A Matter of Place: Rethinking Climate Security in Somalia through Spatial Heterogeneity

Chun Song (chun.song@fao.org), Food and Agriculture Organization
Antonio Scognamillo, Food and Agriculture Organization
Ada Ignaciuk, Food and Agriculture Organization

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Chun Song[a], Antonio Scognamillo[a], Ada Ignaciuk[a]

[a] *Agricultural Development Economics Division, FAO, Food and Agriculture Organization of the United Nations*

Abstract

Recent empirical evidence suggests that climate shocks can increase the incidence of armed conflict in vulnerable contexts via agricultural price channels. Furthermore, previous contributions indicate that in geographically and politically divided countries, the link between climate shocks and conflict, as well as the mediation role of market, may vary significantly between regions. This study extends the current literature by explicitly incorporating the spatial heterogeneity that characterized the association between drought episodes and conflict mediated by agricultural commodity prices in Somalia from 2009 to 2021. Results from random coefficient models reveal that drought is, on average, associated with increased conflict at a given price level. Moreover, increased (decreased) prices for maize (goat) intensify the effect of drought on conflict frequency. While the price elasticity of conflicts in the aftermath of a drought is the most prevalent in conflict-affected districts (climate insecurity hotspots), it may be also high in areas that are currently relatively less exposed to the violence. These areas are the most vulnerable to climate-induced violence due to changes in staple crops and livestock assets price in the aftermath of a drought (climate vulnerability hotspots). The findings of this paper aim to support targeted and coordinated policy interventions for climate-insecure and climate-vulnerable places in a context characterized by resource scarcity, high exposure to climate-related shocks, and frequent and persistent conflicts. Moreover, accounting for the geographical dimension of the economic linkages between changes in climate-related shocks and armed conflicts, this paper provides a lens to reconcile the conflicting empirical findings in the literature by explicitly modelling the effect of different contributing factors. Our approach may be flexibly extended to study other regions facing similar threats from persistent violence and periodic climate shocks, or additional moderator factors influencing the drought-conflict nexus.

Keywords: Drought; conflict; Somalia; heterogeneity; prices; random coefficient model

Highlights

- Somalia has been devastated by conflict and climate shocks and has significant district heterogeneity.
- Increased (decreased) staple crop (livestock) prices during a drought exacerbate the drought's effect on inducing additional violence.

- There is strong correlation between the location of conflict-affected districts and that of high price elasticity of conflict during drought.
- Climate change may exacerbate existing conflict in areas that are not currently sites of chronic conflict.
- For building climate security, district-specific and targeted approaches to stabilizing staple commodities and feed storage in conflict-affected districts are critical.

1 Introduction

Recent studies have attempted to establish an empirical link between climate variability and armed conflict. Conditional and indirect links have been identified, although the findings are mixed (see, for example, Koubi (2019) for a review of these studies). Despite the effort to explore drought-induced conflict, examining this nexus is notoriously challenging due to the fact that the effect is plausibly indirect and conditional on a number of other factors (moderators) which are often interlinked and site-conflict specific. This is especially true for countries including Somalia, which is extremely institutional, political, social, and economic fragmented due to endemic violence among groups fighting for land and resources.

In this context, although extreme weather events, typically measured in terms of precipitation and temperature anomalies, do not directly cause conflicts, they can amplify civil wars and other violent incidents, particularly via economic channels such as livestock prices (Miguel et al., 2004; Maystadt & Ecker, 2014). However, since the climate-shocks-conflicts relationship is mediated by other contextual factors, it is likely to be spatially heterogeneous. Focusing on the mean effect may obscure the complexity of the mechanism that drives conflict locally determining mixed and somewhat misleading findings. Districts with established and accessible local markets, for example, are likely to be less sensitive to price changes during the weather abnormality (Davenport & Shukla, 2021). Additionally, approximating regional responsiveness using the national average may result in an over- or under-estimation of the actual impact locally, potentially misguiding policy interventions. As a result, neglecting the variability of district-specific responses to weather shocks via a specific moderator (e.g., the price channels) may result in biased inferences. This article addresses these shortfalls.

In Somalia, the districts exhibit significant temporal and spatial variation in terms of conflict and drought, as well as other unobservable characteristics. Modeling district variability has significant policy implications for Somalia's climate security and resilience. Armed conflicts destabilize economies and have a detrimental effect on both the country's development and the peacebuilding process although over the last few decades and remarkable progress has been made in the country's peacebuilding efforts.

Notwithstanding this, numerous improvements are still required to ensure the security of the vast majority of Somali citizens. As of the time of writing this article, in 2022, the conflict between the Somali Government and the Islamist armed group of Al-Shabab is ongoing and often involve indiscriminate and targeted attacks on civilians and the forcibly recruitment of children. The violation of the international humanitarian law and the war crimes are uncountable and together with increasingly inter-clan violence, the endemic conflicts killed, injured and displaced civilian millions of civilians. At the moment, over 2.6 millions of Somalis are internally displaced, and the increasing intensity and frequency of climate change related disasters (droughts, floods and desert locust swarms) is exacerbating the humanitarian emergency. Climate change and increased exposure to extreme weather events continue to jeopardize the most vulnerable people's livelihoods and are also considered significant factors fueling armed conflict in Somalia. Climate-related security risks are reshaping the security landscape, jeopardizing decades of government and international organization peacebuilding efforts. Over the last decade, the average rainfall in Somalia has been 15% less than the long-term historical trend, forcing more people into flooded cities, refugee camps, and the ranks of the militant group Al-Shabab (FAO, 2019).

The main objective of this study is to examine the implications of heterogeneity in the drought-conflict mechanisms in Somalia, as well as to identify high-risk districts for climate-induced conflict. It is organized around two primary research questions: (a) Does agricultural commodity prices' moderating (magnifying) effect on the drought-conflict relationship vary across Somalia's districts? And (b) In the event of a drought, which district should be targeted and prioritized for specific peacebuilding policies?

In fact, Ide (2017) points out that climate-related conflicts do not always occur in areas experiencing the most severe effects of climate change. Spatially varying characteristics shape the relationship between climate change and conflicts, determining whether or not a geographically delimited shock, such as drought, will initiate/escalate a conflict. Through modelling heterogeneity, the broader purpose of this study is to contribute to the development of evidence-based policies for better targeting and reducing Somalia's climate insecurity and vulnerability. Modeling spatial heterogeneity is expected to aid the peacebuilding process by providing evidence-based recommendations for targeting and concentrating emergency interventions across different districts to improve preparedness and resilience to multiple shocks. The proposed approach is especially pertinent for Somalia, as the country lacks a single governing authority and political, social, and market institutions vary significantly between regions and districts. For instance, Somaliland's northern region claims independence and operates as a de facto independent state but is not internationally recognized as such. Puntland is committed to Somalia's federal government but maintains a high degree of autonomy. Jubaland, Southwestern State, Hirshabelle, and Galmadug are also federal member states operating under the provisional constitution. By relaxing the assumption of constant effect across districts, is possible to estimate site-specific coefficients through a flexible spatial regime specification.

The findings highlight that, on average, the number of monthly conflicts is positively associated with the intensity of droughts in the models, including the district for which the prices of the main staple crop, i.e., maize, are available. This empirical association is magnified when the prices of maize (the main staple crop) surge in concomitance or in the aftermath of a drought. On average, 1% increase in maize prices in district affected by a drought over the previous three months is associated with 0.23% increase in the number of conflicts. However, the association vary across the districts, ranging from 0.20% to 0.28%, being higher in the agro-pastoral region such as Lower Juba regions, and inter-riverine region. Evaluated at the average observed price increase, the marginal effect implies an average of 5% increase in number of monthly conflict after drought. Moreover, no statistically significant impact of changing goat prices (the main livestock asset) on the drought-conflict relationship.[1] Yet the correlation between the district level conflicts and district sensitivity to price change during drought is significant differently from zero, suggesting that the mean effect may be confounded by not taking explicitly into account the spatial heterogeneity. In fact, the association spreads heterogeneously across the district, ranging from -0.08% to -0.10% and being higher in the pastoralist districts (including Hargeysa and Burao Districts in the Togdheer region, and Diinsoor in the Bay region) where goats are the predominant animals to breed.

The districts with higher mean conditional conflict also tend to be more sensitive with respect to price changes during drought. Econometrically, this translates into a fanning-out pattern with the two estimated vectors (intercepts and slopes). Such correlation from the preferred model specification is robust to alternative functional form (i.e., difference random component specifications), different lengths of the period over which the SPEI is accumulated (i.e., up to 9 months), and different lengths of the period over which the conflict is forwarded (i.e., conflict occurs up to nine months after the price change). Combing both the price elasticity of conflict during drought (estimated slope) and the conditional average level of conflict frequency (estimated intercepts), climate insecurity hotspots and climate vulnerability are pinpointed and visualized to facilitate targeted policy interventions and preventative actions.

The primary contribution of this paper is the estimation of district specific price elasticity of conflict during drought, and the selection of hotspot districts in term of both the effect of agricultural prices on drought-conflicts link, and the severity of local conflict. Additionally, our approach proposes the random coefficient

[1] The average association is significantly different from zero at 12%. It is worth noting that, unlike agricultural prices, the empirical association between conflict and goat prices in the aftermath of a drought has a negative sign, as shortages of pasture and water during a drought cause livestock deaths and reduced body mass, prompting herders to simultaneously sell their animals and the price to fall. This is a well-known phenomenon in Somalia.

modeling as a convenient and useful reduced form technique for estimating spatial variances in terms of conflict's mediator elasticity during drought.[2]. Accounting for the geographical dimension of the economic linkages between changes in climate-related shocks and armed conflicts, this paper provides a lens to reconcile the conflicting empirical findings in the literature. By explicitly modelling the effect of different contributing factors rather than the spatial distribution of those factors. To the best of our knowledge, this paper is the first to explore this argument through a spatially explicit model.

Practically, this enables the observation of district-level climate security variability and facilitates the design of a district-specific peacebuilding and drought resilience approach that invests limited resources in improving market institutions and resilience in specific districts. As an example, early warning systems may pay greater attention to the level of food prices and target food price stabilization efforts in conflict-affected districts (Minot, 2014).

This paper contributes to three strands of literature. First, it is closely related to research on climate change may exert an indirect and conditional effect on conflict risk (Barnett (2003), Scheffran et al (2012) Buhaug et al (2014), and Theisen (2013)). Most studies have demonstrated that extreme weather events tend to accentuate competition over scarce resources while decreasing the opportunity cost of joining conflicts, particularly through economic channels (Collier (2003) Miguel et al. (2004)). Maystadt and Ecker (2014) found an increase in drought intensity and length raises the likelihood of conflict in Somalia. Such an impact is through livestock prices, suggesting the channel of opportunity cost. Yet in these studies, the impact of different market channels on drought-conflict relations is assumed to be region-invariant and using the climate shock as an instrumental variable the authors imply that the instrumented mediators are the only indirect channels through which the climate shocks affects the frequency of conflicts. Second, this paper quantitatively enriches the discussion on regional heterogeneous responses to climate shocks. In vulnerable contexts, climate-related conflicts do not necessarily take place where the effects of climate shocks are more severe, suggesting the existence of spatial heterogeneity (Aremu, 2010; Ide, 2017; Davenport & Shukla, 2021). Our paper is related to Ide et al (2014) as it explores the spatially varying link between drought and conflict. In contrast, we explicitly model the effect of different contributing factors rather than the spatial distribution of those factors. Finally, related to studies and practical guidance on peacebuilding in vulnerable areas, the empirical findings identify hotpot districts in Somalia that are more affected or prone to drought-induced violence and according to the relative structural level of violence in the geographic area distinguish climate insecurity and climate vulnerability hotspots.

[2] Econometrically, in our case, the performance of the model using the random coefficient estimator was significantly improved when compared to the fixed effect model

The insights from this study are expected to support evidence- based policy to better target and coordinate interventions in a context characterized by resource scarcity, high exposure to climate-related shocks, and frequent and persistent conflicts. For example, in the Somalia context, better education on market knowledge for local farmers, food security through humanitarian interventions, food price subsidies as well as crop insurance can also play important role in improving resilience (Breisinger, Ecker, Maystadt, & Trinh, 2014). Moreover, our study aims at orienting evidence-based policy to better target and coordinate interventions in a context characterized by resource scarcity, high exposure to climate-related shocks, and frequent and persistent conflicts. The rest of the paper unfolds as follows: Section 2 provides the background and context, section 3 introduces the data and sample, section 4 presents the econometric model, section 5 is the results, and the last section concludes with policy implications.

2 Background: drought, conflict, and agricultural market in Somalia

This section discusses the institutional context of the weather-related conflict in Somalia and the rationale for the disparate effects of various impact factors. Somalia has suffered from drought, conflict, instability, and the absence of a functioning government since the start of the country's civil war in 1991. In 1991, 1992, 2006, 2008, and 2011, Somalia suffered a series of famines and food security crises. This protracted and complex crisis has affected the lives and livelihoods of millions of people (FAO, 2014), fueling a number of armed factions and conflicts fueled by the absence of functioning judiciary and police.

The complex humanitarian situation is reflected in a highly fragmented administrative framework. There are 18 regions in Somalia. Of these, thirteen are administrative regions, *gobollo*, and five of them are claimed but uncontrolled regions in Somaliland. These are in turn subdivided into seventy-two districts, *degmooyin*, and eighteen claimed but uncontrolled districts in Somaliland. On a de facto basis, northern Somalia is now divided between the autonomous region of Puntland, which considers itself an autonomous state, and Somaliland, as a self-declared but unrecognized sovereign state. In central Somalia, Galmudug is another regional entity that emerged south of Puntland.

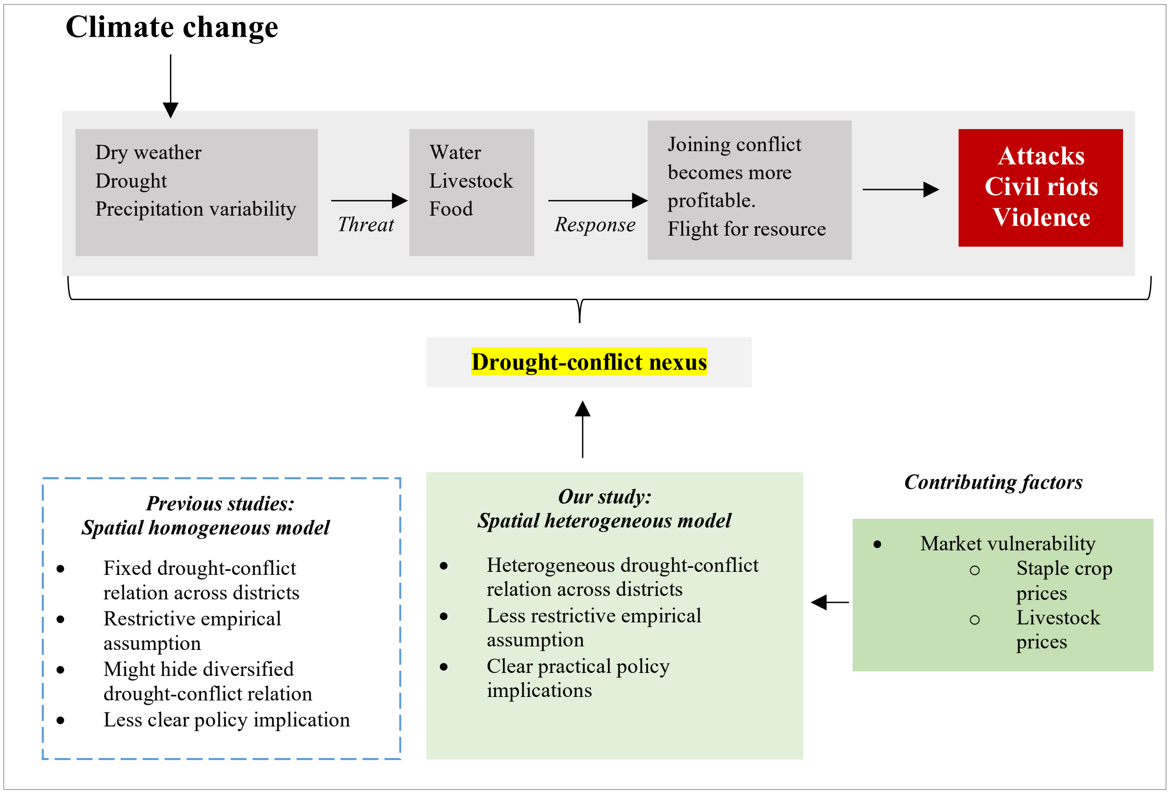
Within this extremely problematical context, the impact of climate change has magnified the endemic Somalia’s food and water crises, compounded by land mismanagement and lack of governance. Previous studies have stated that Africa's remarkable size and diversity make it hard to speculate on conflict and instability, especially in the Horn (USAID, 2012). Each case has its own particular progression, drivers, and routes; every group distressed by clashes has its own novel arrangement of adjustments and levels of versatility (Aremu, 2010). There is no viable alternative to considering specific and relevant information about each instance of contention and shakiness. The reasons for these contentions are ingrained and occurred over a long period of time (Tadesse, 2003, USAID, 2014).

Due to Somalia's diverse regional makeup, the economic impact of weather shocks, such as drought and floods, is a common concern that may be declined in different forms in part because each region has a unique combination of natural, political, social, and economic characteristics that exacerbate, mediate, or alleviate the impact of climate change in non-linear ways. As Ide (2017) points out, climate-related conflicts do not always occur in areas experiencing the most severe effects of climate change. This suggests that the effects of climate change on conflict are spatially variable. Thus, the same drought episode may elicit varying degrees of conflict as a result of different coping mechanisms. For instance, Somalia has two major rivers: the Juba and the Shabelle. Both rivers flow southeast from the Ethiopian Highlands through Somalia to the Indian Ocean. Water scarcity may be expected to affect agriculture's resilience to drought uniformly in this area but unobservable conditions at the local level, such as tribe dynamics and informal community support, may also influence the response to drought, and such complex interaction effects are likely to be obscured by a model that only estimates national averages.

Evidence show that drought can intensify conflict in vulnerable areas due to many interlinked moderator factors. In Somalia, we focus on agricultural commodity prices for three reasons: first, it is a well-established channel that has been proved important in the previous literature (Maystadt & Ecker, 2014). Escalating food prices may have multiple causes, including severe drought and resulting crop failure in major food-producing areas. Partly for this reason climate change is viewed with much concern and diminishing food productivity in response to rising temperatures and increasingly erratic rainfall patterns is frequently cited as a significant threat to societal stability and peace (e.g., Adger et al., 2014, Stern, 2006, World Bank, 2010). Re-examining this well-established channel by relaxing the homogeneity assumption gives additional and crucial insights. Second, market institution is an area of potential policy intervention, through better information or training, which may benefit the most the vulnerable smallholders. In addition, information on market prices on the main staple crop and livestock asset is available for the majority of the districts at a monthly frequency and spatial-granular resolution in Somalia, come near to the resolution and the frequency of the information on rainfalls and temperatures.

Motivated by these discussions, the conceptual framework shown in Figure 1 represents how regional heterogeneity may affects the impact of climate change related disasters on potential conflicts through established market channels. We argue that drought induced agricultural price change reinforce and widespread the humanitarian emergency and the food insecurity fueling the social grievances intra and inter groups. These processes will motivate a larger pool of individuals to join and/or support an active opposition movement to fight for the scarce resources and redress their grievances, thus increasing the likelihood of violence escalation.

Figure 1 Conceptual framework



Source: Author's elaboration

3 Data

3.1 Sample

The data sample we use for our analysis excludes the Mogadishu area. This is due to several reasons: first, a large number of conflicts have taken place in Mogadishu and account for the majority of total conflicts in Somalia. Including Mogadishu might bias our results due to this outlier frequency of conflicts. Second, Mogadishu is the capital, largest city of the country. It is mainly an urban area where the competition for land and resources is overwhelmed by the fights for the control of strategic infrastructure and the political power. Previous studies have also excluded Mogadishu from the analysis (Maystadt & Ecker, 2014). In our study, we found that before removing Mogadishu from the sample, the results of agricultural commodity prices, including the maize and goat prices, were not significant. This implies that the market channels that we explore are more relevant for the rural regions of Somalia. Moreover, the sample is further restricted to the districts in which price information on either maize or goat prices are available. However, for all 18 regions in Somalia, we are able to include in our analysis 16 regions for maize price and 17 regions for goat price.

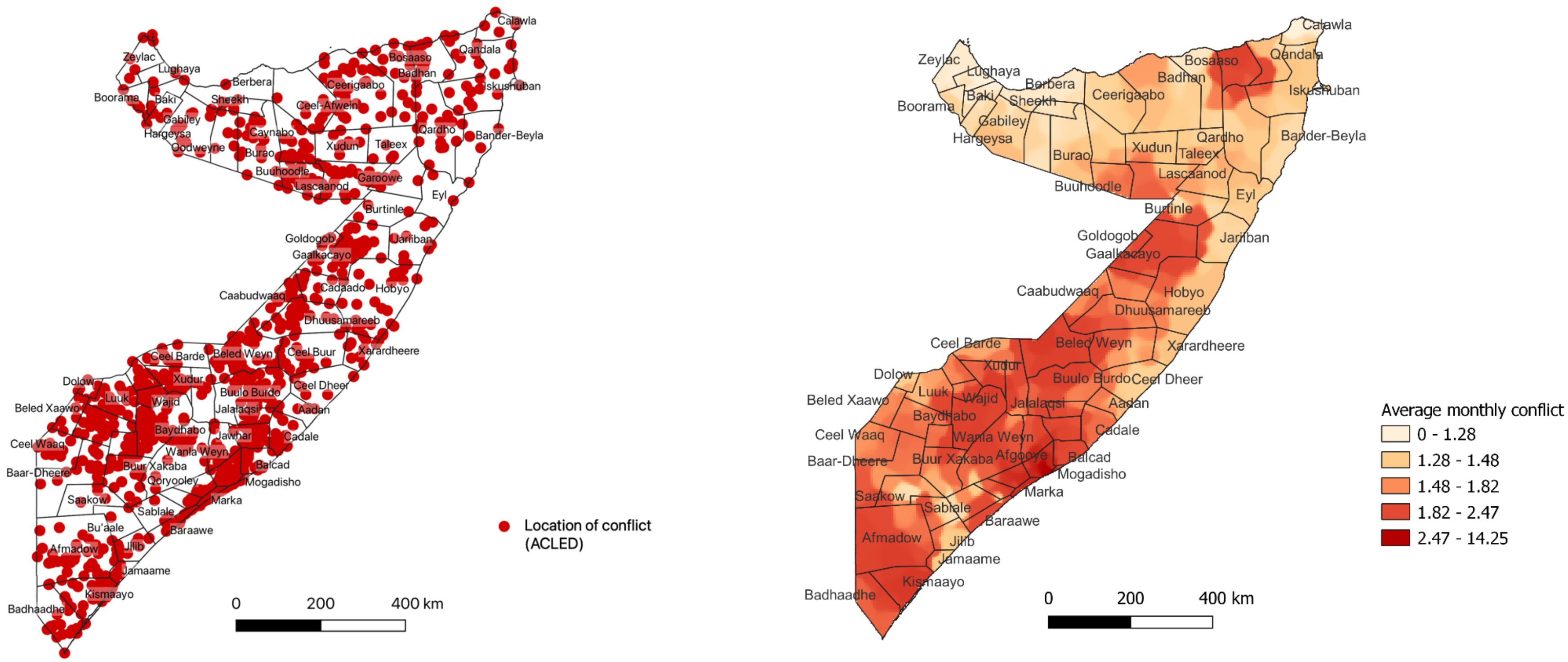
3.2 Conflict measurement

The dependent variables are the frequency of intra-state armed conflict. For this measurement, information for all 73 Somalia districts is obtained from the Armed Conflict Location & Event Data Project (ACLED), a widely adopted dataset in previous conflict studies (for example, Maystadt & Ecker, 2014; (Pape & Wollburg, 2019)). This is a disaggregated datasets that collects the dates, actors, locations, and types of all reported political violence and protest events (Raleigh, Linke, Hegre, & Karlsen, 2010).

ACLED has 6 event types and 25 sub-event types. This enables us to concentrate on the types of conflict that are most relevant for drought-induced conflict measurement. In accordance with previous studies, we define conflict as battles and violent conflicts only (Maystadt & Ecker, 2014). Moreover, we only include within-state conflicts that involve at least one non-state actor, such that the conflict is only domestic conflict that is relevant to drought incidence[3]. On average, between April 2009 and March 2021, each district experienced an average of five conflicts per month. Battles accounts for more than 70% of all conflicts. Figure 2 shows the location of conflict and the average monthly conflict respectively. Conflicts erupt in all the districts considered, including Somaliland, but are more frequent in Lower Juba, Lower Shabelle, Middle Shabelle, as well as Banaadir regions.

[3] Non-state actor refers to armed conflict in which neither party is a member of the state's government (i.e. militias, communal conflict, and inter-rebel fighting). Due to the absence of a variable indicating the causality of conflict in ACLED, our definition of conflict is interpreted as the total number of conflicts, which includes fatal and non-fatal conflicts. For a more detailed discussion of the ACLED dataset's conflict definition, see (Eck, 2012).

Figure 2 location conflicts 2001 to 2021 in Somalia by district: location (left) and frequency (right)

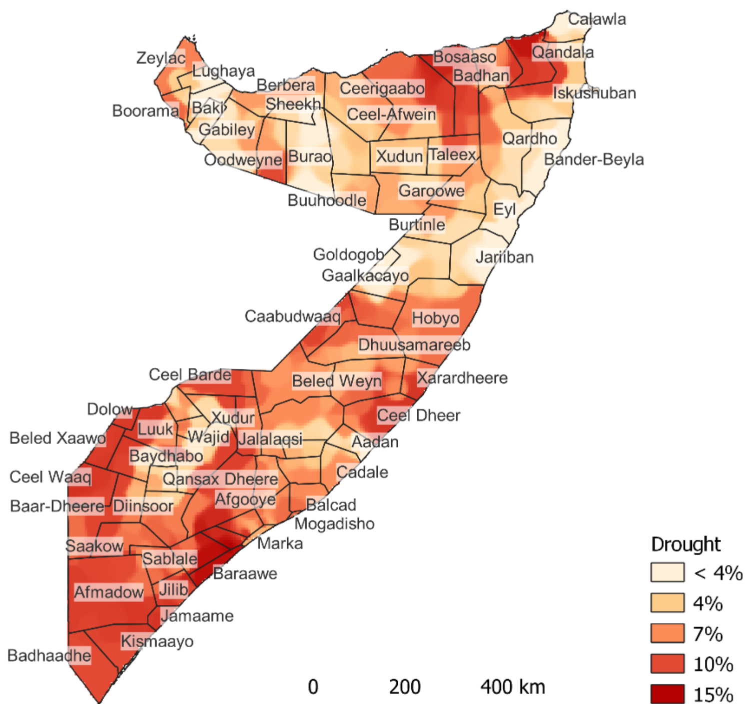


Notes: The locations of conflict are de-duplicated. Data source: Armed Conflict Location & Event Data Project

3.3 Drought measurement

We constructed drought measurements using the historical time series on rainfall precipitation and temperatures obtained from FAO SWALIM (Somali Water and Land Information Management) geo-datasets (Balint, 2013). The raw data are gathered from the country's over 100 manual rainfall stations, eight synoptic weather stations, and eleven automatic weather stations. SWALIM receives data from these automated stations in near-real time via satellite feeds every four hours (SWALIM, 2022). The weather stations collect data on a variety of variables, including rainfall and temperature. Together with the district's latitude, rainfall and temperature data are used to calculate the Standardized Precipitation Evapotranspiration Index over a three-month accumulation period (SPEI-3). The index reflects short-and medium-term moisture conditions and provides a seasonal estimation of precipitation (McKee, Doesken, & Kleist, 1993).

Figure 3 Average percentage of months in a year associated with drought



Notes: Drought defined as continuous SPEI-3 (past three months) below negative 1.5 (moderate and severe drought). Color shows average percentage of month in a year in each district that is associated with drought. Surface plotted with inverse distance weighted average interpolation. Data source: Somali Water and Land Information Management (SWALIM).

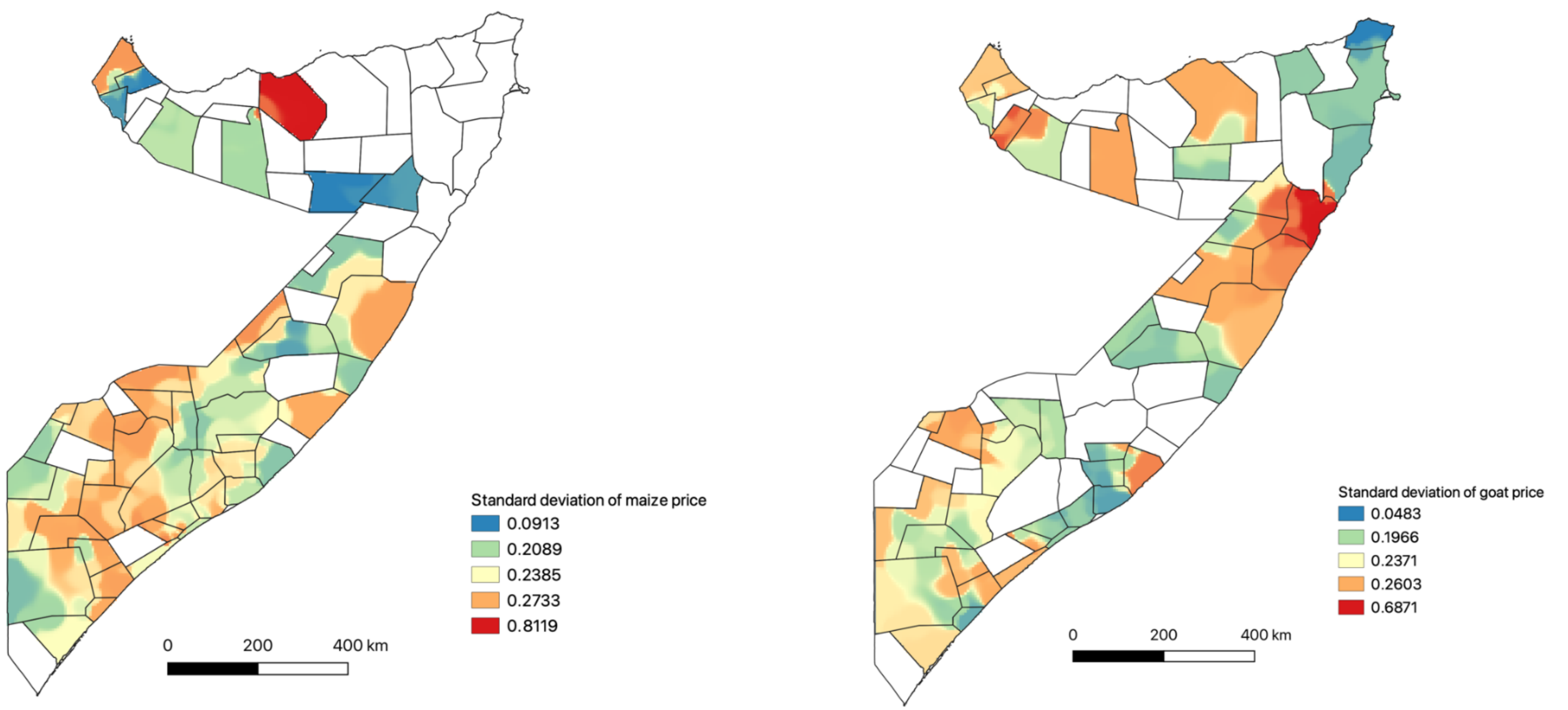
The SPEI provides a representation of monthly precipitation and temperature for a given location because the long-term precipitation record is fitted to a probability distribution. Our selected index provides a comparison of the precipitation over a specific 3-month period with the precipitation totals from the same 3-month period for all the years included in the historical record. In other words, a 3-month SPEI at the end of February compares the December-January-February precipitation total in that particular year with the December-February precipitation historical records across the whole period considered. Wet conditions are shown by SPEI values that are above or below the median. Negative values show less than the median precipitation (dry conditions), and positive values show more than the median precipitation.

Drought in this study is defined as an indicator variable for SPEI being smaller than negative 1.5, which represents extreme and exceptional dry episode that likely lead to loss of crops and pasture, extreme fire danger, total water shortages, drying of deep reservoirs, and usage restrictions. Based on this definition, Figure 3 presents the average percentage of months in a year that are associated with drought according to our definition. The Baraawe District, as well as Qandala and Badhan Districts in the north, tend experience droughts and severe droughts more frequently.

3.4 Agricultural commodity prices

Data related to agricultural market prices is obtained from multiple spatial datasets. The market prices for maize and goats are from the FAO Food Security and Nutrition Analysis Unit (FSNAU). FSNAU operates a market price monitoring system in Somalia, collecting and analyzing weekly data on maize and goat prices across the country's major agricultural commodity markets. Weekly price data are collected and averaged over the course of a month. If no price for a particular commodity is available, it generally indicates that it was not traded during the period, when traders refrain from trading in a market due to deteriorating security conditions, or when the observer is unable to travel or obtain the information in any other way. Maize is the main agricultural commodity that is locally produced, particularly in the central and southern parts of Somalia, and goats are the primary livestock raised in Somalia. Monthly data are available at the district level from 2009 to 2021. Figure 4 presents the standard deviation of prices by district. Certain districts exhibit greater price volatilities.

Figure 4 Standard deviation of maize price (left) and goat price (right)



Notes: Standard deviation of monthly maize (left map) and goat (right map) prices. Surface plotted with inverse distance weighted average interpolation. Data source: FAO Food Security and Nutrition Analysis Unit

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Additionally, we obtained the number of operational water sources at the district level from the FAO Somalia Water Sources Information Management System (SWIMS) from 2009 to 2019. Water sources include functioning boreholes, dug wells, springs, berkad, and togga. Previous studies have established an important connection between water, agricultural production, refugees, and conflict. Groundwater is the only viable resource in most arid and semi-arid environments in Somalia that can sustain rural populations. Moreover, periodic drought forces people off the land who take refuge in the cities, taxing already stressed resources. Given that, the variable has been constructed and used as a further control in our model specification.

4 Empirical Method

With both conceptual and empirical support, we choose a random coefficient estimator to understand the heterogeneity in the droughts-conflicts relationship mediated by agricultural commodity prices[4] (Swamy, 1970). There are three main benefits associated with using a random coefficient estimator in our research setting: (a) testing districts heterogeneity through examining the structure on the variance-covariance matrix; (b) predicting district-specific effects of market price on mediating the adverse effect of drought on conflict, and (c) identifying and screening climate insecurity and vulnerability hotspots. Compared to fixed effect estimators that estimate such heterogeneity through imposing district specific fixed parameters, random coefficient model is flexible yet tractable in depicting both the mean and the variance in the relationship between droughts, prices and conflicts across districts, without imposing heavy parametric restrictions[5].

Formally, the random coefficient estimator allows the regression coefficients of interest, namely the intercepts and slopes (marginal effects of the interaction between the drought and price variables), to covary through a given contributing factor across districts $i = 1, 2, \dots, n$ in Somalia. To start, we specify the initial model as follow: The model using the number of armed conflicts in each month-district as dependent is estimated as in the equation (1) below:

$$log\ (Conflict)_{im} = (\beta_0 + \beta_{0i}) + \beta_1 Drought_{im} + (\beta_2 + \beta_{2i}) log\ (X) * Drought_{im} + \beta_3 log\ (X) + \varepsilon_{im} \quad (1)$$

Where $\beta_0 + \beta_{0i}$ conceives the district intercept terms as an average countrywide intercept plus a local random variability parameter, and similarly, for $\beta_2 + \beta_{2i}$ slopes. The unit of analysis is district – month. X

[4] Alternative estimator to capture possible heterogeneous intercepts and slope is through fixed effect and interaction between district dummies and price drought interaction. These models are also estimated as comparison with random coefficient model.

[5] We also test model performances formally using different metrics. See section 6.1 for more details.

may represent different moderators including either maize or goat prices. The monthly standardized precipitation evapotranspiration index (SPEI) over an accumulation of a 3-month period is used to define a dichotomous variable to identify drought episodes. In particular, drought periods have been identified using a normative threshold for the SPEI to select the periods in which the index fell below -1.5 to capture the occurrence of extreme and exceptional dry episodes. In our empirical framework, such a drought variables takes the value 1 when SPEI index is below the threshold and zero otherwise.

The fixed parameters β_0 and β_2 are the usual intercept and slope representing the average country-wide relationship. The variance and covariance of the random terms β_{0i} and β_{2i} therefore succinctly summarize parameters variability. These coefficients are estimated simultaneously with the fixed parameters through placing a joint probability distribution. The structured variance-covariance matrix described by equation (2) below. Likelihood ratios tests are implemented to test the variance covariance parameters. If indeed all the variance terms are effectively zero, there is no heterogeneity, and that the relationship is adequately described by the country average parameters.

$$\beta_{0i} \sim N(0,\ \sigma_{b0}^2),\ \beta_{2i} \sim N\left(0,\ \sigma_{b2}^2\right), cov(\beta_{0i}\ , \beta_{2i}) = \tau_{b0,b2} \tag{2}$$

The empirical framework also allows to control for region fixed effect and time trends and other relevant geographical factors that may vary across the time. The choice of fixed effect at more aggregated level (region) is motivated by several recent studies. For example, Fisher et al (2012) pointed out that regression models that use state-by-year fixed effect the standard errors are very large because state-by-year fixed effects absorb almost all variation in weather. This causes significant attenuation bias on their parameter estimates. Therefore, we do not include district-year fixed effect but regional fixed effect and linear time trend. Following previous literature, we control for the number of functioning water-related infrastructure in each district, which might confound the association affecting both the frequency of conflicts and the price levels through the agriculture productions (see, for example, Gleick (2014) and Sarsons (2015)).

It's worth noting that this model's objective is to estimate a reduced form relationship between droughts and conflicts through the moderator role of market prices. Numerous conflict studies employ the influential Miguel et al. (2004) identification framework, which examines the effect of economic growth on civil conflict by using precipitation as an IV for economic growth. As in the previous literature, we do not use drought or any other indicator of weather shocks as an instrumental variable for market price (Maystadt & Ecker, 2014), because mounting empirical evidence suggests that assuming climatic shocks affect conflict exclusively through the agricultural commodity price channel is implausible (Dell et al. 2014). Other channels, such as non-farm income (Burke et al. 2015), health (Burke et al. 2015), and migration (Bohra-

Mishra et al. 2014), may also influence act as a moderator between droughts and conflicts. Schlenker & Lobell (2010) also raise this concern, casting doubt on the identification assumption underlying IV estimation. Due to these concerns, we instead estimate the reduced form, with the key variables being the droughts-prices interaction term.

The estimated coefficient for this interaction term can be interpreted as the conditional association of droughts on conflict. It is predicated on two assumptions: (a) no confounders variables in the droughts-conflicts relationship; and (b) no confounders affecting both agricultural commodity prices and conflicts conditional on the drought episode itself, the time variant observed characteristics such as the number of functioning water sources in each district each month and regional time invariant unobserved characteristics such as institutional factors, local support systems, and market access, a linear time trend, and an important time-variant variable. The robustness of the results has been checked across functional form, SPEI accumulation periods, and forwarding conflicts. The structured variance-covariance matrix has been also used to examine the mediation effect of price on the drought-conflict relationship across districts in order to identify relevant policy indications to identify and target climate insecurity and climate vulnerability hotspots. The following section summarizes and interprets the major findings.

5 Results

5.1 Main results

Table 1 summarizes the main findings from the fixed component of the random coefficient model using the preferred model specification. As a comparison, we also report the results of fixed effect regression without random components. Conditional on prices and other controls, the conflicts frequency is positively associated with the occurrence of a drought episode. On average, there are 2% more monthly conflicts in the aftermath of a drought. Furthermore, the association between drought and conflict is amplified when maize prices rise during a drought episode. In fact, the increase in the prices of the major staple crops during a drought reflects the relative scarcity of these goods, which is expected to increase in the aftermath of a dry period. In Somalia, rapidly rising food prices are severely limiting the access of a large number of households to food (FAO, 2017). Besides that, the households most impacted in agricultural areas are predominantly rain-fed subsistence farmers with a low opportunity cost to join conflict. They also tend to spend a disproportionate share of their income on basic foods. As such, volatility in the availability of staple foods and high prices in relation to income can result in social upheaval (Bellemare, 2015). The model estimates a 10% increase in maize prices during a drought is associated with an average of 2% conflict growth. On the other hand, lower livestock (goat) prices are associated with more frequent conflicts, although the prices-droughts interaction coefficient is not significant.[6] However, the negative sign on the average coefficient is consistent with the opportunity cost hypothesis indicating that when the livestock assets price fall, they may exacerbate the impact of the dry episode on the conflict frequency.

Table 1 Estimation results

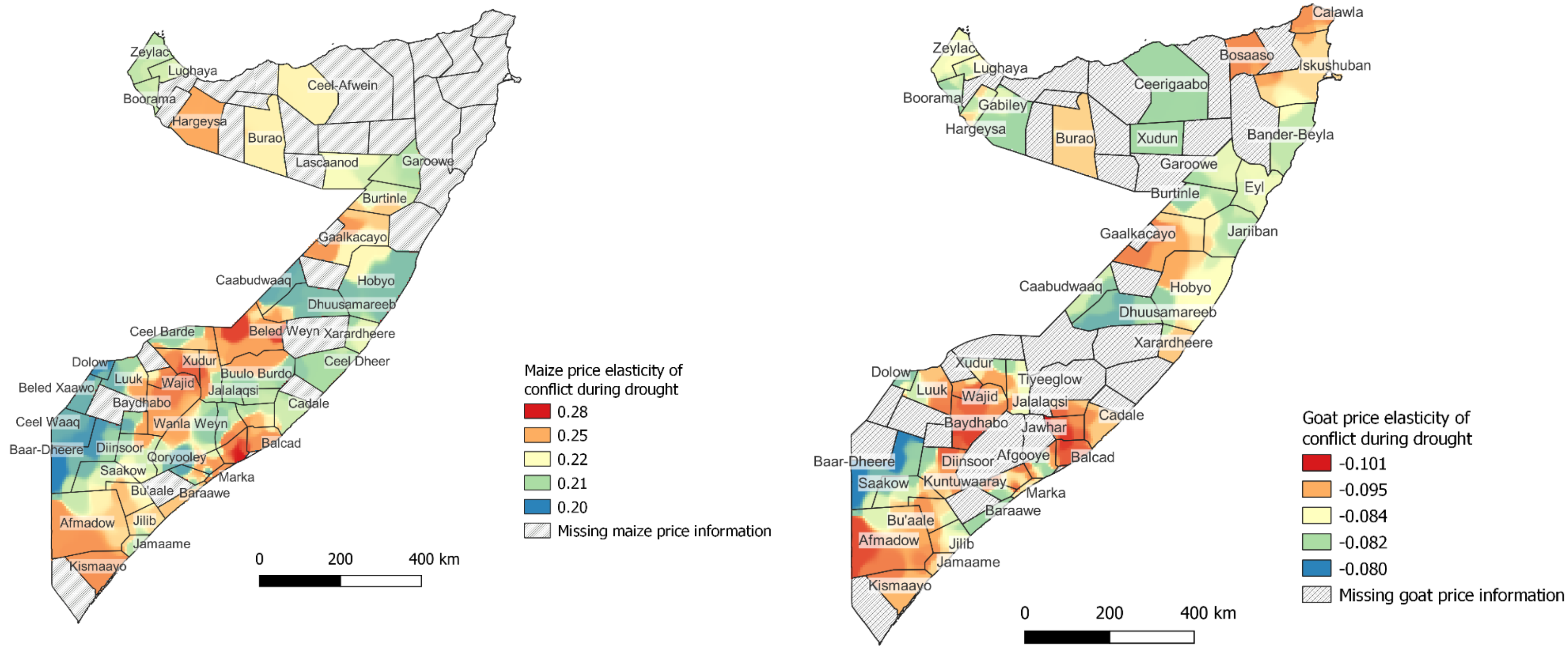
Dependent variable log of monthly conflict	*Independent Variables of Interest*	
	Maize price	Goat price
$\text{Drought} = 1(\text{SPEI} - 1.5)$	*2.11***(0.74)*	*1.16(1.01)*
Log(Price)	*-0.01(0.03)*	*-0.22***(0.04)*
$\text{Drought}\ (\text{SPEI} - 1.5) \times \text{Log(Price)}$	*0.23**(0.09)*	*-0.09(0.05)*
RMSE	0.44	1.50
Region fixed effect	Yes	Yes
Year Time trend	Yes	Yes
N. of Obs. (district-month)	2,593	2,607

*Notes: *** p<0.01, ** p<0.05, * p<0.1. Dependent variable is logged monthly conflict. Control variables includes the number of functioning water sources by district, results not reported. Exclude Mogadishu and districts without any agricultural price information. Drought is the dummy variable SPEI-3 (past three months) below negative 1.5 (moderate and severe drought). Robust standard errors in parenthesis. Model comparisons using likelihood ratio test support the choice of random coefficient model over fixed parameter model. The first fixed effect regression estimates the model with only district specific intercepts. The second fixed effect regression estimates the model with both the district level intercept, and the dummy of district interacting with price-drought interaction term. For the results from alternative random component specifications and variable selections, see Appendix A3.*

In the Appendix, we report alternative model specifications. First, the random coefficient model's performance is compared to that of the fixed effect estimator. Two alternative estimators were specified: a fixed effect estimator that included only the district-specific intercept but excluded the drought-price interaction; and a fixed effect estimator that included both the fixed intercept and the drought-price interaction, implying that each district has its own price elasticity of conflict during drought. Results reported in the appendix A3. In Table 4, we report the Root Mean Squared Error (RMSE) for each model. The random coefficient model outperforms the alternative with fixed effects. The RMSE of the maize prices model is improved by more than 70% when the random coefficient model is used instead of the fixed parameter model with or without district-specific effect, implying a significant improvement in model prediction precision when the random coefficient model is used. In the goat price model, this improvement is less pronounced but still positive (roughly a 2 percent reduction in RMSE using a random coefficient model rather than a fixed parameter estimator). Moreover, we also estimate the model without price and price-drought interaction. The effects are generally very small, further supporting our hypothesis that drought affects conflict mainly conditionally and indirectly.

[6] The coefficient is significantly different from zero only at 12%, i.e., the p value of the estimated coefficient is 0.12.

Figure 5 Estimated random coefficient by districts: maize price and number of conflicts



Notes: Left maps shows 43 districts with available maize price information. Colors based on results from the random component of the interaction between maize price and drought indicator. The corresponding fixed component estimate is significant at 5% level. Table 2 in the Appendix shows robustness check using alternative random coefficient specifications. Right map shows 44 districts with available maize price information. Colors based on results from the random component of the interaction between goat price and drought indicator (the corresponding fixed component estimate is not significant with p value 0.12). Both maps are plotted with smoothed surface using inverse distance weighting interpolation.

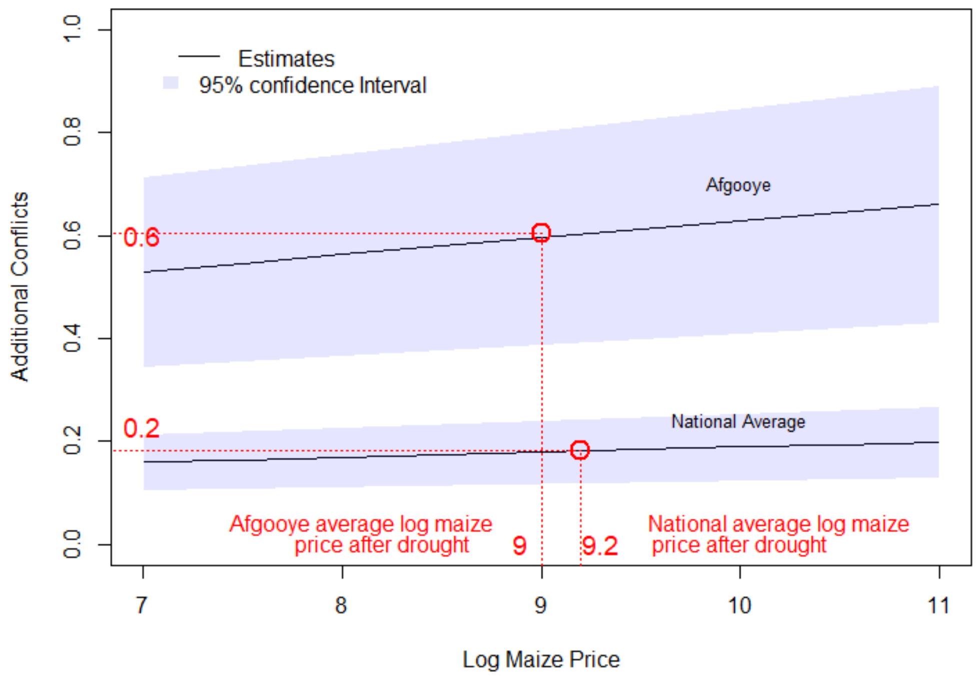
Since the model is estimated using a log-log specification, the coefficient of droughts-prices interaction can be interpreted as the frequency of conflict elasticity to changing prices when a drought occurs. The fixed component reported in Table 1 identifies the average elasticity, while the random component of the model depicts its spatial variation. The left map in Figure 5 graphically represents the district-specific elasticity estimated from random components with respect to the interaction term of drought and maize price. The right map shows the frequency of conflict. Both sets of results are presented on a smoothed surface using spatial inverse distance weighting interpolation to partially reflect the fact that such elasticity may display spatially clustering patterns that do not necessarily happen within administrative boundaries.

The findings show a moderate degree of regional heterogeneity; for a 1% increase in maize price during a drought, the estimated conflict growth ranges from 0.20% to 0.28% across districts. Districts with darker colors are more conflict-elastic due to maize price changes during a drought. The elasticity is greater in the Afgooye District (elasticity = 0.28), the Baydhabo District (elasticity = 0.26), and the Beled Weyn District (elasticity = 0.25). These are mainly agriculturalists' and agro-pastoralists' livelihood zones.

While the interaction between goat prices and drought is not significant in predicting conflict ($p = 0.12$), the signs are largely consistent with our expectation: during drought, a 1% decrease in goat prices is associated with an average 0.09 percent increase in conflict. Unlike agricultural prices, the correlation between conflict and goat prices during a drought is negative, as pasture and water shortages during a drought result in livestock deaths and decreased body mass, prompting pastoralists to de-herd animals, particularly those of low quality, causing the price to fall rather than increase. The right map in Figure 5 illustrates the results graphically. The goat price elasticity of conflict during drought is between -0.08 and -0.10 percent and is greater in the country's major pastoralist districts, including Burao in the north and Diinsor in the Bay region.

The estimated coefficients appear relatively small at first glance. For every 1% increase in maize prices, the conflict will grow by 0.23 percent. However, when expressed as an increase in the absolute number of conflicts, the magnitude implies a significantly higher frequency of conflict, given that the historical average price increase following a drought in Somalia is 18 percent. Additionally, the average price of corn in Somalia is reported to be approximately 10,000 Somalia shillings (9.2 after taking log). At this price level, the average total conflict following a drought is 0.2 per district per month but this figure can reach 0.6 in districts such as Afgooye. As an example, the average price increase following the drought in the Afgooye district is associated to a 5% increase in the number of conflicts relatively to historical monthly average in the area. Figure 6 depicts the total conflict at the district/month level in relation to various maize price levels.

Figure 6 Estimated total conflict related to price change after drought (District/month)

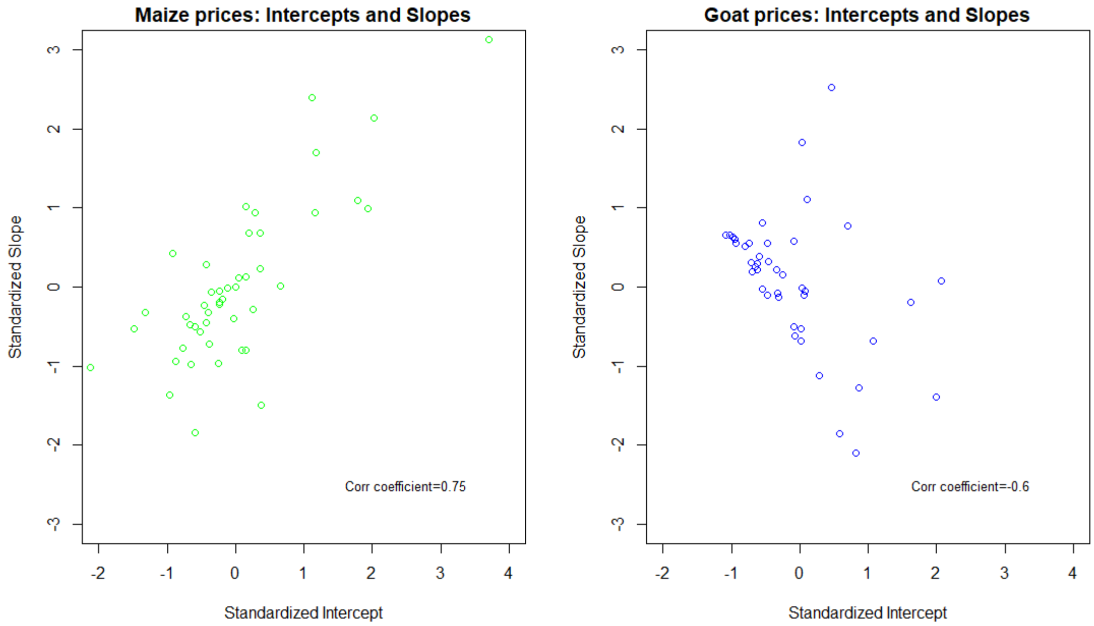


5.2 Climate insecurity hotspots and climate vulnerability hotspots

The correlations between the intercept and slope for maize (left panel) and goat prices (right panel) shown in Figure 7 point out that districts with higher intercepts tend to be more elastic to price changes during droughts.[7] Such a pattern, also called *fanning-out*, in our framework indicates that conflict-affected areas tend to be more sensitive to changes in the level of prices in the aftermath of a drought.

[7] To check the robustness of these results, we firstly run a pooled conditional autoregressive model to test if the conflicts variable is conditional independent on its own previous values. The results, summarized in Figure 10 in Appendix A, highlight that with the exception of the third lag, the conflicts variable does not follow a conditional autoregressive process. Subsequently, the robustness of the slopes/intercepts' correlation has been checked running the baseline model across all the possible combinations of drought index's accumulation periods (i.e., using SPEI index calculated over accumulation periods of 6 and 9 months) and conflicts' lead time (i.e., considering conflicts occurring three, six and nine months after the end point of the drought index's accumulation period). The detailed results shown in Appendix A2 generally confirm (whenever the model converges) the magnitude and the sign of the correlation estimated in the baseline model.

Figure 7 Estimated random coefficient by districts: maize price and goat price



Moreover, taking advantage of the regional variation in both the estimated price elasticity and the frequency of conflicts, we evaluate and distinguish each district's relative position along two axes: (1) the extent to which agricultural price changes exacerbate drought-induced violence in the district, i.e., the price elasticity (estimated random slope) of conflict during drought; and (2) the structural presence of violence in any given district (estimated intercept). Districts that rank at the top tail of both the distributions (i.e., are above the 75th percentile)[8] are referred to as "climate insecurity hotspots". These areas are more likely to experience conflict as a result of prices fluctuations in the aftermath of a drought and are also relatively more conflict-affected areas. Looking at the map, these hotspots tend to be clustered in moderately dry agro-pastoralist areas of the center-south between or along the two major rivers, with the exception of the Gaalkacyo district, which is located in the center-north.[9] In these areas, the agricultural production is solely or primarily reliant on direct rain for farming and poor and erratic rainfall may sharply curb harvests and pushed the prices of cereals and other staple foods to surge. Sharply rising prices may severely constraining food access for large numbers of households. Due to the high density of nomadic pastoralist communities in these districts, which are also along the main route of the migration of herders from different areas, extreme and

[8] As the average slope of the interaction between goat prices and drought is negative, we have conveniently multiplied the vector of the random slopes per -1 before the standardization to ease the interpretation.
[9] The hotspots are located in the Bakool, Bay, Hiran, Middle Shabelle and Lower Juba regions for the model estimated considering the elasticity to maize prices and in the Lower and Middle Shabelle regions for the model estimated considering the elasticity to maize prices. The Appendix B contains information about the selection process as well as the complete list of climate insecurity and vulnerability hotspots available at the Table 4.

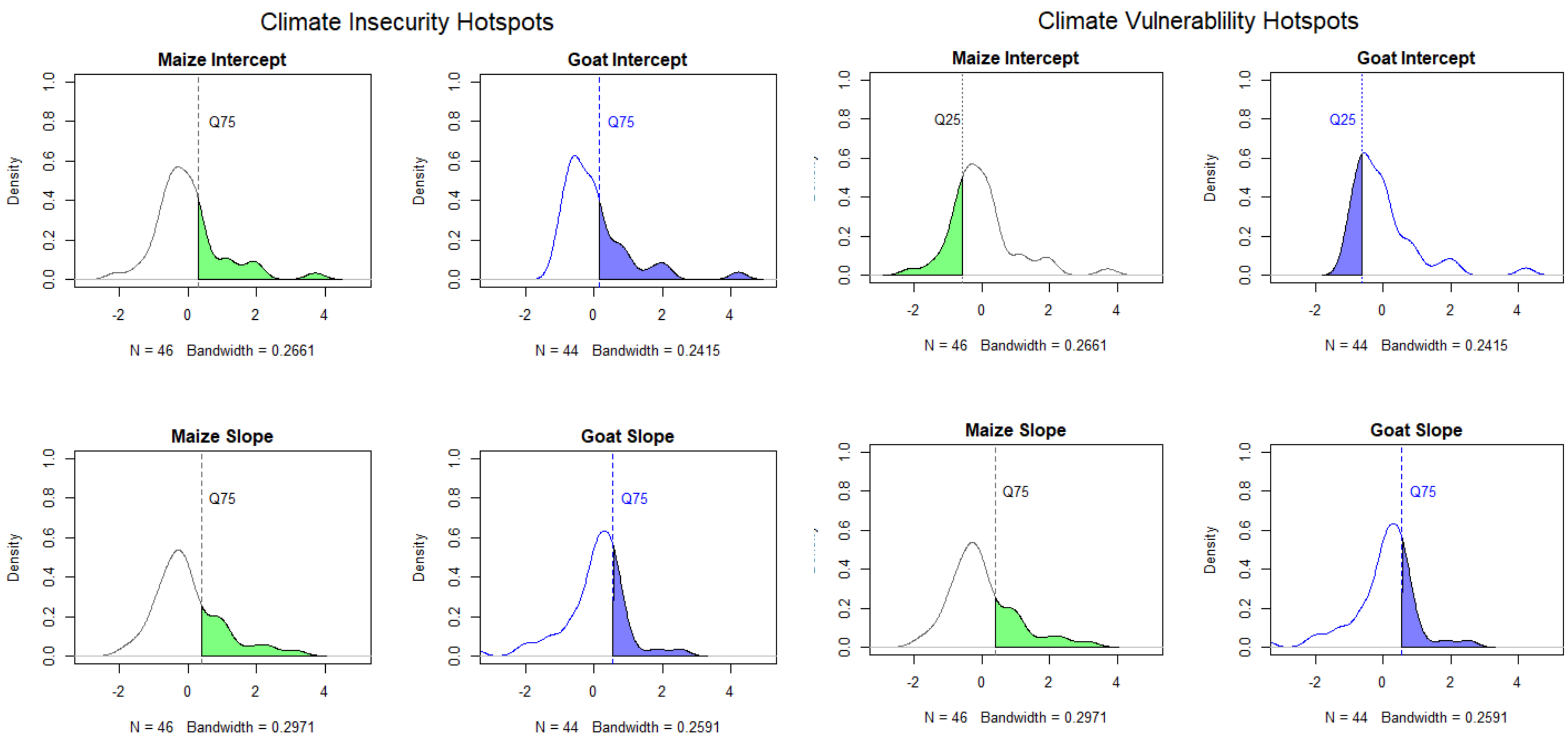
exceptional dry period pose a double threat. Indeed, the shortages of pasture and water may cause livestock deaths and reduced body mass, prompting herders to simultaneously sell their animals, which, in turn, determine the collapse of the livestock assets' price. In this context, the competition for the scarce resources between settled and nomadic pastoral communities as well as the devaluation of the main assets for the herders is likely to fuel tension and lower the opportunity cost joining armed conflicts. (McGuirk & Nunn, 2021)

These mechanisms are self-reinforcing over time and are embedded in a framework marked by significant administrative and ethnic fragmentation, which manifests itself in underdeveloped institutions and markets. Therefore, it is not surprisingly that these areas are also relatively more conflicted structurally. The case of Gaalkacyo district is emblematic as the territory has been historically divided between two administrations, Puntland and Galmudug, and the implementation of the federal system has triggered a resurgence of the conflict motivated by a struggle for land and resources. Similarly, in the southern district, Al Shabaab controls a sizable portion of the territory or its immediate surroundings, as well as the main roads connecting those districts. In the middle Shabelle region, the multi-clan composition adds another layer of complexity, involving a wider range of armed groups. From a policy perspective, these climate insecurity hotspots should be target for peacebuilding interventions aimed at tackling the structural causes of the violence as well as agricultural market, institutional and humanitarian supports to contain the food insecurity in the aftermath of a drought. Improved market education for local farmers, food security through humanitarian interventions, food price subsidies, and crop insurance can also contribute to enhanced resilience (Breisinger, Ecker, Maystadt, & Trinh, 2014).

In addition to the identification of the hotspot for climate insecurity, it is possible to use the random intercepts and slopes distribution to identify hotspot for climate vulnerability i.e., areas which are relatively less affected by conflict but may evolve in future of hotspot of climate–induced violence given their high conflict-sensitivity to the changing prices in the aftermath of extreme and exceptional dry episodes.

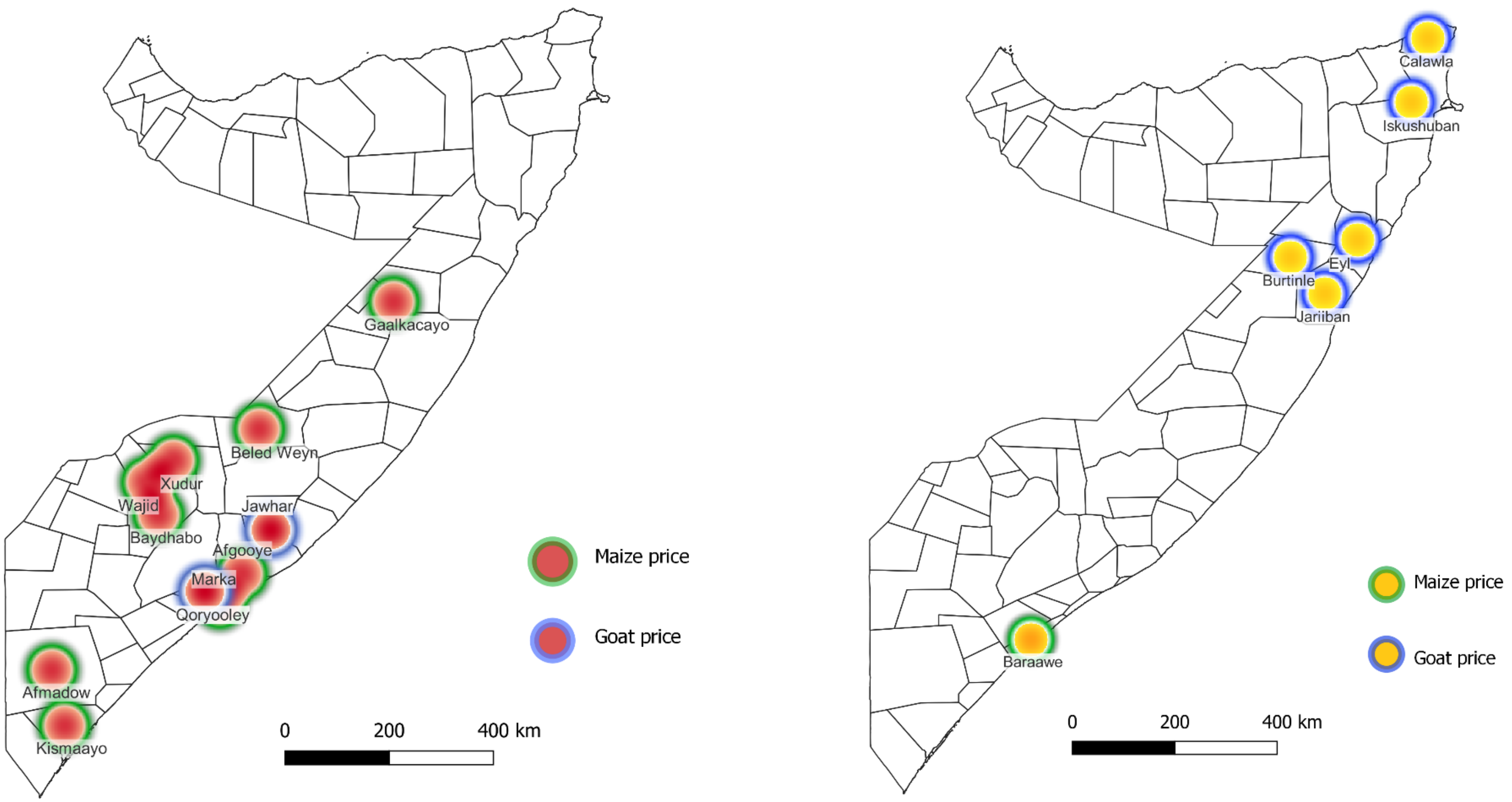
In particular, districts that rank at the top tail of the slope's distribution (i.e., above the 75th percentile) but at the bottom tail of the intercept's distribution (i.e., below the 25th percentile) are identified as climate vulnerability hotspots. These districts are mainly located in the Puntland neutral semiautonomous territories of the north with the exclusion of the Baraawe district located. In the Lower Shabelle region along the coast in south Somalia, which is the most productive irrigated agricultural zone, of Somalia serving as the 'bread-basket' of the country. For various reasons, these areas are less affected by conflict at the time of writing this paper. For example, Baraawe is administered by the national Somali government, although Al-Shabaab has maintained an active network throughout the region and despite offensives to push it out of main towns continues to launch attacks, control roadblocks, and tax local populations. It exploits local tensions and grievances to forge tactical alliances with clans against rivals. In the district in in the north of Puntland there is also an increasing presence of both militias aligned with the Islamic State and Al-Shabaab. These growing threats are adding uncertainty to the already precarious situation in the area given the long-lasting conflicts between Puntland and Somaliland over disputed territories. Although as we are writing the relationships between these two administrative entities are stable, the competing claims have been not settled and may fuel new conflicts should the competition for the resource increase as a consequence of more frequent droughts. The climate vulnerability hotspot should be the targeted for preventive actions to reduce the adverse impact of these extreme dry episodes as, for example, the construction of infrastructures and the implementation of improved water management strategies (European Asylum Support Office, 2021).

Figure 8 Illustration of hotspot selection



Notes: Visual illustration of selecting climate insecurity hotspots (left panel) and climate vulnerability hotspots (right panel) based on estimated conflict frequency elasticity of maize and goat prices during drought (slope) and mean conditional conflict (intercepts). Left panel: climate insecurity hotspots are districts that are above the 75% quantile for both dimensions, respectively. Right panel: climate vulnerability hot spots are districts above the 75% quantile for slope and below the 25% quantile for intercept, respectively.

Figure 9 Climate Insecurity Hotspots (Left) and Climate Vulnerability Hotspots



Notes: Location of selected climate insecurity hotspots (left map) and climate vulnerability hotspots (right map) based on estimated conflict frequency elasticity of maize and goat prices during drought (slope) and mean conditional conflict (intercepts). Left map: climate insecurity hotspots for maize (green border) and goat (blue border), respectively. Right map: climate vulnerability hotspots for maize (green border) and goat (blue border), respectively. Baydhabo district and Afmadow appear both in maize and goat hotspots, for illustration purpose we only show them on the maize hotspots

5.3 Caveats and limitations

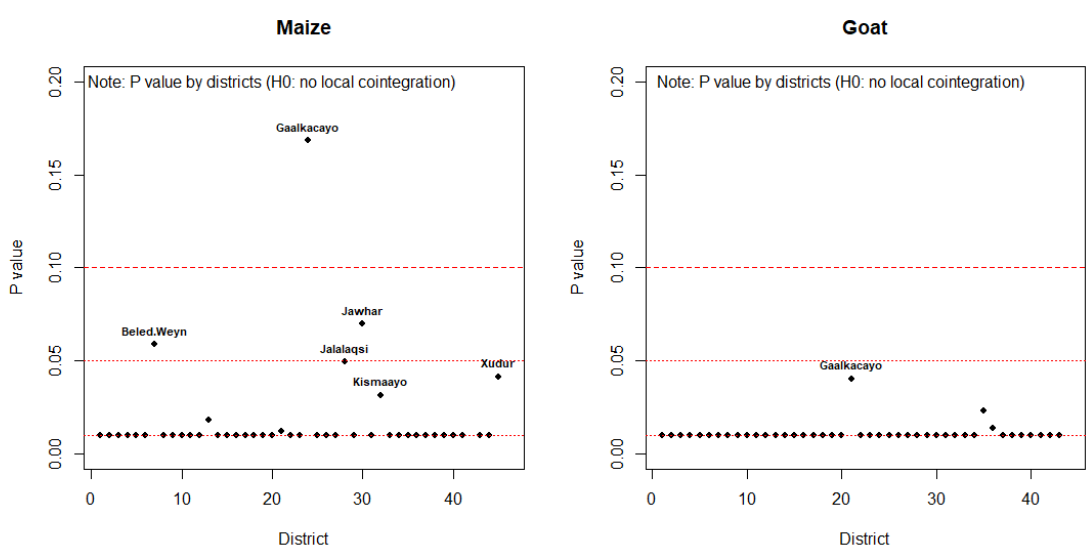
This article's empirical strategy is founded on careful econometric and contextual considerations. While it is appropriate for our research questions, it may have the following limitations, which suggest directions for future research. To begin, data constraints make it difficult to draw broad conclusions about the entire Somalia. Prices for maize are available only in 43 of 73 districts. Prices for goats are available only in 44 of 73 districts. Additional price data with a broader spatial scope would enable a more comprehensive characterization of the relationship between conflict profile and drought across the country. Additionally, the random component of the estimated model is a distribution that allows for discrete parameter variation around the mean. Given that Somalia has two levels of administrative division, region and district, with district being the more disaggregated unit, assuming discrete geographic heterogeneity such that conflict-drought dynamics remain fairly consistent within each district may be an appropriate empirical strategy. Yet it is also reasonable to expect that conflict's spatial variations and price elasticity can be continuous across the landscape. If more disaggregated data were available, this relationship could be estimated and visualized more granularly from location to location.

Second, while the agricultural commodity market is a well-established channel for shaping climate-conflict relationships, it is just one of several possible channels. Food insecurity, for example, is another possible moderator of droughts- conflicts relationship, as a poor harvest has been linked to more severe civil unrest. Due to the fact that the estimated effect is a reduced-form relationship, we emphasize that our estimate represents a mediation effect of price on drought-conflict relations under certain plausible assumptions. Moreover, while the random coefficient model captures regional variation, it does not explain why some areas exhibit high price elasticity of conflict while others do not, necessitating additional case studies in conjunction with qualitative evidence to elucidate the structural reasons for why some areas are more prone to conflict and sensitive to price changes.

Finally, while the random coefficient model takes spatial heterogeneity into account, the literature indicates that conflict and the effect of drought may exhibit spatial dependence through trans-border spillover. For instance, a drought in one district may exacerbate conflict in neighboring districts via displacement or transhumant pastoralist-farmer conflicts (McGuirk & Nunn, 2020). The geographical representation also suggests that the hot spots are spatially adjacent, implying the formation of spatial clusters as a result of the local transmission effect, which would violate the standard *i.i.d* assumption used in any non-spatial models. Furthermore, a previous study discovered a degree of spatial integration among cereal markets throughout the country, possibly as a result of informal institutions that can bridge divides caused by conflict, distance, and internal political fragmentation. Indeed, our data indicate some evidence of local price convergence for both maize and goat. To begin, we define neighbor based on first order queen contiguity. The Moran's I spatial correlation coefficients for maize and goat prices are 0.1 and 0.7, respectively, are both statistically significant at the 1% level, indicating that higher staple crop (primary livestock) prices tend to cluster. Second, spatial price cointegration is examined at the district level. For each district, the time series of maize (goat) prices is compared to the time series of the surrounding districts' average to obtain the spatial autocorrelation residuals, and Engel-Granger test should reject the null hypothesis of non-stationarity if spatial cointegration exists. The resulting p values are depicted in Figure 10. The majority of districts exhibit significant spatial cointegration (with the exception of Gaalkacayo District in terms of maize price), particularly in terms of goat prices. This suggest that spatial dependence in price dynamics may operate through market integration.

One question is whether we need to account for spatial process explicitly in this analysis. In the case of spatial correlation in the level of price the assumption underlying random coefficient model is not violated. Even with spatially correlated cointegration process, the unbiasedness and consistency properties of non-spatial random coefficient estimator are unaltered (Anselin, 1988). Hence the standard non-spatial random coefficients approach leads to proper estimation of the marginal effect, and we do not require spatially explicit reparameterization of Equation 1. In addition, due to the gaps in prices on both the spatial and temporal dimensions, all missing values are imputed using national average, which may result in an overestimation of the true agglomeration. Future research would benefit from more detailed and balanced price data. Nonetheless, defining spatial dependence through spillover and market integration may improve the efficiency of estimation, and aid in the comprehension of drought-conflict relationships, particularly those involving markets channels.

Figure 10 Local Spatial Cointegration Test: Maize and Goat Prices



Given these constraints, this study cannot provide a comprehensive picture of the dynamics of prices, droughts, and conflicts in Somalia. Additional research would benefit from more complete market data and granular conflict patterns, as well as information on factors such as intrastate forced displacement flows that could exacerbate armed conflict across regions. A finer-grained analysis might also explore alternate drought measurement, a wider range of conflict windows, and a more detailed examination of local level agricultural commodity retail prices. Estimating this relationship structurally in a random coefficient model environment will also provide additional insight into the causal relationship between droughts and conflicts.

6 Conclusion and policy implications

Although research on the climate change-conflict nexus aims to understand whether and how climate shock has differential effects on armed conflict, most empirical research estimates the average effects of these impacts across regions, either through direct or thought channels such as market price. This paper investigates district heterogeneity in the moderator role of prices on the droughts-conflicts relationship using a random coefficients estimator as an appealing reduced form empirical methodology. The results show that increased prices for maize (goats) exacerbate the effect of droughts on conflict frequency. We also found evidence for heterogeneous price elasticity due to conflict intensity during the drought, especially for maize prices. These findings add crucial details to the literature concerning the role of droughts and commodity prices insecurity in conflict-affected states.

The results showcase the potential use of the random coefficient model to test and perform exploratory and definitive analyses of district level climate security responses. Using a random coefficient estimator to model the droughts-conflicts relationship allows to: (a) testing districts' heterogeneity (through the structure of the variance-covariance matrix); (b) predicting district-specific effects (instead of the national average); and (c) generating a strategy for the selection of targeting areas for climate resilience and peacebuilding efforts. The approach followed for this analysis allows us to uncover the spatially stratified effects underlying the average empirical association. It also makes more accurate inferences about how different regions are, which was not done in previous studies.

Based on the results, two types of hotspots are selected: (1) climate insecurity hotspots that are conflict-affected and price-elastic, and (2) climate vulnerability hotspots that are less conflict-affected but highly price-elastic. The selection of climate vulnerability hotspots foreshadows a possibility in which regions that are currently not sites for chronic conflict may be potentially redefined as climate-insecure hotspots in the future. Aid agencies should therefore reorient and expand their existing interventions to assist these climate-vulnerable districts to prevent that the adverse effects of climate change may turn these areas in future hotspot of climate insecurity.

From a policy perspective, the evidence produced aims to inform the design of more district-specific and targeted approaches that have a higher potential for being successful in mitigating drought-induced conflict and peacebuilding efforts in Somalia. For example, market-supporting policies should be primarily targeted at areas that are sensitive to changes in prices. Through better market information dissemination, price subsidy, and awareness training on market mechanisms, deherding can be avoided. In a context where the resources for the interventions are limited, identifying areas (hotspots) with higher insecurity informs a more localized intervention. Moreover, early warning systems may pay greater attention to the level of food prices and target food price stabilization efforts in conflict-vulnerable districts (Minot, 2014).

Although the context is Somalia, the method and insights from this paper can be generalized to other contexts. First, similar to Somalia, many conflict-devasted countries also face a comparable situation of the joint impact of domestic conflict and climatic shocks, and the most vulnerable districts tend to be the pastoral and agro-pastoral communities. Examples include Syria (Mathbout, Lopez-Bustins, & Martin-Vide, 2018), Ethiopia (Belay, Beyene, & Manig, 2005), and other SSA countries (von Uexkull, 2014), and the context of our paper can be extended to these countries. Second, the use of models that capture spatial heterogeneity is of particular relevance to these countries because the resources and support tend to be limited. Therefore, the inferences drawn from the average impact might not be as relevant because they do not infer where the resources should be targeted. Finally, each district in Somalia is highly distinctive, and many characteristics are unobservable, such as political dynamics and the presence of military forces. This is also the case in many conflict-intense countries, where different regions have very different political as well as economic characteristics. Assuming homogeneity and the constant impact of different drivers are particularly restrictive in detecting the richer version of a diverse response to the drought.

Since conflicts are rarely, if ever, attributable to single causes, conflict analysis and concomitant efforts to reduce the risks of conflict must consider a multitude of complex relationships and contributing factors. This study does not aim to offer a structural picture of the drought-conflict nexus. It does not claim to estimate the causal impact of shocks (droughts) on conflicts or to explain the complex interlinked factors explaining such an empirical relationship. Rather, the analysis aims to provide quantitative evidence to highlight that the empirical relationship between climate shocks and conflicts is shaped by spatial heterogeneities and moderate by other factors, such as prices. Notwithstanding, our methodology and findings may be relevant in a wide range of contexts, bearing in mind that each conflict is different and has its own distinctive, idiosyncratic triggers that may or may not be related to climate shocks.

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Appendix A: Robustness checks

A1 Random coefficient specifications

Table 2 Robustness check using different random coefficient specifications

Maize price	Model 1		Model 2		Model 3		Model 4		Model 5	
	RCM	*Coef.*	*RCM*	*Coef.*	*RCM*	*Coef.*	*RCM*	*Coef.*	*RCM*	*Coef.*
$Drought$	YES	2.12***	NO	1.95***	NO	2.11***	YES	2.09***	YES	2.07***
$Log(Price)$	NO	0.01	YES	0.05	NO	0.01	YES	0.04	NO	0.04
$Drought \times Log(Price)$	NO	0.23**	NO	0.22**	YES	0.23**	NO	0.23**	YES	0.23**
$RMSE$	0.454		0.451		0.444		0.435		0.440	
AIC	3292		3292		3291		3280		3278	

Goat price	Model 1		Model 2		Model 3		Model 4		Model 5	
	RCM	*Coef.*	*RCM*	*Coef.*	*RCM*	*Coef.*	*RCM*	*Coef.*	*RCM*	*Coef.*
$Drought$	YES	0.80	NO	1.84*	NO	0.81	YES	0.82	YES	1.43
$Log(Price)$	NO	-0.23**	YES	-0.08	NO	-0.23***	YES	-0.11	NO	-0.12
$Drought \times Log(Price)$	NO	-0.06	NO	-0.13**	YES	-0.06	NO	-0.12	YES	-0.10
$RMSE$	0.452		0.445		0.431		0.439		0.438	
AIC	3514		3411		3514		3407		3412	

Notes: Comparison of random coefficients model with random coefficients specification of different variables. Other alternative models dropped due to unconference.

A2 Different SPEI accumulation period and forward-period conflict

It is possible that there might be delayed effect of drought on conflict, either directly or mediated by price. Figure 10 shows the time series analysis of conflict. The number of conflict has small serial correlation after three periods. Table 3 provides the results of estimated correlation coefficient of slopes and intercepts using the combinations of different SPEI accumulation periods and different forward conflicts. We find robust evidence that most correlation coefficients are significantly different from zero, similarly as revealed in the preferred model in Table 1.

Figure 10 Time series analysis of conflict

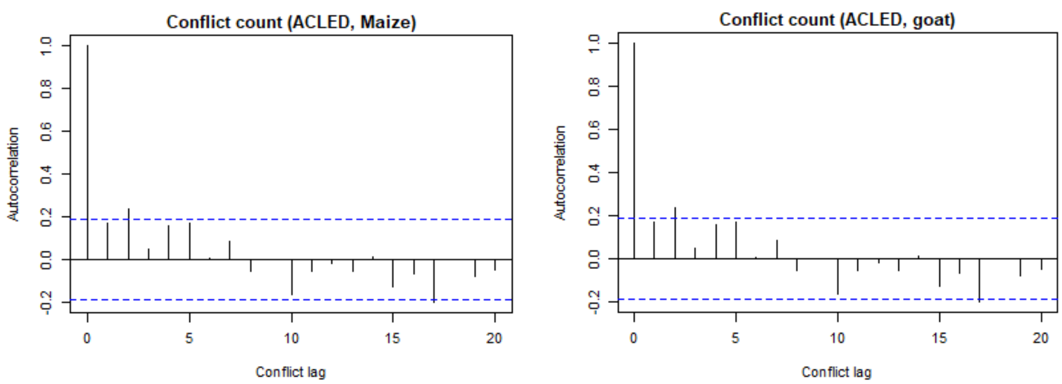

Table 3 Correlation coefficient between slope and intercept: maize price

			Forward conflict			
			0	*3*	*6*	*9*
		3	0.75***	*n.a.*	0.61***	*n.a.*
Maize	***SPEI accumulation period***	*6*	0.55	0.60***	0.74***	n.a.
		9	0.60***	0.58***	*n.a.*	0.34***
		3	-0.60**	*n.a.*	-0.63***	-0.74***
Goat	***SPEI accumulation period***	*6*	-0.19***	*n.a.*	*n.a.*	*n.a.*
		9	-0.72	-0.54***	-0.31***	-0.15

Notes: Correlation coefficients of intercept and slopes. n.a. is reported whenever the model did not converge.

A3 Results with and without fixed effect

Table 4 Correlation coefficient between slope and intercept: maize price

Dependent variable log of monthly conflict	*Independent Variables of Interest*	
	Maize price	Goat price
$\mathbf{Drought} = \mathbf{1}(\mathbf{SPEI} - \mathbf{1.5})$		
FE without district dummy × drought ×price	*0.07*(0.04)*	*-0.05(0.04)*
FE with district dummy × drought ×price	*0.03(0.07)*	*0.31(0.19)*
$\mathbf{Log}(\mathbf{Price})$		
FE without district dummy × drought ×price	-0.01(0.04)	-0.19***(0.04)
FE with district dummy × drought ×price	*0.01(0.03)*	*-0.20**(0.04)*
$\mathbf{Drought}\ (\mathbf{SPEI} - \mathbf{1.5}) \times \mathbf{Log}(\mathbf{Price})$		
FE without district dummy × drought ×price	*0.001(0.003)*	-0.003(0.003)
FE with district dummy × drought ×price	0.001(0.004)	*-0.003(0.002)*
RMSE		
FE without district dummy × drought ×price	1.53	1.53
FE with district dummy × drought ×price	1.54	1.53
N. of Obs. (district-month)	2,593	2,607

Table 5 Correlation coefficient between slope and intercept: maize price

Dependent variable log of monthly conflict	*Independent Variables of Interest*	
	Maize price	Goat price
$\text{Drought} = 1(\text{SPEI} - 1.5)$	*2.03***(0.69)*	*0.80(1.01)*
Log(Price)	*0.008(0.03)*	*-0.23***(0.04)*
$\text{Drought (SPEI} - 1.5) \times \text{Log(Price)}$	*0.22**(0.07)*	*-0.06(0.04)*
Region fixed effect	No	No
Year Time trend	No	No

Appendix B: selection of the hotspots

The selection of hotspots is based on the relative position of each district's conditional mean conflict (i.e., the estimated intercept) and marginal effect of drought-price interaction on conflict (i.e., the estimated slope). For easier comparison, in the first step, both the intercepts and the slope are standardized by subtracting the mean and divided by standard deviation, for maize and goat prices separately. In step 2**,** find the critical values based on quantiles of slopes and intercepts. A district is climate insecurity hotspots if both the standardized slope and standardized intercepts are at 75% quantile among all the districts. A district is climate vulnerability hotspots if the standardized intercepts are at 75% quantile and the standardized slope are below the 25% quantile among all the districts. Table 6 summarizes the selected districts.

Table 6 Climate insecurity and climate vulnerability hotspots

Moderator	**Hotspots**	**Districts**	**Standardized Slope**	**Standardized Intercept**
MAIZE PRICE	Climate insecurity hotspot	*Afgooye*	3.13	3.70
		Beled Weyn	2.39	1.11
		Baydhabo	2.14	2.02
		Xudur	1.70	1.17
		Kismaayo	1.09	1.78
		Marka	0.99	1.93
		Afmadow	0.94	0.29
		Gaalkacayo	0.94	1.17
		Wajid	0.69	0.36
	Climate vulnerability hotspots	*Baraawe*	0.43	-0.93
GOAT PRICE	Climate insecurity hotspot	*Qoryooley*	2.52	0.47
		Jawhar	0.77	0.70
	Climate vulnerability hotspots	*Iskushuban*	0.55	-0.75
		Eyl	0.61	-0.95
		Jariiban	0.63	-0.97
		Burtinle	0.65	-1.08
		Calawla	0.66	-1.02