



Exploring the temporal patterns and crisis-related risk factors for population displacement in Somalia (2016-2018)

Aidan Yuen^{a,b,*}, Abdihamid Warsame^a, Francesco Checchi^a

^a London School of Hygiene and Tropical Medicine, London, England, United Kingdom

^b Australian National University, Canberra, Australian Capital Territory, Australia



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ABSTRACT

Introduction: Over the past 30 years, south-central Somalia, Puntland (north-east) and Somaliland (north-west) have experienced recurring drought- and conflict-related crises. By the end of 2018, the number of internally displaced persons (IDPs) in the region had reached 2.6 million; most were displaced to larger towns under government control, where humanitarian assistance was more accessible. Understanding the drivers of crisis-related displacement can provide insight into how responses can best manage and respond to displacement to prevent downstream morbidity and mortality. We aimed to explore the temporal patterns and crisis-related risk factors for population displacement in Somalia from 2016 to 2018, a period of severe drought.

Methods: We conducted an ecological study of secondary panel data stratified by district and month. The study population included all people in the region from 2016 to 2018. The outcome was defined as the number of new out-migrating internally displaced persons (IDPs) per district-month. Exposure variables included armed conflict, rainfall, food insecurity and food security services. Lags at one, two and three months were generated to explore possible delayed effects. All univariate and multivariate analyses were conducted using negative binomial regression models with mixed effects incorporating the district as a random effect.

Results: From 2016 to 2018, the proportion of IDPs increased from 9% to 25% in Somalia, Puntland and Somaliland. We observed strong associations between IDP out-migration rate and failed rains at a three-month lag, food insecurity at a one-month lag, and the presence of therapeutic food services with no lag. IDP out-migration rate was not associated with armed conflict intensity, and cash- and rations-based food security services.

Discussion: This study identified temporal, and socially and biologically plausible associations between key crisis-related risk factors and displacement in Somalia. The findings suggest a sequence of events spanning a few months, where failed rains and consequent food insecurity likely prompted early population out-migration to larger urban centers where humanitarian services were more accessible. The presence of therapeutics-based food security services could represent a more general correlate of crisis severity and the decision to migrate.

Introduction

Over the past 30 years, south-central Somalia, Puntland (north-east) and Somaliland (north-west) – herein collectively referred to as Somalia – have experienced several drought- and conflict-related crises. In 2010 and 2012, failed rains and limited humanitarian assistance resulted in a famine across south-central Somalia, responsible for an estimated 256,000 deaths, half of whom were children younger than five years (Checchi and Robinson, 2013).

Intensified humanitarian assistance and moderate rainfall led to improvements in the two years following the 2010–2012 famine. By the end of 2014, however, acute emergency conditions had returned to parts of Somalia because of below-average rainfall, while renewed insecurity

hampered humanitarian relief (Food Security and Nutrition Analysis Unit - Somalia, Famine Early Warning Systems Network, 2014). Emergency conditions were further exacerbated throughout 2015 and 2016, which saw a combination of failed rains and exceptional flooding, and the unplanned return of Somalis from Kenyan refugee camps and Yemen (Food Security and Nutrition Analysis Unit - Somalia, 2016).

In 2016, Puntland and Somaliland observed below-average seasonal rains, which prompted both governments to declare states of emergency. From September to December, most regions of Somalia also experienced below-average rainfall, damaging key harvests and livestock viability (United Nations Office for the Coordination of Humanitarian Affairs, 2017). By the end of 2018, the number of internally displaced persons (IDPs) had reached 2.6 million; most were displaced to larger

* Corresponding author at: aidan.yuen@anu.edu.au
E-mail address: aidan.yuen@anu.edu.au (A. Yuen).

towns under government control, where humanitarian assistance was more accessible (Checchi and Robinson, 2013).

During such crises, various humanitarian interventions are deployed to mitigate food insecurity and acute malnutrition. Broadly, these consist of population-wide, or more targeted, cash-, food- and therapeutic-based humanitarian interventions. Targeted services can be directed at either the household- or individual-level and are often offered concurrently. For example, vulnerable households may receive monthly cash transfers, while at-risk individuals, such as young children and pregnant and lactating women with severe or moderate acute malnutrition, may receive additional supplementary therapeutic feeding services to avert further nutritional loss and promote early recovery. These therapeutic services are generally associated with Community Management of Acute Malnutrition programmes, including inpatient and outpatient case management (Doocy et al., 2020).

Of note, the Grand Bargain agreement at the 2016 World Humanitarian Summit recommended the use of cash transfers over food rations as the former are more effective, efficient and acceptable to beneficiaries, and empower local markets (Doocy et al., 2020). If cash-based services prove ineffective, food rations can be provided, but are often unsustainable and disrupt local economies (Bounie et al., 2020).

Despite these measures, excess mortality was still observed in Somalia. Between 2014 and 2018, the estimated crude death rate across Somalia ranged from 0.3 to 0.5 per 10,000 person-days, which increased by about 15% during 2017–2018. The excess death toll was estimated to be 44,700. Analyses suggested that food insecurity was relatively mild in the 2017–2018 crisis compared to past crises, and that it was not a key driver of mortality (Warsame et al., 2020), though in rainfall terms, the drought triggering this crisis was comparable to that preceding the 2010–2012 famine (Shukla et al., 2021).

Little is known about the relative importance of different drivers of displacement from 2016 to 2018 (Warsame et al., 2020). Understanding these drivers can provide insight into how responses can best manage and respond to displacement to prevent downstream morbidity and mortality. This study explored the temporal patterns and crisis-related risk factors for population displacement in Somalia from 2016 to 2018.

Methods

Study type, population, and period

The study involved an ecological study of secondary panel time series data of the outcome, exposures and potential confounders stratified by district and month, herein referred to as district-months. The source data can be accessed at: https://github.com/francescochecchi/mortality_small_area_estimation. The study population included all people in Somalia – which for this analysis included Somaliland in the north-east and Puntland in the north-west – during the study period from January 2016 to December 2018. In this study, Somalia was comprised of 18 regions, which were further sub-divided into 74 districts.

Outcome variable

The outcome was defined as the number of new out-migrating internally displaced persons (IDPs) per district-month. This also included IDPs who were displaced to another city or town within the same district; this was calculated using the rate of IDPs leaving, which was retrieved from an earlier project (Checchi et al., 2020). These rates were based on data provided by the United Nations High Commissioner for Refugees (UNHCR)-led Protection and Return Monitoring Network, which tracks reported displacement and returnee movements among districts, with monthly data available from January 2016 to December 2018. The calculations were supplemented by situation reports on the Humanitarian Relief Web information platform (www.reliefweb.int)

and on the UNHCR website (www.unhcr.org) to approximate refugee (i.e. international) in-flows and out-flows. Displacement flows were then layered over base population estimates to calculate the rates of population displacement.

Base population estimates

In the cited mortality estimation project (Checchi et al., 2020), the authors reconstructed the population of Somalia per distinct-month by combining the above IDP movement data with UNHCR-reported refugee in- and out-flows, assumed natural growth rates of 2.1% per annum, and four alternative baseline datasets of population per district: (i) the March 2014 Population Estimation Survey (UNPESS), carried out by the United Nations Population Fund, and based on a stratified sample of clusters within urban, rural, IDP and nomadic communities; (ii) January 2015 estimates from Afripop, which uses a validated statistical model to estimate population density by 100m² based on remote sensing; (iii) December 2018 data from the Polio Eradication Initiative, which in Somalia updates target vaccination population denominators through active enumeration; and (iv) January 2019 Expanded Programme on Immunization data, adjusted based on vaccination campaign performance data. To synthesise the four alternative sets of reconstructed denominators into one, the authors scored the quality of each of the four sources using criteria proposed by Abdelmagid and Checchi (2018), and computed a single weighted average population denominator for each district-month, using the above quality scores as weights.

In this report, we used the above reconstructed, quality-weighted population denominators as the basis for which to compute rates per population for any variables (e.g. displacement) that should be analyzed per-population, as opposed to absolute values.

Exposure variables

To identify potential exposure variables, an *a priori* conceptual framework was constructed based on the causal pathways responsible for population displacement (Victora et al., 1997). Risk factors that directly lead to population displacement were considered proximal, while those that passed through intermediate variables were considered distal. In subsequent model fitting, the selection of exposures and potential confounders was based on this framework (Fig. 1). Exposures identified in the conceptual framework included armed conflict, failed rains, food insecurity and food security services; proxy variables were used to approximate these factors in all analyses.

Armed conflict was proxied by both the rate of insecurity events and the rate of deaths caused by such events per 100,000 population per district-month. The data were derived from the Armed Conflict Location & Event Data (ACLED) project, which is a global database of individual armed conflict events, such as battles, airstrikes, terrorist attacks, instances of civil unrest, etc. The ACLED project is available worldwide, and record incidents based on media channels and civilian informants (Raleigh et al., 2010).

Rainfall levels were represented by the standard precipitation index (SPI), which provides a measure of rainfall levels compared to past trends (Huntington et al., 2017). In this study, SPI measured the number of standard deviations from the 10-year mean precipitation levels across districts of Somalia for each month (Checchi et al., 2020). Meteorological drought is formally defined as SPI decreases below -1.0 , while excess rainfall is defined as SPI increases above 1.0 (Wichitarapongsakun et al., 2016).

Food insecurity was measured using two proxy variables involving the terms of trade. These two indices measured the Kcal equivalent of local cereals that an average daily wage and a local-quality goat can be exchanged for in the markets, as a measure of purchasing power, and in turn food security, per district-month. Market staple prices for each

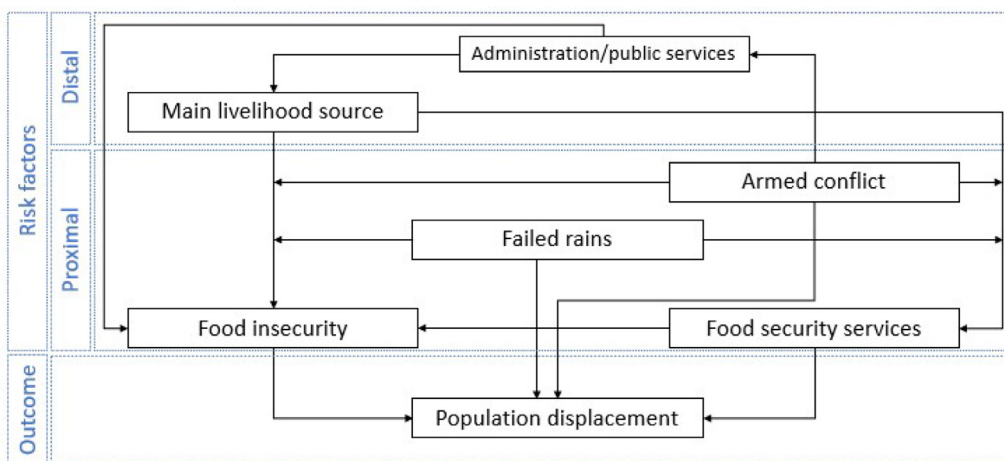


Fig. 1. Conceptual framework of the risk factors predictive of population displacement in Somalia from January 2016 to December 2018. Only variables available for analysis and causal links deemed relevant for model specification were included.

district-month were derived from the Food Security and Nutrition Analysis Unit (FSNAU) (Food Security and Nutrition Analysis Unit - Somalia, 2019). District-months with missing values were given a weighted sum of values from districts across the country; nearby districts were given a higher weight. Outliers were corrected or deleted by observing distributions and time series, and spline smoothing was applied to reduce data jaggedness.

Food security services were measured as the proportion of the population who were beneficiaries of cash-, rations- and therapeutics-based humanitarian interventions per district-month. This unpublished information was shared by the United Nations World Food Programme.

The effect of climactic and non-climactic risk factors on population displacement may not manifest immediately; therefore, lags of one, two and three months were generated to explore possible delayed effects. Lags can also help establish temporality for causal inference.

Statistical analysis

All univariate and multivariate analyses were conducted using generalized linear mixed models. Negative binomial regressions were used given the high overdispersion of the outcome variable, i.e. the count of departing IDPs. The natural log of the district population was included as an offset.

Mixed models were used; these involve a combination of fixed and random effects. The risk factors of interest (e.g. failed rains) were assumed to have a fixed effect on displacement, i.e. a similar magnitude of association across all district-months. However, given the hierarchical structure of the data, with repeated observations clustered within districts, the causal process behind displacement, including unobserved factors, was likely unique to each district. This was addressed by including the district as a random effect.

For the univariate analyses, each exposure variable was assessed in separate models using the most plausible lag. Failed rains were assessed using a three-month lag, given the delayed impact of the climate on livelihoods, food security and subsequent population displacement. Armed conflict, food insecurity and cash- and rations-based food security services were analyzed using a one-month lag, given the immediacy of these risk factors on population displacement. Only therapeutics-based food security services were analyzed without a lag, as these interventions are largely reactive to crises to address acute malnutrition, and as such, are likely to occur concurrently, or even after, population displacement has occurred.

Crude rates, rate ratios and 95% confidence intervals were calculated, and tests for departure from linearity were conducted where appropriate. Likelihood ratio tests were used for hypothesis testing.

For the multivariate analyses, no *a priori* confounders were identified for the proxy variables for armed conflict and failed rains – as such, these were only analyzed using univariate models. In contrast, the multivariate models for the proxy variables for food insecurity were adjusted for armed conflict, failed rains and food security services. Similarly, the proxy variables for food security services were adjusted for district livelihoods, armed conflict and failed rains.

These multivariate models were constructed using the forward approach. The models were initially fitted with the outcome and the exposure variables with the most plausible lag. *A priori* confounders were then introduced into the model according to their position in the conceptual framework – distal variables were introduced first, followed by proximal variables. Covariates that changed the rate ratios by more than 10% were deemed significant confounders. Covariates that changed the standard errors of the log rates of the exposure by more than 10% were deemed collinear and were excluded; no such variables were identified. Hypothesis testing was done using likelihood ratio tests to determine the strength of evidence for an association.

Results

Descriptive analyses

In January 2016, the total population of Somalia was approximately 13,579,000; this increased by 7% by December 2018. The proportion of IDPs also increased from 9% to 25% over this period. Of the 74 districts, 40 had a predominantly pastoralist livelihood (54%), 19 were agropastoralist (26%), 13 were riverine (18%) and 2 were urban (3%) (Table 1).

In Puntland and Somaliland, the number of IDPs leaving was largely concentrated in the regions of Mudug and Sool around the beginning of 2017, with close to 60,000 IDPs. In south-central Somalia, the number of IDPs leaving was largely concentrated in the regions of Bay and Lower Shabelle around the same time. A large spike in IDPs was also observed from Hiraan during the first half of 2018, with close to 100,000 new IDPs (Fig. 2).

The incidence of insecurity events was largely consistent across regions over the study period, ranging from 0 to 6 events per month. In terms of fatalities in Puntland and Somaliland, approximately 150

Table 1
Summary of the demographics of each region in Puntland, Somaliland and south-central Somalia from January 2016 to December 2018.

Region	Districts	Total Population in January 2016 (% IDPs)	Total Population in December 2018 (% IDPs)	Monthly Mean Population (\pm SD)	Main livelihoods (number of districts)
South-central Somalia					
Bakool	5	431,000 (6.4%)	386,000 (28.4%)	409,000 (23,000)	Agropastoralists (4), pastoralists (1)
Banadir	1	1712,000 (22.4%)	2320,000 (47.9%)	1973,000 (203,000)	Urban (1)
Bay	4	834,000 (5.2%)	892,000 (45.6%)	858,000 (19,000)	Agropastoralist (4)
Galgaduud	5	526,000 (7.2%)	554,000 (33.3%)	537,000 (9000)	Agropastoralist (2), pastoralist (3)
Gedo	6	556,000 (15.2%)	591,000 (30.8%)	574,000 (11,000)	Pastoralist (3), riverine (3)
Hiraan	3	507,000 (10.4%)	533,000 (37.7%)	524,000 (10,000)	Agropastoralist (1), pastoralist (2)
Lower Juba	4	569,000 (6.2%)	706,000 (12.8%)	656,000 (41,000)	Agropastoralist (2), riverine (1)
Lower Shabelle	7	1625,000 (10.3%)	1304,000 (16.8%)	1505,000 (113,000)	Agropastoralist (2), pastoralist (1), riverine (3), urban (1)
Middle Juba	3	365,000 (7.6%)	397,000 (17.2%)	383,000 (10,000)	Riverine (3)
Middle Shabelle	4	652,000 (10.4%)	665,000 (20.5%)	664,000 (5000)	Agropastoralist (2), riverine (2)
Puntland (north-east)					
Bari	6	847,000 (7.2%)	905,000 (14.1%)	874,000 (17,000)	Pastoralist (6)
Mudug	5	829,000 (9.3%)	879,000 (27.3%)	852,000 (14,000)	Pastoralist (5)
Nugaal	3	355,000 (2.1%)	375,000 (5.6%)	365,000 (6000)	Pastoralist (3)
Somaliland (north-west)					
Awdal	4	877,000 (0.7%)	940,000 (4.2%)	909,000 (20,000)	Agropastoralist (1), pastoralist (3)
Sanaag	3	505,000 (0.2%)	537,000 (16.3%)	523,000 (11,000)	Pastoralist (2), riverine (1)
Sool	4	380,000 (1.4%)	393,000 (37.1%)	378,000 (8000)	Pastoralist (4)
Togdheer	4	682,000 (3.6%)	706,000 (11.6%)	698,000 (12,000)	Pastoralist (4)
Woqooyi Galbeed	3	1327,000 (3.6%)	1440,000 (7.2%)	1386,000 (37,000)	Agropastoralist (2), pastoralist (1)
Overall	74	13,579,000 (9.1%)	14,523,000 (24.5%)	782,000 (429,000)	Agropastoralist (19), pastoralist (40), riverine (13), urban (2)

deaths were observed in Mudug at the beginning of 2017, and approximately 180 were observed in Bari around the same time. In south-central Somaliland, a spike in fatalities was observed in Banadir, with over 700 deaths near the end of 2017. No clear patterns were apparent between these measures of armed conflict and the number of IDPs leaving (Fig. 2).

Rainfall levels presented peaks and troughs over the study period, with peaks coinciding with the rainy seasons (April to June and October to December) and troughs coinciding with the dry seasons (January to March and July to September). Particularly low seasonal peaks occurred from around October 2016 to December 2016 across all regions of Somalia. This low peak was followed by a spike in the number of IDPs leaving a few months after. Abnormally high peaks, i.e. excess rains, were also observed across all regions at around mid-2018 (Fig. 3).

In Puntland and Somaliland, the terms of trade for wage was largely consistent across months, because bartering is more common in these regions, and so the purchasing power of money is largely unaffected by extraneous factors (Jaspars et al., 2020). Fluctuations in the terms of trade for both wage and goat were more pronounced in the regions of south-central Somalia. The large dips in the purchasing indices of both wage and goat largely coincided with spikes in IDP out-migration (Fig. 4).

The percentage of people receiving food security services showed very similar trends across cash-, rations- and therapeutics-based services. All services peaked at the end of 2016, around the time when IDP out-migration also peaked. This was particularly pronounced in

Bari which saw very few IDPs leaving. Service coverage remained high over 2017 and into 2018, and appeared responsive to IDP out-migration (Fig. 5).

Univariate and multivariate analyses

At a one-month lag, the occurrence of insecurity events was associated with a 19% higher crude rate of IDP out-migration than in the absence of such events. However, there was very weak evidence for an association ($p = 0.1240$) (Table 2). Likewise, at a one-month lag, the occurrence of deaths from insecurity events was associated with a 20% higher rate of IDP out-migration, but again with weak evidence for an association ($p = 0.1000$) (Table 2).

At a three-month lag, an SPI of <-1 (i.e. very low rainfall) corresponded to the highest crude rate of IDP out-migration. There was very strong evidence to show that each category decrease in rainfall was associated with a 17% increase in the crude rate of IDPs leaving ($p = 0.0014$). There was no evidence to show a departure from linearity ($p = 0.3025$) (Table 3).

At a one-month lag, the lowest category of staple cereal that an average daily wage can buy on the market (i.e. 0–9999 Kcal equivalent) featured the highest crude rate of IDPs leaving, while the highest category (i.e. $\geq 50,000$ Kcal) had the lowest crude rate. There was very strong evidence that each category decrease in Kcal cereal equivalent was associated with a 26% increase in the crude rate of IDPs leaving ($p = 0.0003$) (Table 4). After adjustment, the rate ratio remained sim-



Fig. 2. The number of new internally displaced persons (IDPs) (out-migration) and the number of insecurity events and fatalities in regions of Somalia from January 2016 to December 2018.

Table 2

Measures of association between armed conflict and the number of new internally displaced persons (out-migration) in Somalia from January 2016 to December 2018.

Proxy variable (1-month lag)		Total number of district-months (col%)	Crude rate of IDPs leaving per 100,000 person-months (95% CI)	Crude stratum-specific RR (95% CI)	P-value ¹
Insecurity events	Absent	1206 (45.27%)	3081 (2258–4204)	1.00	0.1240
	Present	1458 (54.73%)	3671 (2712–4969)	1.19 (0.95–1.49)	
Deaths due to insecurity events	Absent	1648 (61.86%)	3159 (2348–4251)	1.00	0.1000
	Present	1016 (38.14%)	3805 (2775–5219)	1.20 (0.96–1.50)	

¹ Likelihood ratio test.

ilar, and the evidence for association remained strong ($P = 0.0016$). A linear trend was also apparent (Table 4).

Likewise, there was very strong evidence to show that each category decrease in Kcal cereal equivalent when trading in a medium-sized goat was associated with 20% increase in the crude rate of IDPs leaving ($p = 0.0030$) (Table 4). After adjusting for confounders, the rate ratio remained similar, i.e. there was no evidence of confounding and the evidence for association remained strong ($p = 0.0162$). Contrary to the crude analysis, there was very weak evidence for a departure from linearity ($p = 0.1054$) (Table 4).

After adjustment, the presence of cash-based services corresponded to a 14% lower rate of IDP out-migration than in the absence of such services at a one-month lag, but there was no evidence for an association ($p = 0.1491$) (Table 5). The presence of rations-based services had a 27% lower adjusted rate of IDP out-migration than in the absences of such services at a one-month lag. Unlike the crude analysis, there was some evidence for an association ($p = 0.0646$) (Table 5). The presence of therapeutics-based services corresponded to a 50% higher adjusted

rate of IDP out-migration than in the absence of such services; evidence for an association was also observed ($p = 0.0219$) (Table 5).

Discussion

The current study explored the temporal patterns and crisis-related risk factors for population displacement in Somalia from January 2016 to December 2018, using proxy variables for armed conflict, failed rains, food insecurity and food security services.

The analysis showed that armed conflict – as measured by the presence of insecurity events and deaths from such events – was very weakly associated with rates of population displacement. This runs counter to the literature (Ahmed et al., 2020). This result may be due to residual and unmeasured confounding, as the analyses were unadjusted, or it may be due to misclassification, given the likely under-reporting of conflicts in the ACLED project. Alternatively, the other risk factors may have been stronger drivers of IDP out-migration than armed conflict.



Fig. 3. The number of new internally displaced persons (IDPs) (out-migration) and the rolling 3-month average of absolute rainfall levels (mm) in regions of Somalia from January 2016 to December 2018.

Table 3

Measures of association between the standard precipitation index (SPI) (standard deviations from the 10-year mean precipitation levels) and the number of internally displaced persons (IDPs) (out-migration) in Somalia from January 2016 to December 2018.

Standard precipitation index (SPI) (3-month lag)	Total number of district-months (col%)	Crude rate of IDPs leaving per 100,000 person-months (95% CI)	Crude RR (95% CI)	P-value ¹	Test for departure from linear trend ¹
Linear trend	2442 (100.00%)	2352 (1597–3464)	1.17 (1.06–1.29)	0.0014	0.3025
> 1 (very high)	267 (10.93%)	2396 (1651–3477)	1.00	0.0040	
0 to 1 (normal-high)	619 (25.35%)	3531 (2557–4876)	1.47 (1.09–2.00)		
–1 to 0 (low-normal)	1094 (44.80%)	3717 (2749–5027)	1.55 (1.17–2.06)		
<–1 (very low)	462 (18.92%)	4253 (3041–5948)	1.77 (1.29–2.43)		

¹ Likelihood ratio test.

Indeed, failed rains were strongly associated with higher rates of population displacement compared to normal-to-high rainfall levels. Periods of severe drought likely disrupted key harvests and livestock viability, which we speculate may have led to preventive displacement to avoid potential food insecurity (United Nations Office for the Coordination of Humanitarian Affairs, 2017). Climate- and weather-related displacement is well established in the literature, thus supporting the causal mechanisms and plausibility of this finding (Balsari et al., 2020; McMichael et al., 2012; Chowdhury et al., 2020; Myers, 2002). This association also presented a clear dose-response relationship, i.e. the lower the rainfall, the greater the population displacement; temporality was also clearly established with the three-month lag – both of which further support causality.

Food insecurity was also associated with higher rates of population displacement. A clear dose-response was also observed. The sequence of events could have been that failed rains at three months affected food security at one month, which prompted population out-migration

to larger urban centers where humanitarian relief was more accessible (Jaspars et al., 2020). We speculate that, in contrast to the previous drought, many Somalis may have decided to relocate to locations with greater access to assistance well before local food insecurity deteriorated to levels found in previous analyses (Checchi and Robinson, 2013).

Although food security services may attract IDP in-migration to certain districts, the current study found weak-to-no evidence that cash- and rations-based services prevented population out-migration (Doocy et al., 2020). In contrast, therapeutics-based services were associated with higher rates of population displacement than in the absence of such services, even after adjusting for confounders. This was the only risk factor that was analyzed without a lag, and thus, temporality is dubious in this case. This factor could represent the overall severity of crisis conditions in the district (the burden of acute malnutrition is a key feature of severe food security crises) as a more general prompt for the decision to migrate (Doocy et al., 2020).

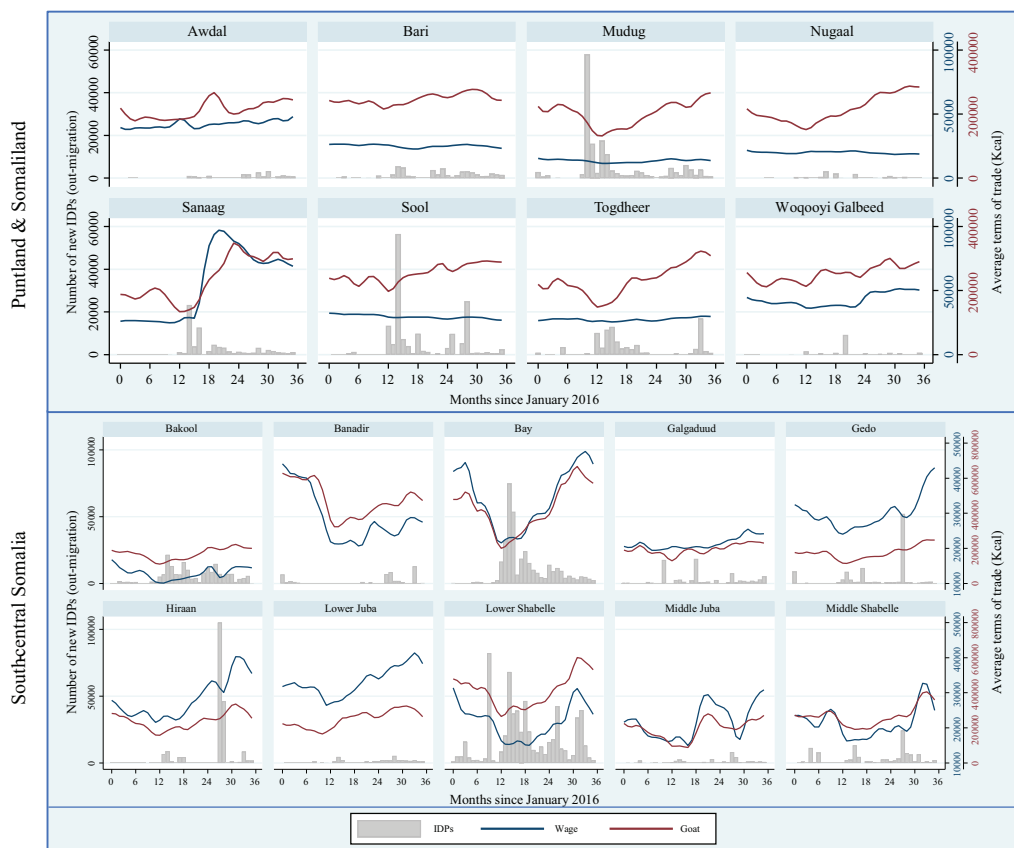


Fig. 4. The number of new internally displaced persons (IDPs) (out-migration) and the average terms of trade (Kcal equivalent of staple cereal that a wage or local-quality goat can buy on the market) in regions of Somalia from January 2016 to December 2018.

Table 4

Measures of association between the terms of trade purchasing power indices (Kcal equivalent of staple cereal that an average daily wage or local-quality goat can buy on the market) and the number of new internally displaced persons (out-migration) in Somalia from January 2016 to December 2018.

Proxy variable (Kcal equivalent of staple cereal that can be bought) (1-month lag)	Total number of district-months (col%)	Crude rate of IDPs leaving per 100,000 person-months (95% CI)	Crude RR (95% CI)	P-value ¹	Test for departure from linear trend ¹	Adjusted RR (95% CI) ²	P-value ¹	Test for departure from linear trend ¹	
Wage	Linear trend	2664 (100.00%)	1723 (1096–2711)	1.26 (1.11–1.44)	0.0003	0.9875	1.24 (1.09–1.42)	0.0016	0.6944
	≥50,000	132 (4.95%)	1650 (951–2863)	1.00	0.0188		1.00	0.0327	
	40,000–49,999	189 (7.09%)	2156 (1334–3483)	1.31 (0.75–2.29)			1.28 (0.72–2.27)		
	30,000–39,999	465 (17.45%)	2825 (1958–4075)	1.71 (1.00–2.94)			2.07 (1.20–3.57)		
	20,000–29,999	1129 (42.38%)	3520 (2603–4758)	2.13 (1.26–3.61)			2.31 (1.36–3.94)		
	10,000–19,999	583 (21.88%)	4489 (3131–6436)	2.72 (1.51–4.91)			2.61 (1.43–4.76)		
Goat	0–9999	166 (6.23%)	4801 (2491–9250)	2.91 (1.28–6.61)			2.92 (1.23–6.92)		
	Linear trend	2664 (100.00%)	1973 (1250–3114)	1.20 (1.06–1.35)	0.0030	0.0135	1.16 (1.03–1.32)	0.0162	0.1054
	≥500,000	139 (5.22%)	1983 (1130–3479)	1.00	0.0002		1.00	0.0180	
	400,000–499,999	124 (4.65%)	1256 (747–2112)	0.63 (0.38–1.06)			0.73 (0.43–1.25)		
	300,000–399,999	289 (10.85%)	3425 (2302–5096)	1.73 (1.00–2.99)			1.60 (0.92–2.77)		
	200,000–299,999	1202 (45.12%)	3410 (2501–4649)	1.72 (1.02–2.91)			1.69 (1.00–2.87)		
0–199,999	910 (34.16%)	3995 (2885–5533)	2.01 (1.17–3.48)			1.83 (1.06–3.17)			

¹ Likelihood ratio test.

² Adjusted for armed conflict, failed rains and food security services.

The study presented several limitations. Given its ecological nature, the associations observed at the aggregate level might not apply to the individual level because of the ecological fallacy. In general, the larger the scale of aggregation, the greater the uncertainty around extrapolating results to the individual level. The current analyses were conducted at the district level, but population displacement was likely clustered in particularly vulnerable communities and households (Warsame et al.,

2020). As such, the results may have had greater utility if patterns were observed over smaller geographical and time intervals, and mapped to more locally specific developments in the food- and conflict-related crises (Checchi et al., 2020).

Many hypothesis tests were performed, given the number of risk factors and lagged terms that needed to be analyzed. As such, some of the low P-values may be spurious and may have arisen from chance, al-



Fig. 5. The number of new internally displaced persons (IDPs) (out-migration) and the percentage of people receiving various food security services in regions of Somalia from January 2016 to December 2018.

Table 5

Measures of association between food security services and the number of internally displaced persons (IDPs) (out-migration) in Somalia from January 2016 to December 2018.

Proxy variable		Total number of district-months (col%)	Crude rate of IDPs leaving per 100,000 person-months (95% CI)	Crude stratum-specific RR (95% CI)	P-value ¹	Adjusted stratum-specific RR (95% CI) ²	P-value ¹
Cash- and voucher-based services (lag 1)	Absent	1493 (56.04%)	3445 (2555–4644)	1.00	0.7658	1.00	0.1491
	Present	1171 (43.96%)	3339 (2455–4540)	0.97 (0.79–1.19)		0.86 (0.69–1.06)	
Rations-based services (lag 1)	Absent	719 (26.99%)	3977 (2757–5737)	1.00	0.1841	1.00	0.0646
	Present	1945 (73.01%)	3204 (2386–4304)	0.81 (0.59–1.11)		0.73 (0.52–1.02)	
Therapeutic-based services (lag 0)	Absent	703 (26.39%)	2,22 (1562–3334)	1.00	0.0015	1.00	0.0219
	Present	1961 (73.61%)	3868 (2855–5239)	1.70 (1.22–2.35)		1.50 (1.07–2.11)	

1 Likelihood ratio test.

2 Adjusted for district livelihoods, armed conflict and failed rains.

though this is unlikely given the very low P-values observed, and the plausibility of the associations (Smith and Ebrahim, 2002).

Ascertainment bias may have arisen due to missing data. Missing data were inevitable as data collection in conflict settings and humanitarian responses is often unsystematic and disrupted by several challenges, including insecurity, impaired communication, reduced funding, and increased turnover of humanitarian staff (Checchi et al., 2017). Variables with missing data, e.g. the terms of trade purchasing power indices, were subjected to imputation techniques, all of which were completed for a previous study (Checchi et al., 2020). Because of this, the dataset for the current study was free from missing data. The effect of this imputation should have been assessed using sensitivity analyses, which was not conducted as part of this study.

Furthermore, most of the data were also collected by humanitarian responders, and as such, the data might not have been collected to a standard consistent with primary research. For example, the proxy

variables for armed conflict were ascertained from the ACLED project, a passive surveillance system that records incidents based on media channels and civilian informants (Raleigh et al., 2010). It is likely that incidents were missed and under-reported, particularly in rural areas. Given this differential misclassification, the effect estimates were likely biased in either direction. The degree of underreporting and resultant misclassification in the conflict data should have been assessed using sensitivity analyses, which were not conducted as part of this study. Such analyses could have involved conducting interviews with locals to gauge the accuracy of the data, or comparing figures with independent reports.

Most of the other risk factor variables were collected for administrative surveillance purposes by aid workers. These data were likely subjected to random error. Non-differential misclassification would have arisen from differences in ascertainment over time or across strata, or from imputation, thus biasing the effect estimates towards the null.

Similarly, the IDP movement outcome data – which were derived from the UNHCR-led Protection and Return Monitoring Network – relied on informants in each district (e.g. NGOs), rather than direct estimations of IDP numbers through statistically valid methods. As such, it is possible that these data may be subject to considerable random and systematic error. If these errors were constant over time and place, we would nonetheless still have some basis to detect associations between the outcome and hypothesized exposures.

Despite these limitations, the current study, showed strong associations between certain risk factors and displacement. The observed associations were also backed by dose-responses, social and biological plausibility, and temporality; the associations are thus robust enough to cautiously infer causality. These findings can help humanitarian actors better understand the dynamics of latent crises in Somalia, and inform resource allocation to improve the effectiveness and efficiency of such responses (Warsame et al., 2020). For example, failed rains were associated with population displacement in three months' time – humanitarian actors could thus be more proactive in their response to prevent displacement or prepare for population influxes, and thus minimize the risk of downstream morbidity and mortality, e.g. from epidemics in overcrowded, unplanned IDP settlements (Seal et al., 2017; Seal et al., 2021).

These findings suggest avenues for future research. In particular, future studies could explore the hypothesized pull factor generated by food security services, and potential interaction between the absence of humanitarian assistance and low terms of trade (Checchi and Robinson, 2013). Future research could also look at the downstream impacts of population displacement – for example, the onset of epidemics and mortality – to help quantify the burden directly attributable to displacement.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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