoralism (Narrow Definition), 0-1	0.19	0.30	8,487	0.00	0.00	0.92
Nearest Neighbor Transhumant Pastoralism (Broad Definition), 0-1	0.21	0.30	8,487	0.00	0.00	0.92
B-S: Land Suitability for Transhumant Pastoralism, 0-1	0.32	0.20	9,421	0.00	0.29	0.90
B-S: Land Suitability for Agriculture, 0-1	0.24	0.20	9,421	0.00	0.22	0.88
ln(Population)	9.55	2.16	9,691	0.00	9.88	16.19
	Ethnic-Group-Year Level Variables, 1989-2018					
Precipitation, cm/month	8.54	5.20	23,400	0.00	8.27	34.96
Phytomass, kg/ha	44.31	28.53	15,600	0.18	43.59	130.71
Temperature, $^{\circ}C$	24.78	3.47	20,280	12.20	25.28	37.12
EPR: Political Power, 0-5	2.13	1.16	12,500	0.00	2.00	5.00
	Ethnic Group Level Variables					
Transhumant Pastoralism (Narrow Definition), 0-1	0.08	0.22	712	0.00	0.00	0.92
Transhumant Pastoralism (Broad Definition), 0-1	0.09	0.23	712	0.00	0.00	0.92
Avg. Neighbor Transhumant Pastoralism (Narrow Definition), 0-1	0.10	0.18	779	0.00	0.00	0.92
Avg. Neighbor Transhumant Pastoralism (Broad Definition), 0-1	0.11	0.19	779	0.00	0.00	0.92
EA: Agriculture, 0-1	0.55	0.18	745	0.03	0.61	0.92
EA: Jurisdictional Hierarchy, 0-4	1.29	0.97	687	0.00	1.00	4.00
EA: Belief in High Gods, 0/1	0.45	0.50	488	0.00	0.00	1.00
Share Muslim, 0-1	0.29	0.38	689	0.00	0.05	1.00
Share Christian, 0-1	0.46	0.35	689	0.00	0.46	1.00
Segmentary Lineage, 0-1	0.50	0.25	722	0.02	0.48	0.98

Note: This table presents basic descriptive statistics. The first panel presents variables that vary at the level of a cell-year. *UCDP: I(Any Conflict)* and *ACLED: I(Any Conflict)* measure conflict incidence for all conflicts. *Precipitation* is measured in average cm per month. *Phytomass* is the average monthly growth of dry vegetation measured in kg/ha. This is computed using the 'Dry Matter Productivity' variable from the *Copernicus* remote sensing program. *Temperature* is from Fan and van den Dool (2008). *Nighttime Lights* is based on data collected by US Air Force Weather Agency and processed by NOAA's National Geophysical Data Center. The second panel presents cross-sectional variables that vary at the level of a cell. *Nearest Neighbor Transhumant Pastoralism* measures, for each cell, the transhumant pastoralism index score of the nearest ethnic group that is contiguous to the ethnic group in which the cell lies. The narrow measure includes only groups that are classified in the *Ethnographic Atlas* as 'nomadic or fully migratory' or as 'seminomadic.' The broad measure additionally includes groups that are 'semisedentary' or that have 'compact but impermanent settlements.' The *Land Suitability* variables are based on data from Beck and Sieber (2010). *Population* is measured in persons and is taken from CIESIN and CIAT (2005). The third panel presents variables that vary at the level of an ethnic-group-year. *EPR: Political Power* is the score assigned to each ethnic group in the *Ethnic Power Relations* dataset, where 0 indicates that the group is either discriminated against or completely excluded from national politics, while a score of 5 indicates that the group has a monopoly on national political power. In cases where an ethnic group shares power in multiple countries, we compute the average score. In this panel, we also present precipitation, phytomass, and temperature aggregated to the level of an ethnic-group-year. The fourth panel presents cross-sectional variables that vary at the level of an ethnic group. *Transhumant Pastoralism* is described in the main text. *Avg. Neighbor Transhumant Pastoralism* measures the average transhumant pastoralism index score across an ethnic group's contiguous neighbors. The variable *EA: Agriculture* measures an ethnic group's historical dependence on agriculture for subsistence; the variable *EA: Jurisdictional Hierarchy* measures the number of jurisdictional layers beyond the local community within an ethnic group; *EA: Belief in High Gods* is an indicator equal to one if an ethnic group believed in a moralizing god before contact with European colonizers; all three of these variables are from the *Ethnographic Atlas*. The variables *Share Muslim* and *Share Christian* measure the estimated share of people in each ethnic group that are today Muslims or Christians respectively. This data comes from the *World Religion Database*, which we match to our *Ethnographic Atlas* data using *Ethnologue* identifiers. The variables *Temperature*, *Nighttime Lights* and *Population* are available in the PRIO-GRID v.2.0 dataset (Tollefsen, Strand and Buhaug, 2012).

Table 2: Balance Table, Sub-Samples by THP Classification

Variable	(1) THP > 0	(2) THP = 0	(3) Difference
	Cell-Year Level, 1989-2018		
UCDP: I(Any Conflict), 0/1	0.024	0.041	-0.017***
	(0.152)	(0.198)	(0.002)
UCDP: I(State Conflict), 0/1	0.017	0.029	-0.012***
	(0.130)	(0.168)	(0.002)
UCDP: I(Nonstate Conflict), 0/1	0.009	0.020	-0.011***
	(0.095)	(0.140)	(0.001)
ACLED: I(Any Conflict), 0/1	0.051	0.098	-0.047***
	(0.221)	(0.297)	(0.003)
ACLED: I(State Conflict), 0/1	0.034	0.063	-0.030***
	(0.180)	(0.243)	(0.002)
ACLED: I(Nonstate Conflict), 0/1	0.051	0.098	-0.047***
	(0.220)	(0.297)	(0.003)
Precipitation, cm/month	2.066	8.513	-6.447***
	(2.715)	(4.857)	(0.078)
Phytomass, kg/ha	9.214	47.835	-38.621***
	(17.333)	(27.446)	(0.475)
Temperature, $^{\circ}C$	25.323	23.859	1.465***
	(4.115)	(3.688)	(0.083)
Nighttime Lights, 0-1	0.037	0.042	-0.006***
	(0.021)	(0.043)	(0.001)
Observations	115,650	148,740	290,730
	Cell Level		
Nearest Neighbor Transhumant Pastoralism (Narrow Definition), 0-1	0.357	0.070	0.287***
	(0.333)	(0.204)	(0.006)
Nearest Neighbor Transhumant Pastoralism (Broad Definition), 0-1	0.378	0.085	0.294***
	(0.323)	(0.214)	(0.006)
B-S: Land Suitability for Transhumant Pastoralism, 0-1	0.390	0.266	0.124***
	(0.196)	(0.186)	(0.004)
B-S: Land Suitability for Agriculture, 0-1	0.099	0.354	-0.255***
	(0.132)	(0.182)	(0.004)
ln(Population)	8.844	10.840	-1.996***
	(1.626)	(1.446)	(0.033)
Observations	3,855	4,958	9,691
	Ethnic-Group-Year Level, 1989-2018		
Precipitation, cm/month	3.840	9.745	-5.905***
	(3.342)	(4.885)	(0.349)
Phytomass	19.923	50.563	-30.640***
	(23.412)	(26.176)	(2.339)
Temperature, $^{\circ}C$	25.171	24.756	0.415
	(4.014)	(3.330)	(0.377)
EPR: Political Power, 0-5	1.894	2.169	-0.274**
	(1.237)	(1.093)	(0.135)
Observations	3,750	17,610	23,400
	Ethnic Group Level		
Avg. Neighbor Transhumant Pastoralism (Narrow Definition), 0-1	0.275	0.049	0.226***
	(0.233)	(0.128)	(0.015)
Avg. Neighbor Transhumant Pastoralism (Broad Definition), 0-1	0.309	0.060	0.249***
	(0.226)	(0.137)	(0.015)
EA: Agriculture, 0-1	0.338	0.593	-0.255***
	(0.208)	(0.133)	(0.015)
EA: Jurisdictional Hierarchy, 0-4	1.555	1.240	0.315***
	(0.852)	(0.980)	(0.100)
EA: Belief in High Gods, 0/1	0.779	0.355	0.424***
	(0.417)	(0.479)	(0.050)
Share Muslim, 0-1	0.565	0.246	0.319***
	(0.478)	(0.337)	(0.039)
Share Christian, 0-1	0.278	0.484	-0.205***
	(0.361)	(0.339)	(0.037)
Segmentary Lineage, 0-1	0.476	0.509	-0.033
	(0.191)	(0.257)	(0.025)
Observations	125	587	780

Note: This table presents balance tests. Column 1 shows averages across groups where our measure of *Transhumant Pastoralism* (THP) is greater than zero. Column 2 shows averages across groups where this measure is equal to zero. We use the broader definition of THP that includes all pastoral groups without fully permanent settlements. Standard errors are clustered by ethnic group. See Table 1 for variable descriptions.

Table 3: Cross-Sectional Evidence of Conflict Spillover from All Neighboring THP Territories: Ethnic Group 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)						
Avg. Neighbor Transhumant Pastoral [δ_1]	0.2741***	0.2592***	0.0700*	0.3235***	0.3354***	0.3247***
	(0.0665)	(0.0597)	(0.0405)	(0.0806)	(0.0763)	(0.0806)
Transhumant Pastoral [δ_2]	0.1361**	0.0787	0.1144***	0.1488**	0.1455**	0.1479**
	(0.0556)	(0.0485)	(0.0415)	(0.0650)	(0.0593)	(0.0652)
Panel B: Transhumant definition includes all groups without fully permanent settlements (broad definition)						
Avg. Neighbor Transhumant Pastoral [δ_1]	0.2590***	0.2437***	0.0686*	0.3164***	0.3196***	0.3181***
	(0.0639)	(0.0569)	(0.0402)	(0.0790)	(0.0752)	(0.0789)
Transhumant Pastoral [δ_2]	0.1548***	0.0989**	0.1143***	0.1561**	0.1649***	0.1545**
	(0.0538)	(0.0474)	(0.0386)	(0.0629)	(0.0590)	(0.0629)
Dep. Var. Mean	0.172	0.130	0.095	0.374	0.281	0.372
Year FE and ln population	Yes	Yes	Yes	Yes	Yes	Yes
Climate-Zone-Year Clusters	390	390	390	312	312	312
Ethnic Group Clusters	711	711	711	711	711	711
Observations	21,330	21,330	21,330	17,064	17,064	17,064

Note: All outcome variables measure conflict incidence at the level of an ethnic group-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. The variable ln population is the natural log of the population of an ethnic group, calculated as the average of 1990, 1995, 2000, 2005, and 2010. Standard errors, which are reported in parentheses, are adjusted for clustering at the level of an ethnic group and a climate zone-year. * p < 0.1, ** p < 0.05, *** p < 0.01.

where e indexes ethnic groups and t years (1989–2018 for UCDP or 1997–2019 for ACLED); y_{et} is an indicator for the presence of conflict within the traditional territory of ethnicity e during year t; $TranshumantPastoral_e^{Neighbor}$ is the average value of our measure of transhumant pastoralism among all ethnic groups that are a neighbor (i.e., contiguous) to ethnicity e. We also allow for the possibility that transhumant pastoralism affects the amount of conflict in their own territory by including $TranshumantPastoral_e^{OwnGroup}$, which is the measure of transhumant pastoralism for ethnicity e. Lastly, $\ln(pop_e)$ is the natural log of the population of ethnicity e, averaged over 1990, 1995, 2000, 2005, and 2010, and α_t denote year fixed effects. The parameter of interest, δ_1, describes the effect of having transhumant pastoral neighbors. Standard errors are two-way clustered at the level of an ethnic group (to account for serial correlation within ethnic groups) and climate zone-year (to account for spatial correlation within 14 climate zones).

Estimates of equation (1) are reported in Table 3. Panel A reports estimates using the narrow definition of transhumance that includes two categories, while panel B reports estimates for the broad measure that includes four categories. Each column reports estimates using a different measure of conflict as the dependent variable: total 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 an ethnic group is more likely to experience conflict if

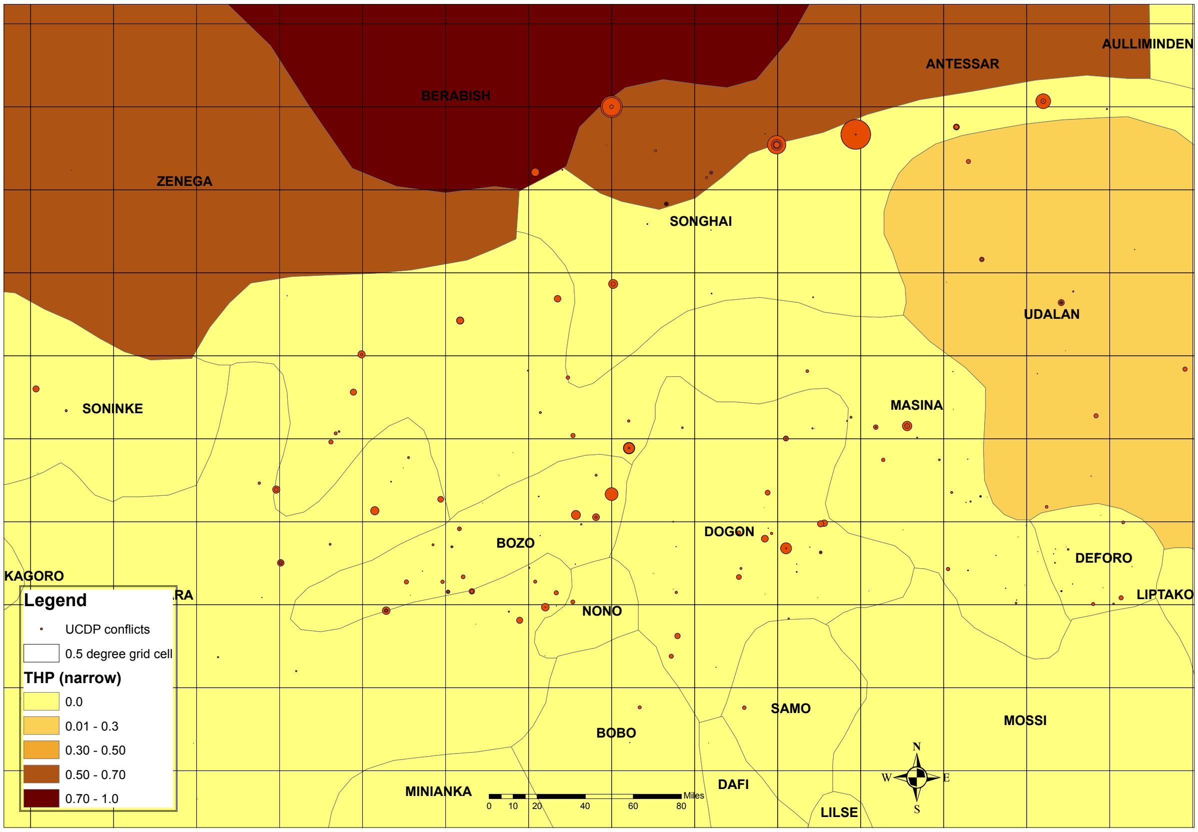

Figure 4: Structure of Data and Analysis. The figures shows 0.5-degree cells, along with the boundaries of the ethnic groups, their names, and their measure of transhumant pastoralism (THP) using the narrow definition of transhumant.

its neighbors are transhumant pastoralists. While this relationship is present for all conflict measures, it is much smaller for non-state conflicts measured using the UCDP data. As discussed, this is not surprising given that the UCDP data has more restrictive inclusion criteria that lower its coverage of smaller-scale conflicts that don't involve the state.

B. Cell-level analysis

We next examine variation at the level of a 0.5 degree grid cell (approx. 55km $\times$ 55km at the equator). The sample comprises 9,691 cells nested in approximately 700 ethnic territories located across Africa. These are shown for a region in Mali in Figure 4 that is traditionally inhabited by the Masina, Dogon, Zenega, Songhai, and others. The map also shows the location of conflicts in the UCDP data from 1989–2018.

Our aim is to study the effect of nearby transhumant pastoralism on conflict in a cell. In the ethnicity-level analysis, we resolved the issue of an ethnic group having multiple neighbors by taking an average across all neighbors. The cell-level analysis allows for a more sophisticated treatment of neighbors. Different cells within one ethnic group will have different neighbors that are relevant. This can be seen in Figure 4. Take, for example, a cell located within the Masina ethnic territory. The relevant neighboring ethnic group varies depending on where in the territory a given cell is located. For the cells in the northwestern portion of the Masina ethnic territory, the relevant neighbor is the Zenega. In contrast, for the cells 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.

We exploit this within-ethnicity variation in the relevant neighboring ethnic group by identifying, using each cell's centroid, the geographically closest ethnic group that is contiguous to the ethnic group in which the cell's centroid is located. We refer to this ethnic group as the cell's 'nearest neighbor' (or 'neighbor' for short).

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

$$y_{iet} = \gamma_1 \, \mathit{TranshumantPastoral}_i^{\mathit{Neighbor}} + \gamma_2 \, \mathit{TranshumantPastoral}_e^{\mathit{OwnGroup}} + \gamma_3 \ln(pop_i) + \alpha_t + \eta_{iet}, \quad (2)$$

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 traditional territory of ethnicity e, and in year t. The variable $\mathit{TranshumantPastoral}_i^{\mathit{Neighbor}}$ is the measure of transhumant pastoralism for the nearest neighboring ethnic group to cell i. The variable $\mathit{TranshumantPastoral}_e^{\mathit{OwnGroup}}$ is the same measure of transhumant pastoralism, but for the ethnicity in which the cell is located. Lastly, $\ln(pop_i)$ is the natural log of the population of cell i, averaged over 1990, 1995, 2000, 2005, and 2010. 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 (2) are reported in Table 4. We use the same dependent variables as in Table 3 as well as both transhumant pastoralism measures. The estimates show the same finding: having a nearest neighbor that is transhumant pastoral is associated with significantly more conflict. Again, we also find that the effects are large for all forms of conflict except for the measure of non-state conflicts when using the UCDP data.

5. Spillover Precipitation Shocks and Agro-Pastoral Conflict

We now turn to our baseline estimating equation which studies whether adverse climate events in transhumant pastoral territories result in conflict in neighboring agricultural lands.

Estimating Equation Using rainfall as our primary measure of climate shocks, we estimate a variant of equation (2) that traces the differential effects of rainfall in neighboring transhumant pastoral territories on conflict. Specifically, we continue to exploit cell-level variation in the identity of the nearest neighboring ethnic group to each cell's centroid, and estimate the following equation:

$$\begin{aligned} y_{iet} = \; & \gamma_0^s \, \mathit{Rain}_{it}^{\mathit{Neighbor}} + \gamma_1^s \, \mathit{Rain}_{it}^{\mathit{Neighbor}} \times \mathit{TranshumantPastoral}_i^{\mathit{Neighbor}} \\ & + \gamma_2^s \, \mathit{Rain}_{et}^{\mathit{OwnGroup}} + \gamma_3^s \, \mathit{Rain}_{et}^{\mathit{OwnGroup}} \times \mathit{TranshumantPastoral}_e^{\mathit{OwnGroup}} \\ & + \gamma_4^s \, \mathit{Rain}_{it}^{\mathit{OwnCell}} + \gamma_5^s \, \mathit{Rain}_{it}^{\mathit{OwnCell}} \times \mathit{TranshumantPastoral}_e^{\mathit{OwnGroup}} \\ & + X_{iet}' \Gamma + \alpha_i^s + \alpha_{c(i)t}^s + \eta_{iet}^s, \end{aligned} \quad (3)$$

where y_{iet} is an indicator for the incidence of conflict in cell i in ethnic group e and 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 pastoral index measure for that neighboring ethnic group; $Rain_{et}^{OwnGroup}$ measures precipitation in group e in year t; $TranshumantPastoral_e^{OwnGroup}$ is the transhumant pastoralism index for ethnicity e; and $Rain_{it}^{OwnCell}$ measures precipitation in cell i in year t. The vector X_{iet}' includes additional covariates that we include in auxiliary robustness and sensitivity checks.

The parameter α_i denotes cell fixed effects, which absorb $\ln(pop_i)$ and also account for time-invariant differences between cells, such as geographic characteristics; $\alpha_{c(i)t}$ denotes country-year fixed effects, which capture any determinant of conflict that varies by country and year, such as nationwide political factors and macroeconomic shocks. To account for serial and spatial dependence, our standard errors are two-way clustered at 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 studied in the conflict literature. The cell fixed effects α_i^s capture all time-invariant determi-

Table 4: 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]	0.0249***	0.0234***	0.0047*	0.0636***	0.0485***	0.0632***
	(0.0054)	(0.0049)	(0.0025)	(0.0097)	(0.0078)	(0.0096)
Transhumant Pastoral [γ_2]	0.0100*	0.0077*	0.0026	0.0256***	0.0172**	0.0249**
	(0.0057)	(0.0046)	(0.0029)	(0.0099)	(0.0078)	(0.0098)
Panel B: Transhumant definition includes all groups without fully permanent settlements (broad definition)						
Neighbor Transhumant Pastoral [γ_1]	0.0276***	0.0268***	0.0040*	0.0603***	0.0484***	0.0600***
	(0.0054)	(0.0049)	(0.0023)	(0.0091)	(0.0075)	(0.0091)
Transhumant Pastoral [γ_2]	0.0096*	0.0073	0.0021	0.0239**	0.0166**	0.0231**
	(0.0054)	(0.0045)	(0.0026)	(0.0094)	(0.0075)	(0.0094)
Dep. Var. Mean	0.035	0.025	0.016	0.085	0.055	0.084
Year FE and ln population	Yes	Yes	Yes	Yes	Yes	Yes
Climate-Zone-Year Clusters	420	420	420	336	336	336
Cell Clusters	7,722	7,722	7,722	7,722	7,722	7,722
Observations	231,660	231,660	231,660	185,328	185,328	185,328

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. The variable ln population is the natural log of a grid-cell, calculated as the average of 1990, 1995, 2000, 2005, and 2010 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.

nants of conflict, such as artificial borders, historical conflicts, and ethnic traits (e.g., Besley and Reynal-Querol, 2014, Michalopoulos and Papaioannou, 2016, Moscona et al., 2020). Also included are country-year fixed effects $\alpha^s_{c(i)t}$, which capture time-varying national-level factors such as changes in country GDP, domestic institutions, ethnic 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). Lastly, equation (3) also includes controls for the direct effects of rainfall in a cell, $\gamma^s_4 Rain^{OwnCell}_{it}$ and in the territory of a cell's ethnic group $\gamma^s_2 Rain^{OwnGroup}_{et}$. Thus, the estimates account for the direct effect of rainfall on conflict (Miguel et al., 2004, Hsiang et al., 2013, Burke et al., 2015, Harari and La Ferrara, 2018).

Results Estimates of the parameters in equation (3) are reported in Table 5 for the narrow definition of transhumant pastoralism and in Appendix Table A1 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^s_0, and its interaction with the neighbor's transhumant pastoralism index measure, γ^s_1.

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 is never statistically different from zero, the differential effects for transhumant pastoral neighbors is always negative and in all columns but one, is 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, reflecting the high inclusion threshold in the UCDP data which is particularly important for smaller-scale non-state conflicts.

To assess the magnitude of the estimates, in the second panel we report the predicted effect of a one-standard-deviation rainfall shock expressed as a percentage of the dependent variable mean. According to these predictions, an adverse rainfall shock causes an increase in conflict that is equal to 40.12% of the mean of total UCDP conflict (column 1); for the ACLED measure of conflict, which has a higher mean, the equivalent figure is 14.6% (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 conflicts. This implies that herder-farmer conflicts can involve state agents such as police, conservation officers, or the military, or they can occur absent any government involvement.

The tables also report the coefficients for $\gamma^s_2 \dots \gamma^s_5$, which are the estimated effects of rainfall in the cell's own ethnic group e and in cell i itself, as well as the differential effects of the rainfall measures when the own 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 only at the 10% level.) Thus, while we find that less rainfall in the territory of the

Table 5: 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]	-0.0006	0.0001	-0.0004	-0.0006	0.0004	-0.0007
	(0.0006)	(0.0006)	(0.0005)	(0.0011)	(0.0009)	(0.0011)
Rain × Transhumant Pastoral [γ_1^s]	-0.0110***	-0.0121***	-0.0013	-0.0096**	-0.0091**	-0.0096**
	(0.0033)	(0.0031)	(0.0021)	(0.0038)	(0.0035)	(0.0037)
Own Ethnic Group						
Rain [γ_2^s]	-0.0000	0.0013	-0.0003	0.0009	0.0014	0.0007
	(0.0010)	(0.0009)	(0.0007)	(0.0014)	(0.0010)	(0.0013)
Rain × Transhumant Pastoral [γ_3^s]	-0.0014	-0.0045	0.0016	-0.0013	-0.0077	0.0004
	(0.0047)	(0.0048)	(0.0038)	(0.0065)	(0.0062)	(0.0065)
Own Cell						
Rain [γ_4^s]	-0.0002	-0.0004	-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]	0.0040	0.0055*	-0.0009	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	-2.04	0.29	-3.36	-0.79	0.83	-0.97
p-value	[0.36]	[0.91]	[0.38]	[0.60]	[0.67]	[0.53]
Rain × Transhumant Pastoral	-38.08	-57.96	-9.91	-13.82	-20.01	-13.86
p-value	[0.00]	[0.00]	[0.53]	[0.01]	[0.01]	[0.01]
Rain + Rain × Transhumant Pastoral	-40.12	-57.67	-13.27	-14.62	-19.17	-14.83
p-value	[0.00]	[0.00]	[0.39]	[0.01]	[0.01]	[0.01]
Dep. Var. Mean	0.035	0.025	0.016	0.084	0.055	0.083
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	7,667	7,667	7,667	7,667	7,667	7,667
Observations	230,010	230,010	230,010	176,341	176,341	176,341

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.

nearest neighboring transhumant pastoral groups leads to greater conflict, there is no evidence of effects for own-cell or own-group precipitation shocks.

Robustness and Sensitivity Checks We now turn to an examination of the sensitivity of our estimates. As we have shown, the estimates using the narrow and broad definitions of transhumant pastoralism are 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, the UCDP measure of state conflict (because of the longer time series), and the ACLED measure of non-state conflict (because of the lower threshold for inclusion).

The first check that we perform builds on the fact that our ethnic characteristic of interest, transhumant pastoralism, can be viewed as an interaction between a measure of transhumance and a measure of pastoralism. Our mechanism of interest suggests that both aspects are important; namely, that the groups move seasonally and that they engage in animal herding. If an ethnic group is characterized by only one of the two, we do not expect to observe the same effects.

Motivated by this, we estimate a version of equation (3) that also includes each of the components of the measure of transhumant pastoralism interacted with rainfall. 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. By accounting for the effect of transhumance of neighboring groups, we are accounting for any effect that mobility alone has in our setting. The exercise also addresses potential concerns arising due to other factors that are 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). Such effects are captured by the inclusion of the pastoralism measure (along with relevant interactions) in the equation directly.

The estimates with the components and their interactions included in the equation are reported in Appendix Table A3. We find that our estimates of interest are robust to controlling for the components of transhumant pastoralism. 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. In addition, both components of the interaction tend to be insignificant, suggesting that these aspects are not important determinants of the effect of rainfall on conflict in neighboring cells. We note that this is not evidence that mobility or pastoralism on their own are unimportant, but that they do not matter differentially through the particular spatial spillover mechanism that we analyze.

We next check the sensitivity of our findings by accounting for other characteristics of neighboring ethnic groups: including their traditional political complexity, the presence of segmentary lineage organization, and a traditional belief in a religion with a moralizing high god, such as Islam. Pre-colonial political centralization 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) and, as noted, many of the conflicts in the Sahel region of Africa have a religious dimension to them.

To ensure that our estimates of interest are not biased by these characteristics, we additionally control for the interaction between these characteristics of the nearest neighboring ethnic group interacted with the rainfall of the group. The estimates, which we report in Appendix Table A4, show that our findings remain robust to the inclusion of these additional controls. The estimated effects are very similar in magnitude and remain highly significant.

The next sensitivity check that we perform is motivated by the potential concern that our measure of rainfall happens to be correlated with other aggregate factors that differentially affect the amount of conflict that is adjacent to transhumant pastoral groups. Given the general increase in the effects of climate change over the period of analysis, a concern is that the rainfall measure 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 (see e.g. 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, which captures any differential effect that trending determinants have on conflict adjacent to transhumant pastoral groups.

Although this captures aggregate time-varying factors that are trending over time, many other factors have more irregular movements. 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, for metals and minerals, and for precious metals (Berman, Couttenier, Rohner and Thoenig, 2017), as well as a price index for agricultural products (McGuirk and Burke, 2020).[9] Estimates of equation (3) with these additional covariates are reported in Appendix Table A5. Again, we find that the estimates are robust to the inclusion of these variables. The point estimates are similar in magnitude and they remain highly significant.[10]

The final check that we perform is about inference. We examine the robustness of our main results to various methods of calculating standard errors. We verify the validity of our conclusions to calculating standard errors that are clustered by country and by country and climate-zone. We also check that our standard errors are similar when we allow for spatial correlation within 1,000 kilometers of a cell and for serial correlation throughout the 30-year sample. In addition, we compute standard errors by randomization inference, whereby rainfall in a cell's nearest neighboring territory is randomly permuted 500 times. As we report in Appendix Table A6, our conclusions are statistically very similar for each of the alternative methods of estimating standard errors.

6. Testing for Precise Mechanisms

The estimates provided to this point are consistent with adverse rainfall shocks inducing transhumant pastoral groups to migrate to nearby agricultural lands before the harvest, resulting in conflict between sedentary farmers and transhumant pastoralists. This interpretation yields a number of testable predictions, which we now take to the data. These are as follows: (1) transhumant pastoral rainfall should primarily affect conflict on agricultural lands; (2) since rainfall matters because it affects plant growth, we should observe similar patterns if we use

[9]The data are from the World Bank's "Pink Sheet" commodity price index dataset. The energy commodities include coal, crude oil, and natural gas; the metals and minerals include aluminum, copper, iron ore, lead, nickel, steel, tin, and zinc; the precious metals include gold, platinum, and silver; and the agricultural products include oils and meals, grains, and other food such as bananas, meat, and sugar. All indices are based on real prices.

[10]Our results are also robust to the direct inclusion of the cell-level variables used in Berman et al. (2017) (local mines in operation and an interaction between the relevant minerals and their prices) and McGuirk and Burke (2020) (local crop coverage interacted with the relevant prices).

phytomass rather than rainfall; (3) 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 (4) transhumant pastoral rainfall should primarily affect conflict during the wet season and not the dry season.

Test 1: Concentration of conflict on agricultural land. The first 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 the territory of agricultural groups. 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 50% and those whose reliance was less than 50%. We then re-estimate equation (3) separately for agricultural and non-agricultural cells.

The estimates, which are reported in Table 6, 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, the estimates show clearly that it is primarily agricultural grid-cells that are responsible for the aggregate effects reported in Table 5.

Test 2: Similar effects for phytomass. Our main 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 herded 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 shocks.

We test for this by re-estimating equation (3) using the measure of phytomass in place of rainfall. The estimates, which are reported in Panel A of Table 7, show that we obtain qualitatively identical estimates. The estimates are also very similar quantitatively. For example, looking at overall conflict, we estimate that a one standard deviation decrease in phytomass in the territory of a neighboring transhumant pastoral group increases conflict by 38% of the mean incidence when the UCDP measure is used (column 1) and by 31% when the ACLED measure is used (column 3). The equivalent effects using rainfall are 40% and 15%.

Unlike rainfall, one might be concerned that our satellite measure of phytomass growth is itself endogenous to conflict and indeed to the location of grazing animals. To address this concern, we instrument the six phytomass variables – i.e., phytomass and phytomass interacted with transhumant pastoralism at the level of the cell's nearest neighbor, the cell's own group, and the cell itself – with their analogous rainfall variables. We find that this yields very similar effects, although they are less precisely estimated in three of the four specifications (see Appendix Table A7).

Table 6: 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) UCDP I(Any)	(2) UCDP I(State)	(3) ACLED I(Any)	(4) ACLED I(Nonstate)	(5) UCDP I(Any)	(6) UCDP I(State)	(7) ACLED I(Any)	(8) ACLED I(Nonstate)
Nearest Neighboring Ethnic Group								
Rain [γ_0^s]	-0.0006	0.0001	-0.0001	-0.0002	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]	-0.0122***	-0.0123***	-0.0172***	-0.0180***	-0.0053	-0.0062	0.0052	0.0056
	(0.0047)	(0.0038)	(0.0056)	(0.0056)	(0.0056)	(0.0051)	(0.0064)	(0.0064)
Own Ethnic Group								
Rain [γ_2^s]	-0.0001	0.0012	0.0002	0.0001	-0.0057	-0.0028	-0.0022	-0.0027
	(0.0011)	(0.0009)	(0.0014)	(0.0014)	(0.0046)	(0.0038)	(0.0067)	(0.0068)
Rain × Transhumant Pastoral [γ_3^s]	0.0093	0.0062	-0.0186	-0.0153	0.0043	-0.0013	0.0079	0.0097
	(0.0134)	(0.0078)	(0.0175)	(0.0187)	(0.0084)	(0.0084)	(0.0115)	(0.0116)
Own Cell								
Rain [γ_4^s]	-0.0002	-0.0004	-0.0006	-0.0004	0.0011	-0.0024	-0.0001	0.0001
	(0.0007)	(0.0006)	(0.0010)	(0.0010)	(0.0031)	(0.0019)	(0.0048)	(0.0048)
Rain × Transhumant Pastoral [γ_5^s]	-0.0075	-0.0066	0.0169	0.0157	-0.0001	0.0064	0.0054	0.0036
	(0.0101)	(0.0077)	(0.0142)	(0.0145)	(0.0060)	(0.0048)	(0.0087)	(0.0087)
Nearest Neighboring Ethnic Group: Additional Calculations								
Effect of 1 Std. Dev. Rain Shock as % of Dep. Var. Mean:								
Rain	-2.01	0.63	-0.13	-0.31	0.02	-0.51	-22.95	-22.73
p-value	[0.33]	[0.80]	[0.93]	[0.83]	[1.00]	[0.97]	[0.00]	[0.00]
Rain × Transhumant Pastoral	-37.74	-53.53	-21.65	-22.70	-25.83	-40.08	11.27	12.26
p-value	[0.01]	[0.00]	[0.00]	[0.00]	[0.34]	[0.22]	[0.42]	[0.39]
Rain + Rain × Transhumant Pastoral	-39.75	-52.89	-21.78	-23.01	-25.81	-40.59	-11.69	-10.47
p-value	[0.01]	[0.00]	[0.00]	[0.00]	[0.31]	[0.19]	[0.33]	[0.39]
Dep. Var. Mean	0.039	0.028	0.096	0.095	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	5,427	5,427	5,427	5,427	2,240	2,240	2,240	2,240
Observations	162,810	162,810	124,821	124,821	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* 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.

Test 3: No effects for temperature. According to our interpretation, we should not find the same effects for temperature as we do for rainfall or phytomass. While it is well documented that temperature is linked to conflict through many potential channels (e.g., Burke et al., 2015, Eberle et al., 2020), these underlying mechanisms are orthogonal to our mechanism of interest. Thus, while temperature may matter for conflict, we do not expect it to matter through our interaction of interest.

We test for this by re-estimating equation (3) using temperature in place of rainfall. The estimates, which are reported in Panel B of Table 7, show that we obtain very different estimates when rainfall is replaced with 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. Thus, we do not observe the same patterns in the data when we use temperature rather than rainfall. This is consistent with our observation that, unlike rainfall, temperature is not a first-order determinant of phytomass growth.[11] This exercise also indicates

[11] If we include both rainfall and temperature together, we find that our estimated rainfall spillover effects from transhumant pastoral neighbors remain large and statistically significant, while we observe no equivalent spillover effect from temperature shocks.

Table 7: 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	0.0004	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	0.90	0.76	1.44	1.58
p-value	[0.83]	[0.88]	[0.51]	[0.48]
Phytomass × Transhumant Pastoral	-38.76	-51.58	-32.47	-33.08
p-value	[0.02]	[0.01]	[0.00]	[0.00]
Phytomass + Phytomass × Transhumant Pastoral	-37.86	-50.82	-31.02	-31.50
p-value	[0.01]	[0.01]	[0.00]	[0.00]
Dep. Var. Mean	0.037	0.026	0.087	0.086
Climate-Zone-Year Clusters	280	280	294	294
Cell Clusters	7,667	7,667	7,667	7,667
Observations	153,340	153,340	161,007	161,007
	Panel B: Effect of Temperature			
Nearest Neighboring Ethnic Group				
Temperature	0.0024	0.0027**	0.0029	0.0027
	(0.0016)	(0.0013)	(0.0028)	(0.0028)
Temperature × Transhumant Pastoral	0.0018	0.0048	0.0027	0.0026
	(0.0036)	(0.0035)	(0.0046)	(0.0045)
Effect of 1 Std. Dev. Temp. Shock as % of Dep. Var. Mean:				
Temp.	5.98	9.23	3.42	3.26
p-value	[0.13]	[0.05]	[0.30]	[0.32]
Temp. × Transhumant Pastoral	4.56	16.37	3.16	3.10
p-value	[0.62]	[0.17]	[0.56]	[0.57]
Temp. + Temp. × Transhumant Pastoral	10.54	25.60	6.57	6.37
p-value	[0.25]	[0.04]	[0.16]	[0.17]
Dep. Var. Mean	0.032	0.023	0.068	0.067
Climate-Zone-Year Clusters	364	364	252	252
Cell Clusters	7,667	7,667	7,667	7,667
Observations	199,298	199,298	137,978	137,978
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.

that the established mechanisms linking temperature to conflict in the literature cannot account for our main spillover effect of interest.[12]

Test 4: 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 shocks lead to conflict that occurs only in the wet season. This is because adverse shocks impel transhumant pastoral groups to migrate earlier to neighboring farmlands, when land is still used for cultivation, which generates competition for resources. By contrast, there is no tension during the dry season, as land is fallow and animal grazing is beneficial for both groups.

We perform the test by estimating a variant of equation (3) where the dependent variable is a measure of conflict that is specific to each of the two seasons. Because the length of each season differs across locations, we measure the dependent variable as a monthly average, either the fraction of months during the season for which there is at least one conflict incident or 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 high spatial resolution. We use the starting and final months of the growing season for the 'main crop' in a cell, which is identified as the crop with the greatest harvested area in the cell. Our sample is therefore restricted to cells that contain some harvested cropland and that experience both seasons within a year. Among these cells, the average duration of the main crop's wet season is 5.75 months.

To ensure that we are capturing 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. We define dry season conflict as conflict events that begin at any point during the rest of the year.[13]

The estimates are reported in columns 1–4 of Panel A of Table 8. We find that the estimated effects are primarily due to conflict events that occur in the wet season. The magnitudes of the estimated effects are generally twice as large for wet-season conflict as they are for dry-season conflict. This is particularly striking because, without an understanding of the nature of conflict that arises from transhumant pastoralism, one might expect that rainfall will have the largest effect on conflict during the dry season when fresh water is particularly scarce. However, we find that the effect is largest during the wet season when fresh water is most abundant because this is the growing season where farmers and pastoralists have competing interests over the use of fertile lands.

[12]Interestingly, we do 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.

[13]In generating these variables, we make use of the fine-grained UCDP data on the timing of events. This allows us to make the distinction between the first incident within a conflict event—which is our object of interest—and other incidents that are more likely to be a continuation of previous clashes.

Table 8: Effects of Neighbor's Rainfall and Phytomass on Conflict during the Wet and Dry Seasons

	Monthly average of UCDP measure (any conflict type) per season											
	All Grid Cells				Agricultural Cells				Non-Agricultural Cells			
	Wet Season		Dry Season		Wet Season		Dry Season		Wet Season		Dry Season	
	(1) Incidence	(2) Number	(3) Incidence	(4) Number	(5) Incidence	(6) Number	(7) Incidence	(8) Number	(9) Incidence	(10) Number	(11) Incidence	(12) Number
	Panel A: Rainfall and Conflict by Seasons											
Nearest Neighboring Ethnic Group												
Rain	0.0001	0.0003	-0.0001	-0.0002	0.0000	0.0003	-0.0002	-0.0003	0.0005	0.0007	0.0004	0.0021
	(0.0002)	(0.0004)	(0.0003)	(0.0010)	(0.0002)	(0.0004)	(0.0003)	(0.0010)	(0.0010)	(0.0017)	(0.0011)	(0.0016)
Rain × Transhumant Pastoral	-0.0030***	-0.0108**	-0.0014	-0.0057	-0.0032**	-0.0077**	-0.0005	-0.0025	-0.0016	-0.0168	-0.0012	-0.0120
	(0.0011)	(0.0051)	(0.0010)	(0.0037)	(0.0015)	(0.0039)	(0.0013)	(0.0041)	(0.0016)	(0.0144)	(0.0013)	(0.0107)
Effect of 1 Std. Dev. Rain Shock as % of Dep. Var. Mean:												
Rain	0.86	2.45	-2.14	-1.35	0.38	2.81	-2.58	-2.75	6.44	4.09	5.36	13.74
p-value	[0.79]	[0.47]	[0.59]	[0.86]	[0.91]	[0.47]	[0.54]	[0.76]	[0.64]	[0.69]	[0.73]	[0.19]
Rain × Transhumant Pastoral	-47.97	-94.54	-21.00	-46.33	-53.57	-74.14	-7.54	-21.27	-22.88	-102.23	-16.92	-78.14
p-value	[0.01]	[0.04]	[0.15]	[0.12]	[0.03]	[0.05]	[0.71]	[0.55]	[0.30]	[0.24]	[0.37]	[0.27]
Rain + Rain × Transhumant Pastoral	-47.10	-92.09	-23.14	-47.68	-53.19	-71.33	-10.12	-24.03	-16.44	-98.15	-11.57	-64.40
p-value	[0.01]	[0.04]	[0.12]	[0.11]	[0.03]	[0.06]	[0.61]	[0.50]	[0.45]	[0.26]	[0.57]	[0.33]
Dep. Var. Mean	0.007	0.014	0.008	0.015	0.007	0.013	0.008	0.014	0.009	0.020	0.008	0.018
Climate-Zone-Year Clusters	420	420	420	420	390	390	390	390	390	390	390	390
Cell Clusters	4,592	4,592	4,592	4,592	3,857	3,857	3,857	3,857	735	735	735	735
Observations	137,760	137,760	137,760	137,760	115,710	115,710	115,710	115,710	22,050	22,050	22,050	22,050
	Panel B: Phytomass and Conflict by Seasons											
Nearest Neighboring Ethnic Group												
Phytomass	0.0001	0.0003	0.0000	0.0002	0.0000	0.0004	0.0000	0.0002	0.0002	-0.0003	-0.0003	-0.0004
	(0.0001)	(0.0003)	(0.0001)	(0.0003)	(0.0001)	(0.0003)	(0.0002)	(0.0003)	(0.0002)	(0.0008)	(0.0002)	(0.0006)
Phytomass × Transhumant Pastoral	-0.0008**	-0.0032*	-0.0001	-0.0014	-0.0009*	-0.0017***	0.0003	0.0006	-0.0005	-0.0047	-0.0003	-0.0034
	(0.0003)	(0.0018)	(0.0004)	(0.0015)	(0.0005)	(0.0006)	(0.0005)	(0.0008)	(0.0005)	(0.0040)	(0.0005)	(0.0032)
Effect of 1 Std. Dev. Phytomass Shock as % of Dep. Var. Mean:												
Phytomass	4.48	7.62	1.76	5.01	2.18	9.95	0.74	5.31	4.75	-3.23	-8.54	-6.13
p-value	[0.39]	[0.23]	[0.73]	[0.39]	[0.73]	[0.20]	[0.90]	[0.48]	[0.52]	[0.76]	[0.23]	[0.46]
Phytomass × Transhumant Pastoral	-32.70	-70.86	-3.60	-27.81	-38.66	-42.66	11.81	13.36	-15.62	-59.07	-9.01	-48.60
p-value	[0.02]	[0.08]	[0.80]	[0.35]	[0.06]	[0.00]	[0.56]	[0.43]	[0.28]	[0.24]	[0.59]	[0.28]
Phytomass + Phytomass × Transhumant Pastoral	-28.22	-63.24	-1.85	-22.80	-36.49	-32.72	12.56	18.67	-10.87	-62.30	-17.55	-54.73
p-value	[0.05]	[0.13]	[0.89]	[0.45]	[0.08]	[0.03]	[0.52]	[0.25]	[0.44]	[0.29]	[0.27]	[0.28]
Dep. Var. Mean	0.008	0.015	0.009	0.016	0.007	0.013	0.008	0.015	0.011	0.026	0.010	0.024
Climate-Zone-Year Clusters	280	280	280	280	260	260	260	260	260	260	260	260
Cell Clusters	4,592	4,592	4,592	4,592	3,857	3,857	3,857	3,857	735	735	735	735
Observations	91,840	91,840	91,840	91,840	77,140	77,140	77,140	77,140	14,700	14,700	14,700	14,700
Cell FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country × Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

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 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. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Test 5: Combinations of predictions. The last exercise that we undertake is to test simultaneously the first three predictions laid out above. In columns 5–8 of Panel A in Table 8, we show that the seasonal differences are stark in agricultural territories. The interaction between a nearest neighbor's rainfall and their measure of transhumant pastoralism matters for wet-season conflict but not for dry-season conflict. By contrast, in non-agricultural territories, we see no significant effects for either wet or dry season conflict (columns 9–12).

In Panel B of Table 8, we replace rainfall with phytomass and find the exact same pattern in the data. Lower levels of phytomass in neighboring transhumant pastoral territories is associated with more conflict in the wet season but not in the dry season. These effects are found in agricultural areas but not in non-agricultural areas. This specific pattern is what we expect to find if adverse rainfall shocks in transhumant pastoral territories cause conflict due to the premature migration of herding animals to agricultural lands during the growing season. This process results in animals grazing on farmland prior to the harvest, generating competition for resources that can escalate into violence.

7. Learning from the Estimates

The estimates reported to this point provide evidence that is consistent with first-hand accounts of the effect that climate change is having on conflict between transhumant pastoral groups and farmers. In this section, we seek to understand the implications of this finding, with a view to informing policy.

We first consider whether our documented channel can shed light on the dramatic increase in religious-extremist violence on the continent in the past decades. If all, or even part, of the observed variation in religious conflict is explained by climate change and farmer-herder tensions, then this may inform efforts to address the underlying grievances and promote peace.

The next question we consider is: what can be done to alleviate the destructive effects that we find? We examine two factors that are potentially important for mitigating the effects of climate change on intergroup violence. The first is international development aid programs, which may help to ease the resource constraints that ultimately lead to violence. The second is equitable representation in government. A lack of representation for pastoral groups in national politics may impede efforts to allocate resources in a manner that avoids conflict. Therefore, we examine whether more equal representation can alleviate violence between farmers and herders.

A. Understanding the Roots of 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 labelled as being a jihadist group and for those events that

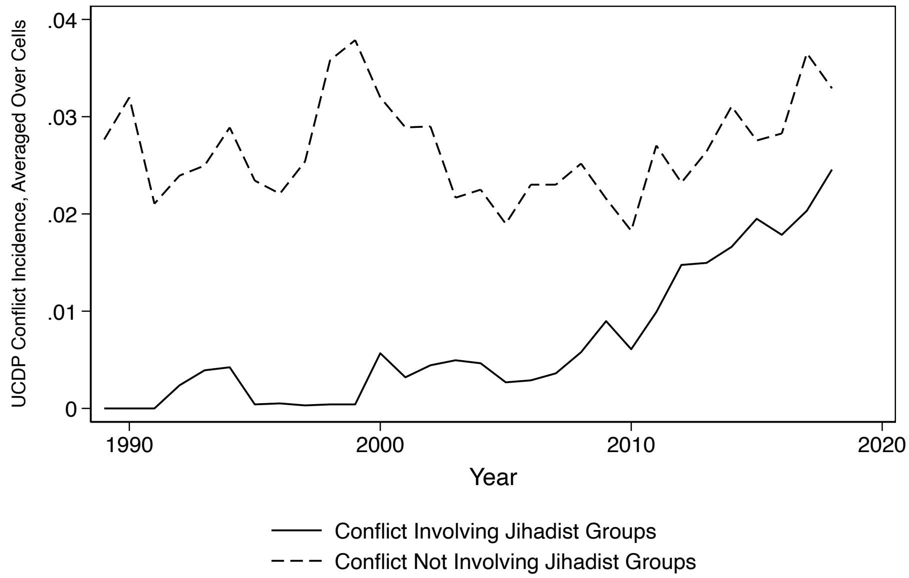

Figure 5: Total Jihadist and non-Jihadist Conflicts over Time in Africa

do not.[14] From the data, it is clear that 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 due to the increased frequency of adverse rainfall shocks in transhumant pastoral territories.[15] 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 Table 2). 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—an ostensibly religious conflict.

We test for this possibility by estimating our baseline specification – equation (3) – but with effects estimated separately for jihadist and non-jihadist conflicts. The estimates are reported in columns 1 and 2 of Table 9. We find statistically significant and quantitatively similar estimates for the coefficient of our interaction term on both types of conflict. This suggests that our mechanism applies equally to 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, show that the effects are much larger for jihadist conflicts than non-jihadist

[14] We identify jihadist conflict events as those for which the word "jihad" is present in either actor's name or in the source headline. We also examined any events for which the word "Islam-" appears in the source headline. For these, we manually examined the actors involved in the conflict and identified the event as being a jihadist conflict if one of the actors is explicitly jihadist. The groups identified include the following: Islamic State, Boko Haram, Al-Qaeda in the Islamic Maghreb (AQIM), Movement for Oneness and Jihad in West Africa (MUJAO), Benghazi Revolutionaries Shura Council, Ansar Dine, Ansaroul Islam, Mujahideen, Signed-in-Blood Battalion, Ansar al-Sharia in Libya (ASL), al-Murabitun, Macina Liberation Front (FLM), Jama'at Nasr al-Islam wal Muslimin (JNIM), Ansar al-Sunnah, Derna Protection Force (DPF), and Al-Shabaab.

[15] For case study evidence supportive of this, see Benjaminsen and Ba (2019) who argue that land-use conflicts are a fundamental determinant of the support for jihadist expansion by pastoral groups in the Mopti region of central Mali.

Table 9: Jihadist Violence

	Conflict in All Grid Cells			
	(1) I(Jihadist)	(2) I(Non-Jihadist)	(3) I(Jihadist)	(4) I(Non-Jihadist)
Nearest Neighboring Ethnic Group				
Rain	-0.0001	-0.0005	0.0007	0.0000
	(0.0003)	(0.0006)	(0.0005)	(0.0021)
Rain × Transhumant Pastoral	-0.0050**	-0.0070***	-0.0056**	-0.0067**
	(0.0022)	(0.0026)	(0.0025)	(0.0030)
Rain × Share Muslim			-0.0021	-0.0011
			(0.0013)	(0.0026)
Rain × Share Christian			-0.0006	-0.0005
			(0.0007)	(0.0028)
Nearest Neighboring Ethnic Group: Additional Calculations				
Effect of 1 Std. Dev. Rain Shock as % of Dep. Var. Mean:				
Rain	-1.13	-2.24	10.94	0.10
p-value	[0.82]	[0.37]	[0.17]	[0.99]
Rain × Transhumant Pastoral	-84.90	-29.96	-87.01	-25.51
p-value	[0.02]	[0.01]	[0.03]	[0.03]
Rain + Rain × Transhumant Pastoral	-86.03	-32.21	-76.07	-25.41
p-value	[0.02]	[0.00]	[0.04]	[0.06]
Dep. Var. Mean	0.007	0.028	0.008	0.031
Cell FE	Yes	Yes	Yes	Yes
Country × Year FE	Yes	Yes	Yes	Yes
Climate-Zone-Year Clusters	420	420	420	420
Cell Clusters	7,667	7,667	6,453	6,453
Observations	230,010	230,010	193,590	193,590

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 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.

conflicts. The shock results in an increase in jihadist conflict that is 86% of the sample mean and an increase in non-jihadist conflict that is 32% of the sample mean. Thus, the estimated effect is over about 2.5 times greater. 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 report estimates that check whether our findings are simply due to the fact that transhumant pastoral groups are more likely to be Islamic. To account for the importance of religion, we measure the estimated proportion of each ethnic group that is Christian and Muslim today and include analogous interactions involving these measures as controls in equation (3).[16] The estimated effects of interest are nearly identical in magnitude and significance after accounting for contemporary religion. This suggests that our estimated effects on jihadist

[16]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. The data are provided with Ethnologue identifiers which we match to our *Ethnographic Atlas*. There are typically multiple *Ethnologue* groups that match to one *Ethnographic Atlas* group. We create *Ethnographic Atlas* level measures by creating population-weighted averages across all *Ethnologue* groups that match to one *Ethnographic Atlas* group.

conflicts are due directly to transhumant pastoralism and not due to its positive correlation with Islam.[17]

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

Development Aid Projects In recent decades, many development organizations have designed interventions that attempt to combat the adverse effects of climate change and environmental degradation. Examples include projects that aim to enhance agricultural productivity, improve irrigation infrastructure, or expand protected conservation areas. A potential solution is to implement more of these interventions. However, given the specific mechanism that we uncover, it is not clear that any of these policies will help.

The conflict that we identify is due to adverse shocks causing pastoral groups to migrate to nearby farmlands while the growing season has not concluded. Improving the agricultural productivity of farmland does not necessarily solve this underlying problem. Moreover, irrigation projects potentially facilitate the conversion of marginal lands to farmland, thus reducing the land available to pastoral groups for grazing. Land privatization and the creation of protected conservation lands that ban animal grazing are also likely to have the same effect. In general, any policy that constrains the land available to pastoralists in response to a drought 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 data from the *Aid Data* repository, which reports detailed information on all bilateral and multilateral foreign aid projects from 1947–2013. We measure the cumulative number of projects that have been implemented in each country and year since 1947.[18] We normalize this by the number of cells in a country. We denote this variable $ForeignAid_{ct}$. We then estimate the following equation, which allows our effect of interest to vary by the prevalence of foreign aid projects in a country:

$$\begin{aligned}
y_{iet} \quad = \quad & \psi_0^s \, Rain_{it}^{Neighbor} + \psi_1^s \, Rain_{it}^{Neighbor} \times TranshumantPastoral_i^{Neighbor} \\
& + \psi_2^s \, Rain_{it}^{Neighbor} \times TranshumantPastoral_i^{Neighbor} \times ForeignAid_{ct-1} \\
& + \psi_3^s Rain_{it}^{Neighbor} \times ForeignAid_{ct-1} + \psi_4^s TranshumantPastoral_i^{Neighbor} \times ForeignAid_{ct-1} \\
& + \psi_5^s \, Rain_{et}^{OwnGroup} + \psi_6^s \, Rain_{et}^{OwnGroup} \times TranshumantPastoral_e^{OwnGroup} \\
& + \psi_7^s \, Rain_{it}^{OwnCell} + \psi_8^s \, Rain_{it}^{OwnCell} \times TranshumantPastoral_e^{OwnGroup} \\
& + \alpha_i^s + \alpha_{c(i)t}^s + \xi_{iet}^s, \qquad (4)
\end{aligned}$$

where $ForeignAid_{ct}$ is as described above and all indices and other variables are as defined in equation (3). The estimates of interest are ψ_1^s, which is our main spillover effect when transhumant

[17]We come to the same conclusion if we examine our baseline measure of aggregate conflict incidence. We find that controlling for contemporary religion does not alter our baseline estimate.

[18]Here, 'projects' imply project-locations; for example, if one umbrella program is implemented in ten locations, it is measured as ten separate projects.

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 *Aid Data* 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 are reported in Panel A of Table 10. We find no evidence that agricultural aid reduces the effects of rainfall in transhumant pastoral territory on conflict in nearby cells. In fact, while the point estimates are imprecise, their sign and magnitudes suggest that agricultural aid may exacerbate the effects of interest.

To investigate whether these 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.[19] The estimates, which are reported in Panel B of Table 10, provide no indication that any of these types of aid can 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 (4) 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 fixed effects interactions, we exploit only within-country variation over time rather than cross-country variation in $ForeignAid_{ct}$. 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 this procedure are presented in Appendix Table A9. The coefficients for $Rain_{it}^{Neighbor} \times TranshumantPastoral_i^{Neighbor}$ are evaluated at the mean value of each fixed effect. The results again suggest that, if anything, agricultural projects may exacerbate the effects that we uncover. There is a very small effect in the opposite direction for non-agricultural projects.

Conservation Areas The next analysis that we undertake looks specifically at the stock 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 leases typically either forbid the use of protected lands for grazing or impose regulations or fees when use is allowed, conservation lands 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 a country using data from *Protected Planet*, which is a global database of protected areas and other effective area-based conservation mea-

[19] 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 10: Heterogeneity by the Presence of International Aid Projects

	Conflict in All Grid Cells			
	(1) UCDP I(Any)	(2) UCDP I(State)	(3) ACLED I(Any)	(4) ACLED I(Non-State)
	Panel A: Heterogeneity by International Agricultural Aid			
Nearest Neighboring Ethnic Group				
Rain × Transhumant Pastoral	-0.0130***	-0.0122***	-0.0039	-0.0037
	(0.0038)	(0.0035)	(0.0039)	(0.0039)
Rain × Transhumant Pastoral × Total Agriculture Aid	-0.0060	-0.0069	-0.0114	-0.0118
	(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)
	Panel B: Heterogeneity by International Aid Types			
Nearest Neighboring Ethnic Group				
Rain × Transhumant Pastoral	-0.0117***	-0.0118***	-0.0106**	-0.0103**
	(0.0044)	(0.0041)	(0.0050)	(0.0049)
Rain × Transhumant Pastoral × Irrigation Projects	0.0151	-0.0060	-0.0273	-0.0254
	(0.0294)	(0.0282)	(0.0397)	(0.0394)
Rain × Transhumant Pastoral × Forestry Projects	0.0401*	0.0117	0.0570	0.0504
	(0.0217)	(0.0185)	(0.0371)	(0.0368)
Rain × Transhumant Pastoral × Conservation Projects	0.0078	-0.0080	-0.0188	-0.0237
	(0.0272)	(0.0183)	(0.0356)	(0.0352)
Rain × Transhumant Pastoral × Land Projects	-0.0506	-0.0089	-0.0155	-0.0167
	(0.0572)	(0.0527)	(0.0598)	(0.0596)
Rain × Transhumant Pastoral × Other Agriculture Projects	-0.0185*	-0.0071	-0.0182	-0.0155
	(0.0098)	(0.0088)	(0.0139)	(0.0137)
Rain × Transhumant Pastoral × Other Non-Agriculture Projects	0.0006	0.0003	0.0008	0.0008
	(0.0005)	(0.0004)	(0.0005)	(0.0005)
Dep. Var. Mean	0.032	0.023	0.068	0.067
Cell FE	Yes	Yes	Yes	Yes
Country × Year FE	Yes	Yes	Yes	Yes
Climate-Zone-Year Clusters	364	364	252	252
Cell Clusters	7,667	7,667	7,667	7,667
Observations	199,342	199,342	138,006	138,006

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.

sures.[20] We compile panel data that measures total conservation area in km^2 in a country-year, normalized by the number of cells in a country.

We estimate a variant of equation (4) using this measure of conservation rather than the measure of foreign aid. The estimates, which are reported in Table 11, suggest that conservation lands exacerbate the effects of drought experienced by transhumant pastoral groups. To illustrate this, in the second panel of the table we report the predicted effect of a one standard deviation rainfall shock in terms of the dependent variable mean at different points in the distribution of the

[20]The database was accessed via the URL `protectedplanet.net` on May 16, 2021.

Table 11: Heterogeneity by the Presence of Conservation Lands

	Conflict in All Grid Cells			
	(1) UCDP I(Any)	(2) UCDP I(State)	(3) ACLED I(Any)	(4) ACLED I(Nonstate)
Nearest Neighboring Ethnic Group				
Rain × Transhumant Pastoral	-0.0030	-0.0034	0.0011	0.0012
	(0.0044)	(0.0042)	(0.0061)	(0.0061)
Rain × Transhumant Pastoral × Conservation Land (km^2/cell)	-0.1049	-0.1353*	-0.1773**	-0.1808**
	(0.0708)	(0.0710)	(0.0753)	(0.0754)
Nearest Neighboring Ethnic Group: Additional Calculations				
Effect of 1 Std. Dev. Rain Shock as % of Dep. Var. Mean:				
Rain × Transhumant Pastoral when Conservation at 10th pctile	-11.9	-18.5	1.1	1.3
p-value	[0.46]	[0.38]	[0.90]	[0.89]
Rain × Transhumant Pastoral when Conservation at 90th pctile	-53.7	-92.9	-28.6	-29.1
p-value	[0.01]	[0.00]	[0.00]	[0.00]
Dep. Var. Mean	0.032	0.023	0.077	0.077
Cell FE	Yes	Yes	Yes	Yes
Country × Year FE	Yes	Yes	Yes	Yes
Climate-Zone-Year Clusters	420	420	322	322
Cell Clusters	7,462	7,462	7,462	7,462
Observations	223,860	223,860	171,626	171,626

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.

conservation land variable. We find that an adverse shock in a neighboring transhumant pastoral territory has no significant effect on conflict in countries with minimal conservation land (i.e., at the 10th percentile). However, in countries with a large share of protected conservation land (i.e., at the 90th percentile) the same shock increases conflict by 29–93%.

In Table A10, we additionally include controls for $Rain_{it}^{Neighbor} \times TranshumantPastoral_i^{Neighbor} \times \alpha_c^s$ and $Rain_{it}^{Neighbor} \times TranshumantPastoral_i^{Neighbor} \times \alpha_t^s$. Again, we evaluate the coefficient for $Rain_{it}^{Neighbor} \times TranshumantPastoral_i^{Neighbor}$ at the mean value of each fixed effect. The results of this exercise strongly support our conclusion above. When countries expand conservation areas, pastoral droughts lead to even more conflict as herders face more constraints.

C. Climate Change, Representation in Government, and Conflict

Thus far, we have established that much of the conflict induced by droughts in transhumant pastoral territories involves the state. This suggests that national political economy forces may play an important role in either moderating or amplifying this relationship. In this section, we test whether the same spillover effects are present or not when pastoral groups have more political power.

The logic behind the test is 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 only.[21] On the other hand, if pastoral groups occupy a greater share of national political power, then property rights are more likely to be balanced between the interests of both farmers and herders.

Numerous studies have documented cases of policy bias against pastoral groups. Typically, this stance is explicit, with transhumant pastoralism being viewed as inefficient or outdated. For example, the former president of Tanzania, Jakaya Kikwete, has expressed his views in numerous public statements or in parliament. In his 2005 inaugural speech to Parliament, he conveyed his view that: "Our people must change from being nomadic cattle herders to being modern livestock keepers." In a 2006 press conference: "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) Database, which documents the nature of political power held by ethnic groups. 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 values of the variable 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 political power in a country that is held by groups that are transhumant pastoral. We measure the total amount of political power in a country by aggregating the power of all ethnic groups: $\sum_e Power_{ec(i)t}$. We measure the amount of power held by transhumant pastoral groups by: $\sum_e TranshumantPastoral_e \times Power_{ec(i)t}$. Our measure of the share of power held by transhumant pastoral groups is then:

$$Power^{THP}_{c(i)t} = \frac{\sum_e TranshumantPastoral_e \times Power_{ec(i)t}}{\sum_e Power_{ec(i)t}}.$$

The distribution of the measure across countries and years is shown in Appendix Figure A2. From this it is clear that the amount of political power held by pastoral groups is limited. The median value of $Power^{THP}_{c(i)t}$ is 0.09 and a third of the observations have a measure that is equal to zero, indicating that there are no transhumant pastoral groups that 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 (3) that allows our effect of interest to differ depending on the extent to which transhumant pastoral

[21] An example of this are restrictions or bans on grazing, which have recently been implemented in a number of countries (Avuwadah, 2021).

Table 12: Heterogeneity by Share of Political Power Held by Transhumant Pastoral Groups: Using the Narrow Definition of Transhumance

	Conflict in All Grid Cells			
	(1)	(2)	(3)	(4)
	UCDP I(Any)	UCDP I(State)	ACLED I(Any)	ACLED I(Non-State)
Nearest Neighboring Ethnic Group				
Rain × Transhumant Pastoral	-0.0153**	-0.0146***	-0.0510***	-0.0510***
	(0.0061)	(0.0054)	(0.0091)	(0.0091)
Rain × Transhumant Pastoral × THP Power Share	0.0411*	0.0330	0.1790***	0.1781***
	(0.0227)	(0.0206)	(0.0391)	(0.0392)
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	-57.3	-73.1	-82.1	-82.5
p-value	[0.01]	[0.01]	[0.00]	[0.00]
Rain × Transhumant Pastoral when THP Power at 90th pctile	-10.8	-23.2	5.3	4.8
p-value	[0.47]	[0.23]	[0.62]	[0.66]
Dep. Var. Mean	0.032	0.024	0.074	0.074
Cell FE	Yes	Yes	Yes	Yes
Country × Year FE	Yes	Yes	Yes	Yes
Climate-Zone-Years	406	406	308	308
Cells	6,965	6,965	6,962	6,962
Observations	194,442	194,442	148,128	148,128

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.

groups hold political power in that country and year, $Power^{THP}_{c(i)t}$. The estimating equation is:

$$\begin{aligned} y_{iet} \; = \; & \phi^s_0 \, Rain^{Neighbor}_{it} + \phi^s_1 \, Rain^{Neighbor}_{it} \times TranshumantPastoral^{Neighbor}_i \\ & + \phi^s_2 \, Rain^{Neighbor}_{it} \times TranshumantPastoral^{Neighbor}_i \times Power^{THP}_{c(i)t-1} \\ & + \phi^s_3 Rain^{Neighbor}_{it} \times Power^{THP}_{c(i)t-1} + \phi^s_4 TranshumantPastoral^{Neighbor}_i \times Power^{THP}_{c(i)t-1} \\ & + \phi^s_5 \, Rain^{OwnGroup}_{et} + \phi^s_6 \, Rain^{OwnGroup}_{et} \times TranshumantPastoral^{OwnGroup}_e \\ & + \phi^s_7 \, Rain^{OwnCell}_{it} + \phi^s_8 \, Rain^{OwnCell}_{it} \times TranshumantPastoral^{OwnGroup}_e \\ & + \alpha^s_i + \alpha^s_{c(i)t} + \xi^s_{iet}, \end{aligned} \tag{5}$$

where all indices and variables are as in equation (3). 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 determines how much the main spillover effect changes as transhumant pastoral groups gain more political power.

Estimates of equation (5) are reported in Table 12. 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, $\hat{\phi}_2^s$, 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 $Rain_{it}^{Neighbor} \times TranshumantPastoral_i^{Neighbor}$ at different values of $Power_{c(i)t-1}^{THP}$. The first predicted effect that we report is for a value of $Power_{c(i)t-1}^{THP}$ 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 57% for all conflicts using the UCDP measure and 82% for all conflicts using the 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: 11% for UCDP and 5.3% for ACLED.

In Appendix Table A12, we again include controls for $Rain_{it}^{Neighbor} \times TranshumantPastoral_i^{Neighbor} \times \alpha_c^s$ and $Rain_{it}^{Neighbor} \times TranshumantPastoral_i^{Neighbor} \times \alpha_t^s$. Using only within-country variation in $Power_{c(i)t-1}^{THP}$, we find qualitatively identical results.

Overall, the results suggest that political power plays an important role in explaining our main results. When transhumant pastoral groups are afforded a higher share of political power, droughts in their home territories cease to induce the same outbreak of conflict in neighboring areas.

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 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 adverse rainfall shocks in transhumant pastoral territories are 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 documents a relationship between adverse rainfall shocks 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 plumb the effects through a series of falsification exercises. We found that the conflicts induced by the shocks are concentrated in nearby agricultural lands and occur during the wet season, which is when land is still used to cultivate crops, and not during the dry season, when land is available for grazing. We also found that the effect of rainfall operates through its influence on phytomass growth, which grazing animals require for sustenance.

While we found robust evidence for these spillover effects, we did not find evidence for direct effects; namely, that rainfall in a location affects conflict in the same location. This implies that our inter-ethnic spillover mechanism accounts for much of the established relationship between adverse rainfall shocks and conflict in Africa. Viewed from the perspective of the determinants of conflict, our findings are also quantitatively important. We estimate that if rainfall were higher by one standard deviation in each cell during the thirty-year period from 1989–2018, the overall incidence of conflict in Africa would be lower by 12%. The equivalent figure for state conflict is even larger at 18%, as herder-farmer clashes often involve government forces operating on the side of agricultural groups.

Our estimates also shed light on a specific form of conflict that has become more pervasive in Africa in recent decades, namely extremist-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 in fact due to the mechanism that 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 provides important policy implications. We first examine 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 find no evidence that implementing agricultural development aid projects or expanding protected conservation areas contribute to the reduction of conflict that occurs due to adverse rainfall shocks in transhumant pastoral locations. These findings suggest that such projects do not get at the root cause of the conflict and may even be counterproductive.

By contrast, we do 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 will have significant dividends in the form of peace. Indeed, if taken literally, our estimates imply that more equitable politics could eliminate fully the effects of drought on conflict that we document.

Taken as a whole, our findings highlight the importance of understanding the ethnic and cultural context of locations when estimating the effects of climate change on conflict. As we have shown, these effects operate through a specific spillover mechanism that is suggested by the ethnographic literature. Our findings also stress the role that policies and institutions can play in combating the deleterious effects of climate change. Policies that further constrain pastoral groups do not appear to help. Instead, institutions that facilitate the appropriate balance of grazing and cultivating rights can play an important role in mitigating the costs of climate change in agro-pastoral zones across the African continent. Our findings suggest that this is more likely to be achieved if pastoral groups are given greater political representation.

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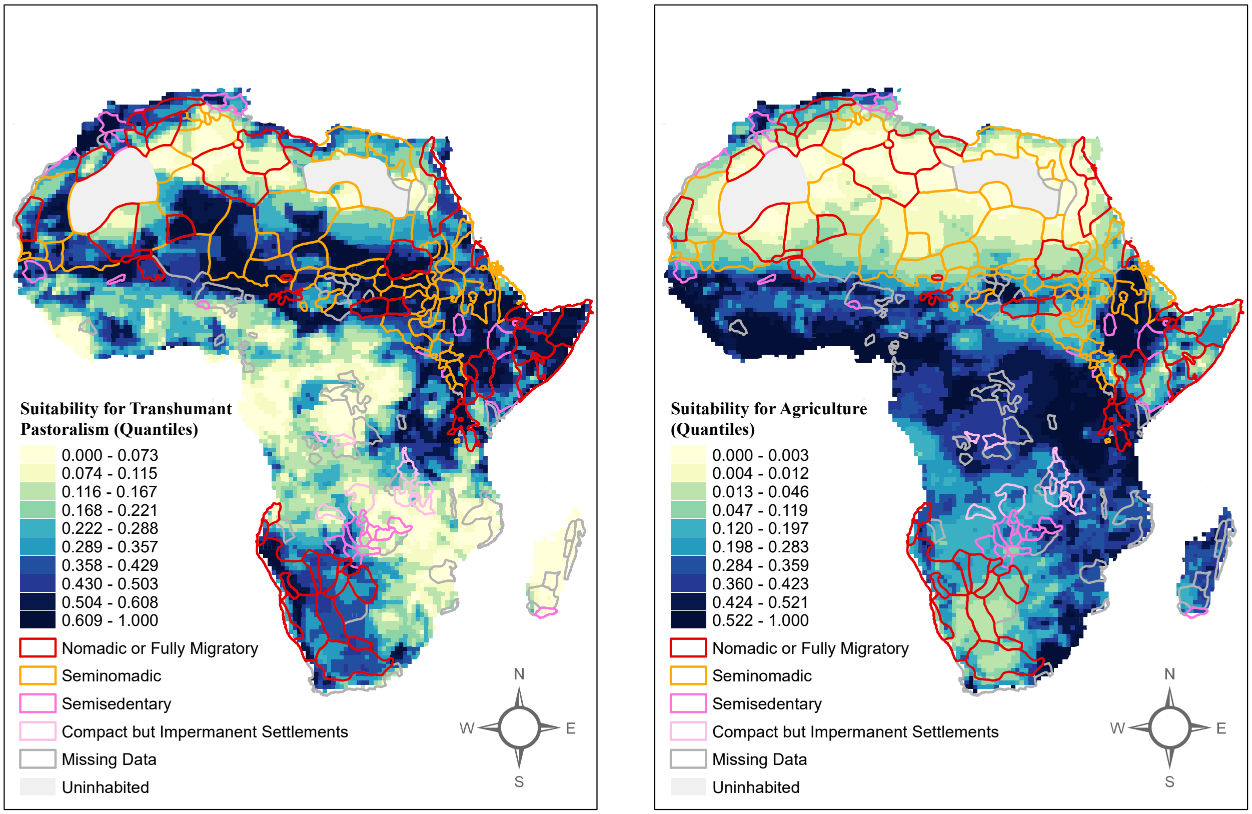
Online Appendix Figures



(a) Suitability for transhumant pastoralism

(b) Suitability for sedentary agriculture

Figure A1: Ecological conditions and transhumant pastoralism

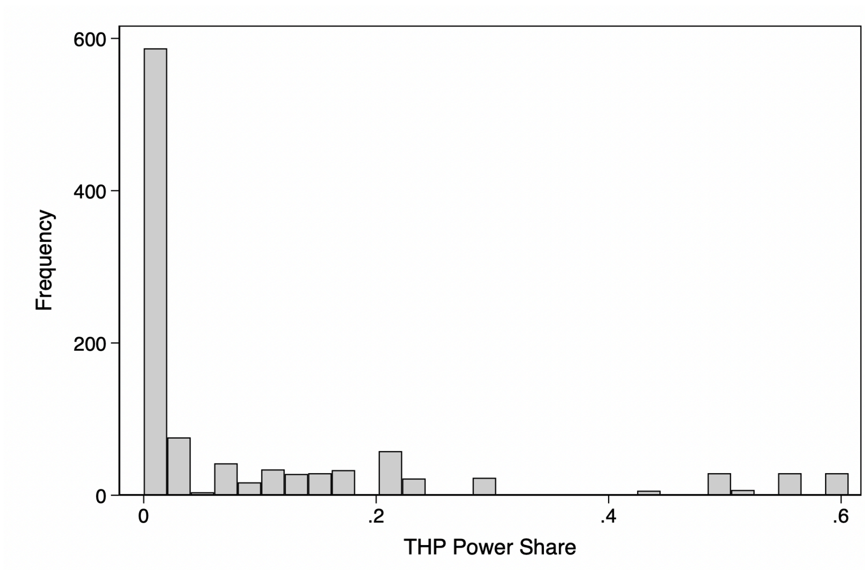


Figure A2: Histogram of power held by transhumant pastoral groups across countries and years

Online Appendix Tables

Table A1: Effect of Rain Shock in Nearest Neighboring THP Territory on Conflict in a Cell: Broad 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]	-0.0006	0.0002	-0.0005	-0.0004	0.0005	-0.0005
	(0.0006)	(0.0006)	(0.0005)	(0.0011)	(0.0009)	(0.0011)
Rain × Transhumant Pastoral [γ_1^s]	-0.0082***	-0.0105***	0.0007	-0.0093**	-0.0080**	-0.0094**
	(0.0031)	(0.0028)	(0.0019)	(0.0037)	(0.0036)	(0.0037)
Own Ethnic Group						
Rain [γ_2^s]	0.0002	0.0015	-0.0002	0.0010	0.0015	0.0008
	(0.0011)	(0.0009)	(0.0007)	(0.0014)	(0.0011)	(0.0014)
Rain × Transhumant Pastoral [γ_3^s]	-0.0049	-0.0064	-0.0009	-0.0028	-0.0078	-0.0013
	(0.0042)	(0.0042)	(0.0035)	(0.0062)	(0.0058)	(0.0062)
Own Cell						
Rain [γ_4^s]	-0.0003	-0.0005	-0.0001	-0.0005	-0.0008	-0.0003
	(0.0007)	(0.0006)	(0.0005)	(0.0010)	(0.0009)	(0.0010)
Rain × Transhumant Pastoral [γ_5^s]	0.0048	0.0061**	0.0000	0.0054	0.0055	0.0041
	(0.0033)	(0.0030)	(0.0024)	(0.0048)	(0.0039)	(0.0048)
Nearest Neighboring Ethnic Group: Additional Calculations						
Effect of 1 Std. Dev. Rain Shock as % of Dep. Var. Mean:						
Rain	-1.98	0.75	-3.99	-0.62	1.01	-0.79
p-value	[0.38]	[0.78]	[0.31]	[0.69]	[0.61]	[0.62]
Rain × Transhumant Pastoral	-28.34	-50.49	5.20	-13.38	-17.55	-13.48
p-value	[0.01]	[0.00]	[0.72]	[0.01]	[0.03]	[0.01]
Rain + Rain × Transhumant Pastoral	-30.32	-49.74	1.21	-14.00	-16.54	-14.26
p-value	[0.00]	[0.00]	[0.93]	[0.01]	[0.03]	[0.01]
Dep. Var. Mean	0.035	0.025	0.016	0.084	0.055	0.083
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	7,667	7,667	7,667	7,667	7,667	7,667
Observations	230,010	230,010	230,010	176,341	176,341	176,341

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.

Table A2: Phytomass

	Phytomass		
	(1)	(2)	(3)
Rain	0.4151***		0.4092***
	(0.0357)		(0.0350)
Temp		-0.2223***	-0.2018***
		(0.0400)	(0.0383)
Share of RSS explained by weather variable(s) (in %)	3.63	0.61	4.13
F statistic	135.55	30.84	75.07
Effect of 1 Std. Dev. Shock as % of Dep. Var. Mean:			
Rain	1.63		1.61
p-value	[0.00]		[0.00]
Temp		-0.58	-0.53
p-value		[0.00]	[0.00]
Dep. Var. Mean	30.57	30.57	30.57
Cell FE	Yes	Yes	Yes
Country × Year FE	Yes	Yes	Yes
Climate-Zone-Years	224	224	224
Cells	9,691	9,691	9,691
Observations	155,032	155,032	155,032

Note: This table presents phytomass (in kg/ha) as a function of rainfall (in cm/month) and temperature (in °C), conditional on cell fixed effects and country-by-year fixed effects. *RSS* refers to the residual sum of squares after partialling out the cell fixed effects and country-by-year fixed effects. Standard errors (in parentheses) are adjusted for serial correlation at the level of a cell and spatial correlation at the level of a climate zone. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table A3: Robustness to Controlling for the Components of Transhumant Pastoralism

	Conflict in All Grid Cells			
	(1)	(2)	(3)	(4)
	UCDP I(Any)	UCDP I(State)	ACLED I(Any)	ACLED I(Nonstate)
Nearest Neighboring Ethnic Group				
Rain	-0.0015	0.0003	-0.0019	-0.0019
	(0.0011)	(0.0008)	(0.0015)	(0.0015)
Rain × Pastoral	0.0046	-0.0016	0.0068	0.0066
	(0.0044)	(0.0035)	(0.0062)	(0.0061)
Rain × Transhumant	0.0041*	0.0022	0.0029	0.0031
	(0.0025)	(0.0018)	(0.0039)	(0.0039)
Rain × Transhumant Pastoral	-0.0196***	-0.0136**	-0.0186**	-0.0186**
	(0.0069)	(0.0056)	(0.0088)	(0.0088)
Nearest Neighboring Ethnic Group: Additional Calculations				
Effect of 1 Std. Dev. Rain Shock as % of Dep. Var. Mean:				
Rain	-5.22	1.33	-2.67	-2.80
p-value	[0.16]	[0.73]	[0.22]	[0.21]
Rain × Transhumant Pastoral	-67.89	-65.12	-26.64	-26.77
p-value	[0.00]	[0.02]	[0.04]	[0.04]
Rain + Rain × Transhumant Pastoral	-73.10	-63.79	-29.31	-29.56
p-value	[0.01]	[0.03]	[0.04]	[0.04]
Dep. Var. Mean	0.0346	0.0250	0.0838	0.0834
Cell FE	Yes	Yes	Yes	Yes
Country × Year FE	Yes	Yes	Yes	Yes
Climate-Zone-Year Clusters	420	420	322	322
Cell Clusters	7,667	7,667	7,667	7,667
Observations	230,010	230,010	176,341	176,341

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.

Table A4: Robustness to Additional Controls for Ethnicity-Level Characteristics

	Conflict in All Grid Cells			
	(1)	(2)	(3)	(4)
	UCDP I(Any)	UCDP I(State)	ACLED I(Any)	ACLED I(Nonstate)
Nearest Neighboring Ethnic Group				
Rain	-0.0026*	-0.0011	-0.0025	-0.0026
	(0.0015)	(0.0013)	(0.0023)	(0.0023)
Rain × Transhumant Pastoral	-0.0116***	-0.0122***	-0.0094**	-0.0097**
	(0.0036)	(0.0031)	(0.0038)	(0.0038)
Rain × Jurisdictional Hierarchy	0.0005	0.0000	-0.0002	-0.0002
	(0.0006)	(0.0005)	(0.0008)	(0.0008)
Rain × Segmentary Lineage	0.0025	0.0020	0.0032	0.0031
	(0.0019)	(0.0016)	(0.0029)	(0.0030)
Rain × High Gods: Active, Not Supportive	0.0021	0.0014	0.0030	0.0031
	(0.0021)	(0.0016)	(0.0036)	(0.0036)
Rain × High Gods: Active, Supportive	0.0014	0.0018*	-0.0009	-0.0009
	(0.0013)	(0.0011)	(0.0022)	(0.0022)
Nearest Neighboring Ethnic Group: Additional Calculations				
Effect of 1 Std. Dev. Rain Shock as % of Dep. Var. Mean:				
Rain	-8.73	-5.29	-3.41	-3.62
p-value	[0.10]	[0.39]	[0.28]	[0.26]
Rain × Transhumant Pastoral	-39.23	-58.88	-13.08	-13.50
p-value	[0.00]	[0.00]	[0.01]	[0.01]
Rain + Rain × Transhumant Pastoral	-47.96	-64.16	-16.49	-17.12
p-value	[0.00]	[0.00]	[0.01]	[0.00]
Dep. Var. Mean	0.0355	0.0249	0.0865	0.0861
Cell FE	Yes	Yes	Yes	Yes
Country × Year FE	Yes	Yes	Yes	Yes
Climate-Zone-Years	420	420	322	322
Cells	6,554	6,554	6,554	6,554
Observations	196,620	196,620	150,742	150,742

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.

Table A5: Robustness to Additional Controls for Time-Varying Characteristics

	Conflict in All Grid Cells			
	(1)	(2)	(3)	(4)
	UCDP I(Any)	UCDP I(State)	ACLED I(Any)	ACLED I(Nonstate)
Nearest Neighboring Ethnic Group				
Rain	-0.0006	0.0001	-0.0006	-0.0007
	(0.0006)	(0.0006)	(0.0011)	(0.0011)
Rain × Transhumant Pastoral	-0.0114***	-0.0126***	-0.0096***	-0.0095***
	(0.0034)	(0.0031)	(0.0036)	(0.0035)
Year × Transhumant Pastoral	-0.0004	-0.0002	-0.0064***	-0.0064***
	(0.0006)	(0.0006)	(0.0018)	(0.0017)
Price Index: Energy × Transhumant Pastoral	0.0006***	0.0004**	0.0005**	0.0005**
	(0.0002)	(0.0001)	(0.0002)	(0.0002)
Price Index: Metals and Minerals × Transhumant Pastoral	0.0001	0.0003	-0.0003	-0.0003
	(0.0002)	(0.0002)	(0.0003)	(0.0003)
Price Index: Precious Metals × Transhumant Pastoral	-0.0005*	-0.0005**	0.0005	0.0005
	(0.0003)	(0.0002)	(0.0005)	(0.0005)
Price Index: Agriculture × Transhumant Pastoral	-0.0001	0.0001	0.0006	0.0006
	(0.0005)	(0.0004)	(0.0007)	(0.0007)
Nearest Neighboring Ethnic Group: Additional Calculations				
Effect of 1 Std. Dev. Rain Shock as % of Dep. Var. Mean:				
Rain	-2.06	0.33	-0.88	-1.06
p-value	[0.36]	[0.90]	[0.56]	[0.49]
Rain × Transhumant Pastoral	-39.63	-60.46	-13.71	-13.71
p-value	[0.00]	[0.00]	[0.01]	[0.01]
Rain + Rain × Transhumant Pastoral	-41.69	-60.13	-14.60	-14.77
p-value	[0.00]	[0.00]	[0.00]	[0.00]
Dep. Var. Mean	0.0346	0.0250	0.0838	0.0834
Cell FE	Yes	Yes	Yes	Yes
Country × Year FE	Yes	Yes	Yes	Yes
Climate-Zone-Years	420	420	322	322
Cells	7,667	7,667	7,667	7,667
Observations	230,010	230,010	176,341	176,341

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.

Table A6: Robustness to Various Inference Procedures

	Indicator for the presence of conflict			
	(1)	(2)	(3)	(4)
	UCDP I(Any)	UCDP I(State)	ACLED I(Any)	ACLED I(State)
	Panel A: Clustering by country			
Nearest Neighboring Ethnic Group				
Rain [γ_0^s]	-0.0006	0.0001	-0.0006	0.0004
	(0.0006)	(0.0005)	(0.0011)	(0.0009)
Rain × Transhumant Pastoral [γ_1^s]	-0.0110**	-0.0121***	-0.0096***	-0.0091***
	(0.0044)	(0.0039)	(0.0022)	(0.0026)
Country Clusters	49	49	49	49
	Panel B: Clustering by country and climate-zone			
Nearest Neighboring Ethnic Group				
Rain [γ_0^s]	-0.0006	0.0001	-0.0006	-0.0007
	(0.0006)	(0.0005)	(0.0009)	(0.0010)
Rain × Transhumant Pastoral [γ_1^s]	-0.0110***	-0.0121***	-0.0096***	-0.0096***
	(0.0033)	(0.0029)	(0.0014)	(0.0015)
Country Clusters	49	49	49	49
Climate-Zone Clusters	14	14	14	14
	Panel C: Spatial HAC within 1000km			
Nearest Neighboring Ethnic Group				
Rain [γ_0^s]	-0.0006	0.0001	-0.0006	-0.0007
	(0.0007)	(0.0006)	(0.0010)	(0.0010)
Rain × Transhumant Pastoral [γ_1^s]	-0.0110***	-0.0121***	-0.0096**	-0.0096**
	(0.0040)	(0.0035)	(0.0043)	(0.0043)
Dep. Var. Mean	0.035	0.025	0.084	0.055
Cell FE	Yes	Yes	Yes	Yes
Country × Year FE	Yes	Yes	Yes	Yes
Observations	230,010	230,010	176,341	176,341

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 country. * p < 0.1, ** p < 0.05, *** p < 0.01.

Table A7: IV 2SLS Estimates: Instrumenting Phytomass with Rain

	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				
Phytomass	-0.0036	-0.0013	-0.0048	-0.0052
	(0.0026)	(0.0021)	(0.0036)	(0.0036)
Phytomass × Transhumant Pastoral	-0.0030	-0.0075**	-0.0061	-0.0061
	(0.0038)	(0.0036)	(0.0039)	(0.0039)
Own Ethnic Group				
Phytomass	-0.0030	0.0023	0.0030	0.0017
	(0.0051)	(0.0044)	(0.0068)	(0.0068)
Phytomass × Transhumant Pastoral	0.0033	-0.0039	-0.0117	-0.0069
	(0.0114)	(0.0099)	(0.0154)	(0.0152)
Own Cell				
Phytomass	0.0043	0.0002	0.0007	0.0022
	(0.0054)	(0.0045)	(0.0077)	(0.0077)
Phytomass × Transhumant Pastoral	0.0010	0.0078	0.0153	0.0107
	(0.0114)	(0.0101)	(0.0145)	(0.0144)
Nearest Neighboring Ethnic Group: Additional Calculations				
Effect of 1 Std. Dev. Phytomass Shock as % of Dep. Var. Mean:				
Phytomass	-32.02	-16.16	-18.31	-19.86
p-value	[0.18]	[0.54]	[0.18]	[0.16]
Phytomass × Transhumant Pastoral	-26.82	-94.22	-23.42	-23.27
p-value	[0.44]	[0.04]	[0.11]	[0.12]
Phytomass + Phytomass × Transhumant Pastoral	-58.84	-110.38	-41.73	-43.14
p-value	[0.13]	[0.03]	[0.01]	[0.01]
First Stage Kleibergen-Paap LM Test Stat.	35.71	35.71	33.36	33.36
p-value	[0.00]	[0.00]	[0.00]	[0.00]
Dep. Var. Mean	0.04	0.03	0.09	0.09
Cell FE	Yes	Yes	Yes	Yes
Country × Year FE	Yes	Yes	Yes	Yes
Climate-Zone-Year Clusters	280	280	294	294
Cell Clusters	7,667	7,667	7,667	7,667
Observations	153,340	153,340	161,007	161,007

Note: All phytomass variables and interactions are instrumented with their corresponding rainfall variables. 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.

Table A8: Descriptive Statistics for Country-Year Level Variables

	Country-Year Level Variables					
	Mean	SD	Count	Min	Median	Max
Total Agriculture Aid	3.87	8.56	1,421	0.00	0.97	97.40
Total Non-Agriculture Aid	52.36	121.44	1,421	0.00	11.78	1176.00
Irrigation Projects	0.41	0.81	1,421	0.00	0.11	7.67
Forestry Projects	0.88	1.75	1,421	0.00	0.25	17.00
Conservation Projects	0.50	1.14	1,421	0.00	0.10	12.33
Land Projects	0.47	1.09	1,421	0.00	0.11	13.00
Conservation Land (km^2/cell)	0.05	0.04	1,728	0.00	0.03	0.21
THP Power Share	0.10	0.17	977	0.00	0.00	0.61

Note: This table presents basic descriptive statistics for the country-year level variables used in our heterogeneity analyses.

Table A9: Heterogeneity by the Presence of International Aid Projects, Controlling for Country FE and Year FE interacted with Main Interaction of Interest

	Conflict in All Grid Cells			
	(1)	(2)	(3)	(4)
	UCDP I(Any)	UCDP I(State)	ACLED I(Any)	ACLED I(Non-State)
	Panel A: Heterogeneity by International Agricultural Aid			
Nearest Neighboring Ethnic Group				
Rain × Transhumant Pastoral	-0.0369***	-0.0376***	0.0015	0.0015
	(0.0112)	(0.0110)	(0.0135)	(0.0135)
Rain × Transhumant Pastoral × Total Agriculture Aid	-0.0158*	-0.0175**	-0.0033	-0.0032
	(0.0083)	(0.0080)	(0.0114)	(0.0116)
Rain × Transhumant Pastoral × Total Non-Agriculture Aid	0.0011*	0.0011*	-0.0005	-0.0005
	(0.0006)	(0.0006)	(0.0008)	(0.0008)
	Panel B: Heterogeneity by International Aid Types			
Nearest Neighboring Ethnic Group				
Rain × Transhumant Pastoral	-0.0348***	-0.0366***	-0.0044	-0.0046
	(0.0115)	(0.0111)	(0.0139)	(0.0139)
Rain × Transhumant Pastoral × Irrigation Projects	0.0270	-0.0047	0.0350	0.0388
	(0.0368)	(0.0346)	(0.0524)	(0.0520)
Rain × Transhumant Pastoral × Forestry Projects	0.0066	-0.0089	0.1560**	0.1493**
	(0.0265)	(0.0252)	(0.0659)	(0.0654)
Rain × Transhumant Pastoral × Conservation Projects	0.0133	-0.0054	-0.0444	-0.0490
	(0.0322)	(0.0228)	(0.0406)	(0.0400)
Rain × Transhumant Pastoral × Land Projects	-0.0911	-0.0380	-0.1528*	-0.1581**
	(0.0604)	(0.0539)	(0.0784)	(0.0781)
Rain × Transhumant Pastoral × Other Agriculture Projects	-0.0162	-0.0104	-0.0178	-0.0146
	(0.0129)	(0.0128)	(0.0188)	(0.0185)
Rain × Transhumant Pastoral × Other Non-Agriculture Projects	0.0009	0.0009	0.0004	0.0003
	(0.0007)	(0.0007)	(0.0008)	(0.0008)
Dep. Var. Mean	0.032	0.023	0.068	0.067
Cell FE	Yes	Yes	Yes	Yes
Country × Year FE	Yes	Yes	Yes	Yes
Rain × Transhumant Pastoral × Country FE	Yes	Yes	Yes	Yes
Rain × Transhumant Pastoral × Year FE	Yes	Yes	Yes	Yes
Climate-Zone-Year Clusters	364	364	252	252
Cell Clusters	7,667	7,667	7,667	7,667
Observations	199,342	199,342	138,006	138,006

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. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table A10: Heterogeneity by the Presence of Conservation Lands, Controlling for Country FE and Year FE interacted with Main Interaction of Interest

	Conflict in All Grid Cells			
	(1)	(2)	(3)	(4)
	UCDP	UCDP	ACLED	ACLED
	I(Any)	I(State)	I(Any)	I(Nonstate)
Nearest Neighboring Ethnic Group				
Rain × Transhumant Pastoral	0.0099	0.0106	0.0872***	0.0864***
	(0.0137)	(0.0128)	(0.0217)	(0.0217)
Rain × Transhumant Pastoral × Conservation Land (km^2/cell)	-0.4334***	-0.4411***	-0.7746***	-0.7660***
	(0.1299)	(0.1224)	(0.1794)	(0.1791)
Nearest Neighboring Ethnic Group: Additional Calculations				
Effect of 1 Std. Dev. Rain Shock as % of Dep. Var. Mean:				
Rain × Transhumant Pastoral when Conservation at 10th pctile	33.38	49.77	133.45	132.80
p-value	[0.51]	[0.44]	[0.00]	[0.00]
Rain × Transhumant Pastoral when Conservation at 90th pctile	-139.25	-192.97	3.62	3.90
p-value	[0.00]	[0.00]	[0.88]	[0.87]
Dep. Var. Mean	0.032	0.023	0.077	0.077
Cell FE	Yes	Yes	Yes	Yes
Country × Year FE	Yes	Yes	Yes	Yes
Rain × Transhumant Pastoral × Country FE	Yes	Yes	Yes	Yes
Rain × Transhumant Pastoral × Year FE	Yes	Yes	Yes	Yes
Climate-Zone-Year Clusters	420	420	322	322
Cell Clusters	7,462	7,462	7,462	7,462
Observations	223,860	223,860	171,626	171,626

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.

Table A11: Heterogeneity by Share of Political Power Held by Transhumant Pastoral Groups, Controlling for Country FE and Year FE interacted with Main Interaction of Interest

	Conflict in All Grid Cells			
	(1)	(2)	(3)	(4)
	UCDP I(Any)	UCDP I(State)	ACLED I(Any)	ACLED I(Non-State)
Nearest Neighboring Ethnic Group				
Rain × Transhumant Pastoral	-0.0557**	-0.0507**	-0.0854**	-0.0855**
	(0.0174)	(0.0165)	(0.0292)	(0.0291)
Rain × Transhumant Pastoral × THP Power Share	0.0958**	0.0769**	0.2765***	0.2763***
	(0.0377)	(0.0343)	(0.0751)	(0.0752)
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	-208.30	-253.20	-137.49	-138.25
p-value	[0.00]	[0.00]	[0.00]	[0.00]
Rain × Transhumant Pastoral when THP Power at 90th pctile	-99.81	-136.87	-2.56	-2.81
p-value	[0.02]	[0.02]	[0.91]	[0.91]
Dep. Var. Mean	0.032	0.024	0.074	0.074
Cell FE	Yes	Yes	Yes	Yes
Country × Year FE	Yes	Yes	Yes	Yes
Rain × Transhumant Pastoral × Country FE	Yes	Yes	Yes	Yes
Rain × Transhumant Pastoral × Year FE	Yes	Yes	Yes	Yes
Climate-Zone-Year Clusters	406	406	308	308
Cell Clusters	6,965	6,965	6,962	6,962
Observations	194,442	194,442	148,128	148,128

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.

Table A12: Heterogeneity by Share of Political Power Held by Transhumant Pastoral Groups, Controlling for Country FE and Year FE interacted with Main Interaction of Interest

	Conflict in All Grid Cells			
	(1)	(2)	(3)	(4)
	UCDP I(Any)	UCDP I(State)	ACLED I(Any)	ACLED I(Non-State)
Nearest Neighboring Ethnic Group				
Rain × Transhumant Pastoral	-0.0557**	-0.0507**	-0.0854**	-0.0855**
	(0.0174)	(0.0165)	(0.0292)	(0.0291)
Rain × Transhumant Pastoral × THP Power Share	0.0958**	0.0769**	0.2765***	0.2763***
	(0.0377)	(0.0343)	(0.0751)	(0.0752)
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	-208.30	-253.20	-137.49	-138.25
p-value	[0.00]	[0.00]	[0.00]	[0.00]
Rain × Transhumant Pastoral when THP Power at 90th pctile	-99.81	-136.87	-2.56	-2.81
p-value	[0.02]	[0.02]	[0.91]	[0.91]
Dep. Var. Mean	0.032	0.024	0.074	0.074
Cell FE	Yes	Yes	Yes	Yes
Country × Year FE	Yes	Yes	Yes	Yes
Rain × Transhumant Pastoral × Country FE	Yes	Yes	Yes	Yes
Rain × Transhumant Pastoral × Year FE	Yes	Yes	Yes	Yes
Climate-Zone-Year Clusters	406	406	308	308
Cell Clusters	6,965	6,965	6,962	6,962
Observations	194,442	194,442	148,128	148,128

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.