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Weather, wheat, and war: Security implications of climate variability for conflict in Syria

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Abstract

We examine how Syria's local growing seasons and precipitation variability affected patterns of violence during the country's civil war (2011–19). Among Syria's 272 subdistricts (*nahiyah*), we study conflict events initiated by the Assad regime or its allies, and, separately, by other armed non-government groups ('rebels'). Throughout the war, *violence to capture agriculture* has been used regularly to control valuable cropland and harvests. Combatants also seek to deny their adversaries access to these resources by deploying *violence to destroy agriculture*. We test the hypothesis that conflict was most likely during local growing seasons due to both of these motivations. Additionally, we examine whether unusually dry conditions further elevated the risk of conflict during growing season months. A theory for why higher levels of conflict would occur during unusually dry conditions is that livelihood losses elevate incentives to control scarce crops and also facilitate recruitment of militants or their sympathizers. We find that violent events initiated by the government and rebel groups are both more likely during the growing season than other times of the year. There is also evidence that dry conditions during the growing season led to an increase in government-initiated attacks over the duration of the war. We find the strongest relationship between precipitation deficits and both government- and rebel-initiated violence in later years of the war. Compared with our growing season results, the rainfall deviation estimates are less consistent across models.

Keywords

agriculture, civil war, drought, Syria

Introduction

In 2011 the Arab Spring brought the world's attention to the Middle East and North Africa. Large pro-democracy uprisings led to political upheaval throughout the region. Since the first deadly violence erupted in Daraa in mid-March, Syrian unrest escalated quickly and by early 2020 had claimed 586,100 lives, including 116,000 civilians (SOHR, 2020). There are currently approximately 6.2 million Syrian internally displaced persons, the largest number of any country in the world, and an estimated 9.3 million Syrians face food insecurity (UNSC, 2020). Millions of refugees have fled Syria to neighboring countries and to Europe (UNHCR, 2018).

Syria's civil war has been fought between President Bashar al-Assad's regime and a variety of non-government opposition groups (hereafter 'rebels'). The regime also deployed non-government militias. A basic distinction between pro- and anti-government forces conceals the great complexity of the war, however. Several main factions coalesced during the conflict: pro-government militias, opposition rebels, Islamic State in Iraq and Syria (ISIS[1]), Kurdish autonomous forces, and Turkish-backed fighters. Each group received some level of foreign support. Russia and Iran supported Assad, while jihadists were funded by Saudi Arabia and Qatar (Shaheen et al., 2015; AbuKhalil,

[1] The organization is sometimes referred to as 'Islamic State of Iraq and the Levant', 'Islamic State of Iraq and Syria', 'Islamic State', and the Arabic acronym Daesh. We use 'ISIS' hereafter.

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2018). Until 2019, the USA was a patron of Kurdish forces and Turkey reportedly aided ISIS on occasion (Yayla & Clarke, 2018; Mogelson, 2020).

The origins of Syria's war are still disputed. Most scholars point to some combination of three conditions: political awakening among the population, Assad's repression of dissent, and deteriorating ecological conditions. Some 'environmental security' research names Syria as a prototypical drought-induced civil war. Kelley et al. (2015) claimed that collapsing Syrian agriculture drove urban migration. This change amplified existing grievances among the populations in cities and led to the protests that escalated throughout 2011. Other research found that meteorological droughts led to protests between January and June 2011 in Sunni regions of the country where migrants arrived (Ash & Obradovich, 2020). The association between Syria's war and drought has nevertheless been disputed, with researchers emphasizing Assad's harmful political and economic policies and also pointing to problematic assumptions about migrants' activities in those studies (De Châtel, 2014; Fröhlich, 2016; Selby et al., 2017; Selby, 2019).

Any evidence that environmental factors led to Syria's civil war falls in line with research that found temperature extremes (Burke et al., 2009; Hsiang, Burke & Miguel, 2013; Maystadt, Calderone & You, 2015; van Weezel, 2020) and rainfall deficits (Fjelde & von Uexkull, 2012; Hendrix & Salehyan, 2012; Maystadt & Ecker, 2014; Raleigh, Choi & Kniveton, 2015; von Uexkull et al., 2016; Harari & La Ferrara, 2018; van Weezel, 2019; Döring, 2020) elevate armed conflict risk. Weather trends will become increasingly unpredictable as climatic change continues (Giorgi, 2006; Dai, 2013) and this could have impacts on crop productivity that lead to violence (Vesco et al., 2021).

While weather variability can lead to instability, violence is not inevitable. Irrigation infrastructure (Gatti, Baylis & Crost, 2020), institutions that manage resource use (Linke et al., 2018a), food security improvements (Hendrix & Brinkman, 2013; Koren, 2019), and poverty reduction or political reforms (Mach et al., 2019) can prevent conflict. Recent research has focused on environmental migration (Koubi et al., 2021; Adger et al., 2021; Linke et al., 2018b), and has argued that accommodating these vulnerable populations can reduce conflict.

In this article, we investigate whether local growing season rainfall deficits increased the likelihood that the Syrian government or its allies or rebels perpetrated violence. To our knowledge, our research is the first that studies how local crop seasonality and weather variability influenced patterns of violence in Syria after the civil war began. Relatively few studies of the war in Syria have focused on agricultural land at all (Jaafar & Woertz, 2016; Eklund et al., 2017; Sly, 2019; Ash & Obradovich, 2020), despite the need for such consideration. Manipulation of food supplies has been a strategy in violent conflicts for centuries (Oberschall & Seidman, 2005) and food insecurity remains a focus of ongoing conflict research (Koren, Bagozzi & Benson, 2021).

A euphemism commonly used to describe rebel groups as 'living off the land' (Koren & Bagozzi, 2017; Zhukov, 2017: 57) is especially pertinent for our study. Beyond food for sustenance, the revenues earned from selling harvests have funded ISIS, Free Syrian Army (FSA), Syrian Democratic Forces (SDF),[2] and other Syrian groups (Sly, 2019; Kanfash & al-Jasem, 2019). Rebel organizations often relied on local populations for their supply of food and other resources (Weinstein, 2006; Hazen, 2013; Hendrix & Brinkman, 2013; Crost & Felter, 2016; Koren, 2019). Governments struggle to diminish those resources that support rebel fighting. In Syria, the Assad regime has launched airstrikes repeatedly to destroy cropland and grain-processing infrastructure, denying its opposition control over these valuable assets (Fahim & Saad, 2012; Gutman & Raymond, 2013; Ciezadlo, 2015).

With most of the environmental security literature focused on the start of the Syrian war, the relationship between the environment and conflict during the war remains understudied.[3] In 2018, the Food and Agriculture Organization (FAO) estimated that agriculture accounted for 60% of GDP; only 18% of GDP was agricultural in 2010 before the war (FAO, 2019). While many families moved to cities beginning in 2011 (Ide, 2018), thousands of farming households remained in rural Syria and tended crops throughout the conflict. Our focus on such households is a logical extension of research finding that environmental stress contributed to the onset of Syria's war (Ash & Obradovich, 2020).

Our findings are most readily generalizable to Yemen's current civil war. The Saudi-led Arab Coalition has systematically destroyed crops and farming

[2] Some sources use 'Syrian Defense Forces' and 'Syrian Democratic Forces' interchangeably. We use 'SDF' hereafter.

[3] There are studies of Syrian agriculture after 2011. However, ISIS research models land use as a dependent variable rather than conflict events (Eklund et al., 2017). Vegetation health has declined in three northern governorates through 2015 (Eklund & Thompson, 2017) according to other research, but violent event data was not part of the empirical analysis.

infrastructure in regions held by Sanaa in their effort to replace the central Houthi-led government. Experts have labeled the campaign in Yemen 'killing agriculture' (Sowers, 2018: 13; Mundy, 2018).

Syria's civil war and the environment

Several studies have reported that worsening environmental conditions and changing weather patterns were major drivers of Syria's civil war (Femia & Werrell, 2012; Gleick, 2014; Kelley et al., 2015). Following rapid migration to urban areas from drought-stricken farmland, protests in predominantly Sunni areas of the country grew throughout 2011 (Ash & Obradovich, 2020). Against the position that climate change was a main cause of the war, Selby et al. (2017) argue that significant urban migration occurred as a result of economic policies. From 2001 to 2007, Syria's oil revenue dropped by two-thirds, which led the government to remove fuel and fertilizer subsidies (Gobat & Kostial, 2016). These events combined with Assad's repression of Kurds living in the north were the root of an agrarian crisis that predated recent 2006–10 droughts (Selby, 2019). Additional skepticism about the link was found by De Châtel (2014) and Fröhlich (2016), who found that migrants from the areas that suffered droughts were not the main participants in 2011 protests.

Farmers' decisions are based on an assessment of weather, soil quality, market forces that determine crop prices, and the availability of fertilizers, pesticides, and equipment. The civil war made these calculations more complicated for Syrians. Battles and one-sided attacks destroyed land, infrastructure, and supply routes (Koren & Bagozzi, 2017). After Kurdish SDF forces took control of Euphrates river basin territory in northern Syria, Turkey repeatedly cut the river's flow rate by over 50% during important months in the crop calendar (Ramadan, 2018; Hubbard, 2018). ISIS and Kurdish forces also manipulated the flow of the Euphrates while in control of the Tishreen Dam in Aleppo governorate (von Lossow, 2016). Roughly one-third of Syria's land is agricultural (FAO, 2019). Cultivated land is found in all provinces and close to towns and villages, which means there was great risk of violence exposure among the population when conflicts over cropland occurred.

Valuable natural resources and conflict

To understand the role of agriculture in Syria's war, we rely upon the micro-dynamics of civil war literature (Kalyvas, 2006), which shows that armed actors' strategies are influenced by the resources at their disposal. Both the government and rebels are responsive to changes in their resources base. Zhukov (2017) found that supply line disruptions lowered the intensity of government violence against civilians because a reduction in material assets caused it to rely more heavily upon that population. Such 'interdiction' of supply chains by rebel groups has occurred recently during the Libyan Civil War and in the form of Taliban attacks inside Pakistan that target NATO supply routes (Zhukov, 2017). In Syria, 'the stated goal of the FSA assaults on army positions in Aleppo has been to disrupt supply lines and stop the [government] shelling of civilian areas' (Zhukov, 2017: 59).

Valuable natural resources such as oil, diamonds, drug harvests, timber, and rubber, alongside others, have fueled numerous civil wars (Le Billon, 2001; Hazen, 2013). Edible crops and arable land for producing staple foods – Syria's main crop is wheat – can be particularly valuable during wars. Scholars have established a relationship between agriculture and conflict through lost wages or reduced national tax revenues when crops fail (Miguel, Satyanath & Sergenti, 2004; von Uexkull et al., 2016; Mach et al., 2019; Buhaug et al., 2020). But food supplies are also an asset, which means that abundance instead of scarcity could lead to conflict. Rebel violence in Africa, for instance, targeted farming areas in order to deny those resources to the central government (Koren, 2019). Especially in the absence of external support, rebels often rely on a local population for food (Hendrix & Brinkman, 2013); 'insurgents gain strength from extorting agricultural exporters' (Crost & Felter, 2016).

Rebels fighting civil wars have routinely created institutions to manage populations and territory as a legitimate state would (Kolstø, 2006; Mampilly, 2011; Stewart, 2018). Within their Syrian territories, both SDF and ISIS regulated lucrative farming and agricultural revenues with institutions to police, tax, and recruit from within the population. Beginning in late 2014, farming regions of northern Syria had become an ISIS stronghold (Hassan & Nordland, 2018) that included the Euphrates and Khabur rivers (Syria's largest), the reservoir Lake Assad, and wheat-producing Al-Hasakah governorate. By 2016, it was estimated that at least 30% of ISIS revenues came from selling agriculture and taxing farmers (Almukhtar, 2016). Eklund et al. (2017) found that agricultural production rose between 2000 and 2015 in areas controlled by ISIS. Jaafar & Woertz (2016) similarly found that between 2014 and 2016 ISIS earned profits selling agricultural goods. At the height of its influence, ISIS contracts for leasing land were secured through an official 'Ministry of Agriculture and

Livestock' (Callimachi & Rossback, 2018). ISIS supply routes regularly crossed the Syria–Iraq border (Markey, 2012; Eklund et al., 2017) and the group issued official license plates for vehicles (Almukhtar, 2016). In 2016, ISIS annually taxed every farmer $46 US per hectare and 10% of the wheat harvest, in addition to requiring households to rent farm equipment that the group had stolen when it took control (Almukhtar, 2016). These lucrative farmland resources were worth using violence to capture and defend.

Mechanisms linking agriculture, weather variability, and conflict in Syria

We distinguish between two types of agricultural conflict in Syria. To secure food supplies and revenues, government and rebel forces alike will be motivated to use *violence to capture agriculture*. In hotly contested Idlib and Aleppo, for example, government and rebel front lines shifted village-by-village as both sides sought to control farmland during various periods of the war. Similar events have occurred between rebel groups without the involvement of government forces (e.g. SDF gained ISIS territory). These rebel interactions have been common because the groups rely more heavily upon local crops than the government, which enjoys Russian patronage. After dry conditions in 2016–17 and a dismal 2018 wheat harvest (the smallest since 1989), Syria's trade minister announced imports of 1.5 million tons of Russian wheat (El Dahan, 2018).

The second form of agricultural conflict is *violence to destroy agriculture*. The Syrian Air Defense Force (SADF) has the capacity to deploy incendiary munitions from fighter jets and has done so frequently to ruin harvests (BBC, 2019). While rebels lack such capabilities, some groups have used other means to commit the same type of violence (especially ISIS). Destroying crops can give the government a strategic advantage by reducing food security within opposition regions (Hendrix & Brinkman, 2013; Martínez & Eng, 2018; Koren, 2019). This was almost certainly the motivation behind government strikes during the growing season in April and May 2019 in Idlib (al Habeet town), Hama (Kafr Nabouda town), and Aleppo to harm Hayat Tahrir al-Sham (formerly al-Nusra), who were losing control by this point in the war (BBC, 2019).

Within the growing season, we also believe *droughts have the potential to amplify conflict risks*. Below average rainfall has the strongest relationship with conflict during the growing season (von Uexkull et al., 2016) because this is the time when farming households incur the greatest income losses. Poverty resulting from crop failure can compel people to earn a living by supporting or committing violence (Fjelde, 2015; McGuirk & Burke, 2017; Vestby, 2019; Buhaug et al., 2020). A similar effect has been found for livestock losses (Maystadt & Ecker, 2014). Informing either side of the civil war about their opponent's tactical operations, identifying leaders to assassinate, or facilitating weapons shipments could all lead to more intense conflict during a civil war. Vestby (2019) describes how a rural worker's motivations to engage in illicit work rises when agricultural productivity falls: 'Assuming that market prices are not perfectly elastic to local supply, the expected gain from agricultural labor goes down. For those in the population whose gain follows the above model, it means that more time will be allocated to illicit wage labor such as participation in violent action' (Vestby, 2019). During a protracted war like Syria's, there are ample opportunities to earn wages working for both the government and rebels. 'Very early in 2011, the government began to use money and services to buy the allegiance of unemployed youth, and to distribute guns, cars, and security clearances to trusted loyalists and their families' (Lund, 2015). When drought ruined harvests, ISIS offered food and resources to poor farmers. 'As farming communities limped from one debilitating crisis to another, the recruiters – all members of what soon became the Islamic State – began to see a return on their investment' (Schwartzstein, 2017).

Droughts have affected the everyday life of Syrians even if they were not farming tenants or landowners. Wage-earners on farms also often lost their income. In 2001 the International Monetary Fund reported that agricultural jobs in 1998 accounted for 29% of Syrian employment (Sarris, 2003). Crop failures from the 2006–10 droughts caused as many as 800,000 people to lose their livelihoods and the wheat yield dropped by 47% in 2008, which was the first year in decades that Syria imported wheat (IRIN, 2009). Long before the current war, the FAO documented widespread economic damage resulting from a 1999 drought. Official Syrian statistics showed 'a substantial decline in employment in 1999, a major drought year', and the reduction (–23.5%) 'highlights the importance of agriculture for employment in the economy' (Sarris, 2003).

As it relates to the motivations for violence outlined above, this is a perfect storm for instability. At the time that there is greatest competition over valuable scarce resources because of drought-induced shortages, there are many people entering poverty who might use or support violence. 'Across rural Iraq and Syria, farmers, officials, and village elders tell similar stories of desperate farmhands swapping backhoes for assault rifles' (Schwartzstein, 2017).

All sides of the Syrian conflict have strategically targeted cropland, whether to capture or destroy agriculture (Enab Baladi, 2019). In May 2019, human rights observers witnessed SADF sorties firing upon cropland with incendiary devices in Idlib, Hama, and Aleppo (BBC, 2019). As ISIS influence waned in June 2019, the retreating fighters burned thousands of acres of wheat to deprive other fighters of this resource (Sly, 2019). ISIS could not use the crops and it opted for violence to destroy agriculture that it could not profit from. Government forces destroyed crops that they did not need (because of Russian support) and ISIS destroyed crops that it could not use (because they were fleeing). In both cases, violence was designed to deny the opponent valuable resources. Shortly after the ISIS attack described above, the group claimed in an official statement that these fires would 'burn the pockets of the apostates as well as their hearts' (Tarling & Ensor, 2019). The reference to 'burning pockets' presumably signifies the lost revenues from crop sales. There are plentiful examples of violence to capture agriculture in the international media as well. In September 2018, when a drought led to dismal wheat harvests in Syria (El Dahan, 2018), Turkish-backed forces launched 'Operation Olive Branch' to take control of olive groves and production equipment from Kurds living in Afrin.

Inspecting Armed Conflict Location and Event Data project event notes (ACLED; Raleigh et al., 2010) for Syrian violence similarly illustrates the role of agriculture during the war (see dataset description below). During June 2019 (late in the growing season), 'regime forces shelled al Manara in al Ghab Plain in northern Hama countryside using artillery and rocket fire, setting fires to the crops in the area' (Event #62273). One year earlier in Idlib province during June 2018, '[r]egime forces shelled Najiyeh in the western countryside of Jisr-Ash-Shugur. Shelling resulted in wildfires that destroyed crops and fields' (Event #33598). These are clear instances of violence to destroy agriculture. Rebel groups have also used the strategy. During May 2019, 'YPG shelled the areas on the outskirts of Mare' in northern Aleppo countryside using machine gun fire, setting fire to crops in the area' (Event #61615).

ACLED also records violence to capture agriculture. In Raqqa during May 2017, 'SDF forces clashed with ISIS in an advancement effort towards wheat silos, Mansurah village, South Baath (Azadi) Dam' (Event #25981). Near the peak of the growing season, SDF sought infrastructure that would allow them to capitalize on the upcoming wheat harvest. In Afrin district on the 6 January 2019, 'Islamist factions operating as part of former Operation Olive Branch (rebels armed by Turkey) arrested more than 45 civilians in order to seize their property and farms during the olive picking season' (Event #51212).

Hypotheses

The relationships outlined above have observable outcomes that we test as hypotheses using subdistrict (*nahiyah*)-month level data. Government-initiated (H1) and rebel-initiated (H2) conflict events will be more likely during the growing season than at other times of the year. During the growing season, precipitation deficits will be associated with more government-initiated (H3) and rebel-initiated (H4) violence. In the current analysis, we focus on the actors who perpetrate violence, rather than on the target.

Data

Environmental variables

To measure subdistrict monthly precipitation deficits, we use the Climate Hazards group Infrared Precipitation with Stations (CHIRPS) rainfall dataset (Funk et al., 2015). These data are derived from rain gauge and satellite observations. CHIRPS are 0.05° spatial resolution data and cover the years 1981 to 2019. The temporal resolution of CHIRPS is a pentad (five-day period). For every observation-month, we calculate a standard precipitation index (SPI) that measures deviation of rainfall in that month from the historical average (McKee, Doesken & Kleist, 1993). We use an SPI three-month average. An SPI3 in March compares March–January in a given year to March–January data for all years (in April it compares April–February to all April–February data, etc.). We also run the analysis with other periods measuring the monthly average (see Tables IV and S5).

Online appendix Figure A1 maps the subdistrict average SPI3 values for all years included in our analysis (2011–18). During some years there are stark differences across Syria, as in 2012 when the northwest was wetter than usual and the south and northeast received less rain than the historical average. In other years, rainfall was more uniform across the country (consistently little in 2016, and plenty in 2018). These annual averages can hide more extreme variation during particular months. Figure A2 includes maps showing the SPI3 variation across months in an example calendar year (2011).

In our analysis, we use a dichotomous variable measuring 'dry conditions' when SPI3 is below –1.0 standard

Table I. Descriptive statistics for ICEWS and ACLED data at the subdistrict level

a. ICEWS (2011–18)	*Mean*	*Std. dev.*	*Max.*	*Min.*
Government-initiated ICEWS	0.087	0.281	1	0
Non-government-initiated ICEWS	0.071	0.257	1	0
Government-initiated ICEWS count (log)	0.136	0.530	5.384	0
Non-government-initiated ICEWS count (log)	0.109	0.470	5.849	0
Growing season month	0.450	0.498	1	0
SPI1 ≤ -1 SD	0.165	0.371	1	0
SPI3 ≤ -1 SD	0.149	0.356	1	0
SPI6 ≤ -1 SD	0.202	0.402	1	0
Temperature (°C)	18.722	7.598	37.023	0.098
b. ACLED (2017–19)	*Mean*	*Std. dev.*	*Max.*	*Min.*
Government-initiated ACLED	0.295	0.456	1	0
Non-government-initiated ACLED	0.294	0.456	1	0
Government-initiated ACLED count (log)	0.562	1.063	5.771	0
Non-government-initiated ACLED count (log)	0.415	0.778	5.759	0
Growing season month	0.470	0.499	1	0
SPI1 ≤ -1 SD	0.098	0.298	1	0
SPI3 ≤ -1 SD	0.095	0.293	1	0
SPI6 ≤ -1 SD	0.130	0.336	1	0
Temperature (°C)	19.389	7.515	37.023	0.923

deviation (SD) from the historical average (see also von Uexkull et al., 2016). We also test a ≤ -1.5 SD operationalization of SPI3 (see Tables A4 and A6). See Table I for descriptive statistics of all variables.

We identify the main wheat growing season using phenology data from the Anomaly Hotspots of Agricultural Production (ASAP) research initiative. ASAP defines growing seasons using the long-term average (2003–16) of a ten-day MODIS normalized difference vegetation index (NDVI). These are 1 km raster data that identify an averaged calendar day (ranging 1–365) marking several important growing season dates. The start of the growing season in each pixel is defined by ASAP as the time that NDVI grows above 25% of the ascending amplitude of the seasonal profile. We calculate the average starting day pixel value within each subdistrict. We also measure the mean date that the season ends, which ASAP defines as the point when NDVI drops below 35% of the descending trend. Our variable identifying local growing season months is assigned a value of 1 for all months in between the averaged start and end dates. The subdistricts' average growing season start and end months are mapped in Figure A3 in the Online appendix. The growing season start month varies considerably from around October in some southern regions to January in parts of the north and along the Euphrates. End of the growing season occurs approximately one-quarter of the way through the year. A histogram showing the average growing season length reveals considerable variation across Syria and these differences highlight the usefulness of our subnational data (see Figure A4).

To account for the fact that extreme heat could reduce conflict activity, we control for temperature using the ERA5 daily average 2 m surface air temperature data at a 0.25° ($\sim$25 km) spatial resolution from the EMCF Copernicus project.[4] We convert the raster pixel values from Kelvin to Celsius and average the daily values within each month. Finally, we use a zonal statistic measuring the mean pixel value within a subdistrict-month.

Conflict events

For the duration of the war (2011–18), we use the Integrated Crisis Early Warning System (ICEWS) data (ICEWS, 2016). ICEWS is a georeferenced conflict incident database that records interactions between social and political actors. Recent research that studied protests in Syria also used ICEWS data (Ash & Obradovich, 2020). Conflict events are recorded using an automated system that scrapes news article details from online sources ($\sim$300 publishers in many languages). ICEWS is developed using the BBN ACCENT coder, a natural

[4] Available at https://cds.climate.copernicus.eu/cdsapp#!/dataset/reanalysis-era5-single-levels?tab=form.

language processing tool that extracts the relationship between actors in a story from the text. Incidents are subsequently coded in the ICEWS dataset using the Conflict and Mediation Event Observations (CAMEO) taxonomy of event type. CAMEO distinguishes between perpetrator (the 'Source Name' variable) and the target. Examples of event types include 'Use conventional military force' (CAMEO #190), 'Carry out roadside bombing' (CAMEO #1833), or 'Fight with small arms and light weapons' (CAMEO #193). We present a full table of CAMEO codes that we extracted for analysis in Table A1 in the Online appendix and offer a brief justification for our selection. Our ICEWS data from 2011 to 2018 include 37,123 events.

To make government and rebel actor distinctions we use the 'Source Name' field. For rebel actors we select 'Opposition force (Syria)', 'Rebel Group (Syria)', 'Syrian Kurds', 'Terrorist (Islamic State of Iraq and the Levant)', 'Militia (Syrian Kurds)', and 'Free Syrian Army', among others (see Table A2 in the Online appendix for a complete list). To measure the activity of government armed forces, we select 'Military (Syria)' (there are 12,943 such events), 'Air Force (Syria)', 'Military Personnel – Special (Syria)', and 'Police (Syria)', among others. We include pro-government militia violence in this category.

Using an approach similar to others (e.g. Nordkvelle, Rustad & Salmivalli, 2017), we converted the subdistrict-month total event count into a dichotomous dependent variable for our analysis. We test a model using the (logged) total number of incidents instead of the dichotomous measurement and most of our results are similar (see Table III). Figure 1 maps the (logged) number of ICEWS government- and rebel-initiated violent events by year and subdistrict. Comparing government- and rebel-initiated conflict, the maps of violence appear similar. The goal of both actors is to confront their adversary, resulting in considerable overlap. In earlier years of the war (2012–14) both government- and rebel-initiated violence centers mainly in key cities such as Aleppo, Raqqa, Hama, and Homs (see Panels a–d and i–l). As the networks of Islamist forces gained strength, violence spread to the southeast in rural Homs and Dar Az Zawar provinces (see Panels e–g and m–o). Intense fighting remained afterward, especially in the northern cities, and this overall spike in violence beginning in late 2015 is evident in Figure 3a, which graphs ICEWS violence over time at a monthly resolution. By early 2018, ISIS territory north of the Euphrates river was retaken in violent strikes conducted by SDF and Kurdish militias supported by the USA (ISW, 2018; Hassan & Nordland, 2018).

We also use 2017–19 ACLED data. These are the only years where data are available. We run models of the government- and rebel-initiated events that are identical to our ICEWS estimates. ACLED data include the date of each event, the actors involved, incident type, and other important descriptive information. Event types include 'Violence against civilians', 'Air/Drone strike', and 'Non-state actor takes over territory', among others. ACLED records 67,724 violent events in Syria during this time period. We exclude 'protests' and nonviolent event types from our analysis. Figure 2 maps ACLED event totals for each year (see Figure 3b for a timeline). As with ICEWS, the government actor classification in our ACLED dataset includes forces of the Assad regime, its international patrons (e.g. Russian airstrikes are included in this category), and pro-regime militias. Table A3 in the Online appendix presents a list of the actors in both the government and non-government categories. Violence in 2017 was widespread according to ACLED data, clustering in the last two years around Aleppo (especially for government-initiated violence, as Panel c shows). The peak of ISIS activity is visible along the Euphrates in 2017 (Panel d) but wanes in 2018 as they lost control and moved southeast toward the Iraq border (Panels e–f).

The initial escalation of conflict appears in the first two years of the ICEWS conflict data (see Figure 3a). A noticeable spike in rebel violence corresponds to the US intervention in the war and several rebel offensives that began in September 2014 (Sciutto, Castillo & Yan, 2014; Cellan-Jones, 2014). In late 2015 and early 2016, interventions by Russia and a major ground offensive by rebels against the government also intensified (Cellan-Jones, 2015; Aboufadel, 2015). Conflict intensity rises and falls over time, but violence in Syria has not followed predictable 'fighting seasons' as it does in some countries. Afghanistan's conflict, for example, slowed during harsh winters that limited insurgent attacks. This timing of conflict in Syria within the year is important to consider in testing H1 and H2, which state that fighting will be most likely during the local growing season. Absent the strategic importance of crops, there is no alternative explanation (such as heavy snowfall that limits mobility) for why violence would be especially likely during these times. We control for temperature to account for any chance that extreme heat limits fighting. Overall, ACLED records fewer rebel-initiated events than government strikes. Figure 3b shows that during some months (e.g. in late 2017 to mid 2018) violence by the two sides rose and fell together. At other times (e.g. throughout 2019), government attacks increased steadily

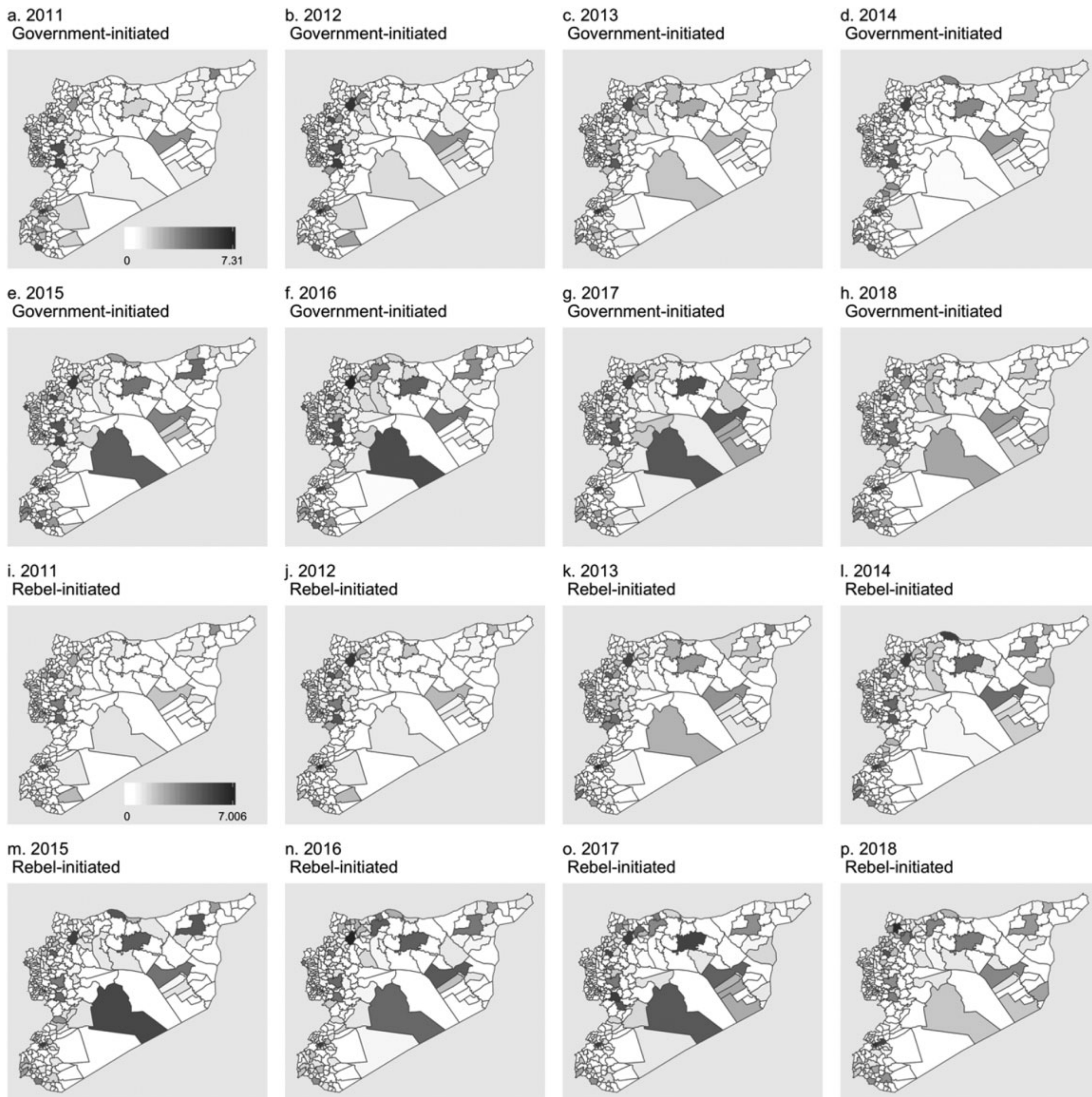

Figure 1. ICEWS government (Panels a–h) and rebel (Panels i–p) conflict event counts (logged) across Syrian subdistricts, 2011–18

for months without a corresponding rise in rebel-initiated violence.

Estimation

We test the effect of the growing season (H1–H2) and precipitation deficits (H3–H4) separately. For our growing season models, we use ordinary least squares (OLS) regression to estimate whether a subdistrict experienced conflict Y in unit i and month t as a function of:

$$Y_{it} = \beta_0 + \beta_1 X_{it} + Y_{it-1} + Y_{itw} + \beta_2 i\_t + \beta_3 o + \beta_4 C + \epsilon$$

with intercept β_0 and where β_1 captures the influence of the growing season designation (X_{it}) of each observation. We report β_1 with 95% confidence intervals. For the separate regressions of government- and rebel-initiated violence, we control for previous subdistrict conflict in Y_{it-1}. We include spatial autoregressive term Y_{itw}, which measures the average number of conflict events by the

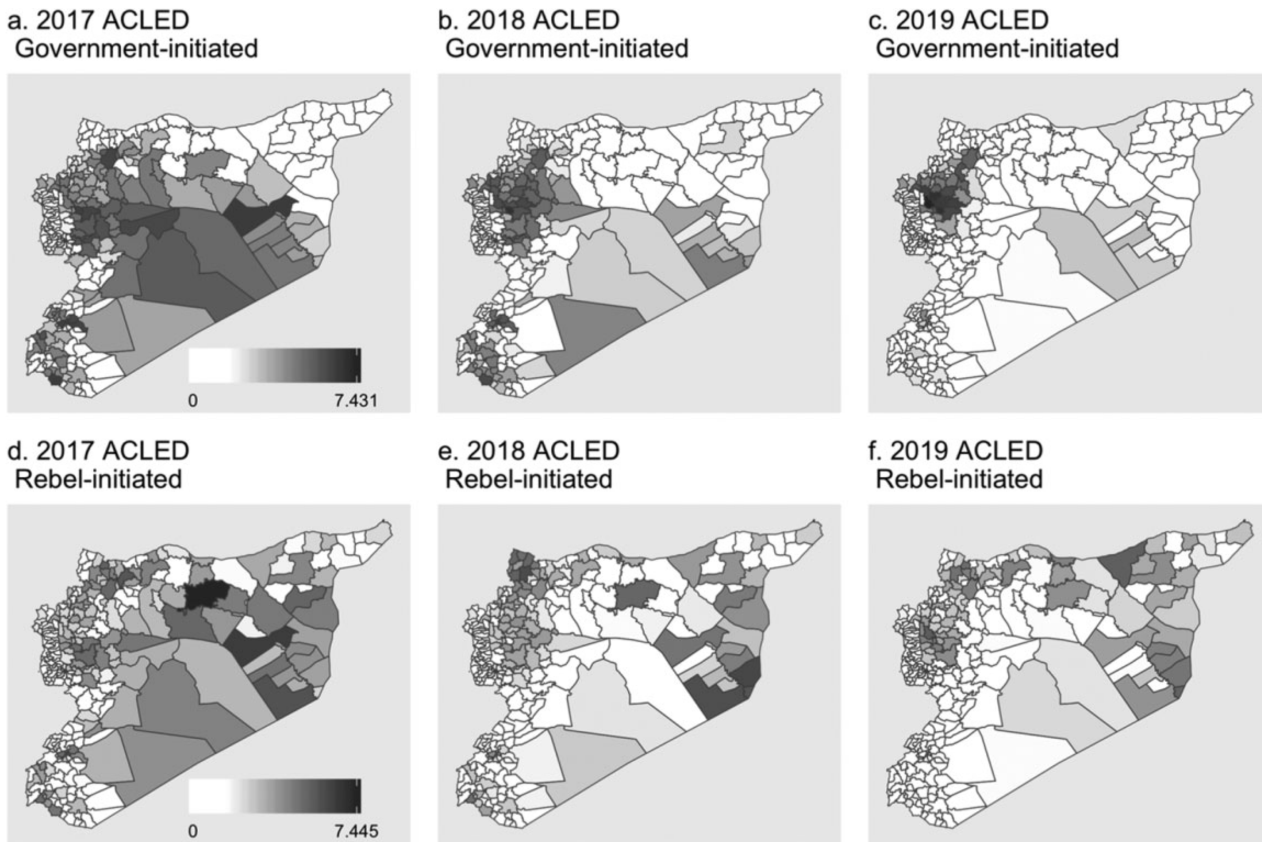

Figure 2. ACLED government (Panels a–c) and rebel (Panels d–f) conflict event counts (logged) across Syrian subdistricts, 2017–19

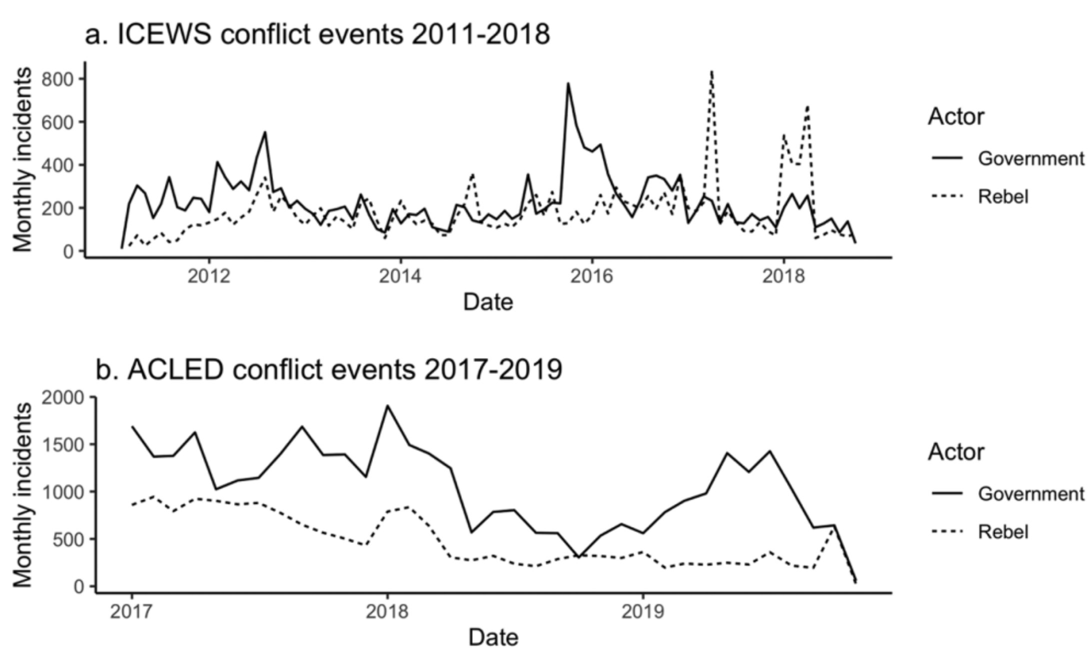

Figure 3. Monthly average incident counts for Syria's civil war according to ICEWS (Panel a, 2011–18) and ACLED (Panel b, 2017–19) datasets

actor in a first-order subdistrict neighboring weights matrix w. We also include temperature, C. We include grid-month (i_t) and year (o) fixed effects (β_2 and β_3, not reported). Stochastic error is represented as ϵ and clustered for administrative unit two (district).

We use an OLS model to test precipitation deficit effects that is similar to previous research evaluating the effect of SPI anomalies on violent conflict (Nordkvelle, Rustad & Salmivalli, 2017). Using this approach we consider rainfall to be a randomly assigned treatment variable (see also Vestby, 2019; Buhaug et al., 2020). These estimates are slightly different than for the growing season models:

$$Y_{it} = \beta_0 + \beta_1 X_{it} + Y_{it-1} + \beta_2 o\_p + \beta_3 i + \epsilon$$

with intercept β_0 and β_1, which captures the SPI (X_{it}) effect. We include month-province (o_p) and subdistrict (i) fixed effects (their coefficients, β_2 and β_3, respectively, are not reported). Standard errors ϵ are clustered in districts.

There are debates in the literature about using 'bad controls' (that are endogenous) and how to model certain assumptions about independence of observations. We test the effect of removing all control variables from the estimation and the results are essentially the same for all hypotheses (see Table A7 in the Online appendix). Considering SPI to be a random treatment variable in a regression with the fixed effects we specify reduces concerns about endogeneity (see Nordkvelle, Rustad & Salmivalli, 2017: 630). Because we are measuring within-unit change, adding control variables to the models (e.g. physical geography, infrastructure, or demography) will not fundamentally change our findings about the significance and direction of growing season and precipitation deficit effects.

Results

Table II presents our main results and the corresponding model diagnostics. To test H1–H2, we use the entire dataset. For H3–H4, we run our analysis on the growing season observations (resulting in a different number of observations in Models 1–2 and 3–4). Using ICEWS data covering the duration of the war, government- and rebel-initiated violence are both more likely during growing season months than at other times of the year (84.5% and 82.0% more likely, respectively). During later years of the war, ACLED results are quite similar (60.1% and 62.0% more likely). These findings lend strong support to hypotheses H1–H2. The results using a model with a (logged) event count dependent variable – this measurement approximates the intensity of violence – were similar (see Table III). The results without control variables were also nearly the same, but the effect was stronger and exceeds a doubling of the conflict risk (often $\geq$ 100%, see Table A7 in the Online appendix). Because of the importance of agriculture for the capabilities of armed actors, cropland is contested violently during the growing season.

We next test whether unusually low levels of rainfall raise the risk of violence during the growing season (see Table II Models 3–4). Covering the duration of the war, ICEWS Model 3a shows that dry conditions raise the risk of government-initiated conflict by 1.4%. Model 4a shows that ACLED government-initiated violence is 10.1% more likely. In the Online appendix we provide details of selected ACLED events that occurred in dry growing season months. These results, which lend support to H3, are somewhat sensitive to our measurement of dry conditions and the operationalization of the conflict variable. The dry conditions effect in the ICEWS data remains (conflict is 2.0% more likely in Table III Model 3a) when we model the (logged) incident count dependent variable. Our result also remains very similar in a model with no control variables (see a 1.6% increase in Table A7 Model 3a in the Online appendix). Table IV shows that ICEWS government- initiated attacks are not statistically significant when dry conditions are measured using SPI1 and SPI6 (see Models 1a and 3a). However, the ACLED results showing a higher risk of government-initiated violence in Table II remain for SPI6 in Table IV (see the 11.7% increase in Model 4a). Results for SPI2 and SPI4 confirm that government-initiated violence in the ACLED dataset is more likely during dry times of the growing season (see the 11.0% and 7.8% increase in Table A5 Models 2a and 4a). Table A5 also shows that there is no effect of SPI2 or SPI4 on any type of conflict in the ICEWS dataset. If dry conditions are defined as SPI3 ≤ -1.5 SD (see Table A6), the dry conditions effect also disappears in ICEWS but remains for government-initiated ACLED conflict, which is 16.6% more likely.

The ICEWS models show no statistically significant results for rebel-initiated conflict during dry conditions (H4). However, the ACLED results for later years of the war show that dry conditions are associated with a 5.6% increase in the chances that a subdistrict experienced rebel-initiated conflict (see Table II Model 4b). This finding holds with SPI6 instead of SPI3 (7.8% increase reported in Table IV), in a model with no control variables (9.0% in Table A7 in the Online appendix), and if we use the drier threshold for SPI3 (14.9% in Table A6). The support for H4 using ACLED is noteworthy, but

Table II. Effects of growing season and SPI3 upon conflict in the ICEWS (Models 1 and 3) and ACLED (Models 2 and 4) datasets

	Model 1: Growing season (ICEWS 2011–18)		*Model 2: Growing season (ACLED 2017–19)*		*Model 3: SPI3 ≤ –1.0 (ICEWS 2011–18)*		*Model 4: SPI3 ≤ –1.0 (ACLED 2017–19)*	
	a.	*b.*	*a.*	*b.*	*a.*	*b.*	*a.*	*b.*
(Intercept)	–0.059*	–0.044	0.106	–0.221	0.840*	0.875*	0.571*	0.462*
	[–0.116; –0.003]	[–0.109; 0.021]	[–0.170; 0.382]	[–0.519; 0.077]	[0.795; 0.885]	[0.824; 0.926]	[0.503; 0.639]	[0.415; 0.510]
Growing season month	0.845*	0.820*	0.601*	0.620*				
	[0.769; 0.921]	[0.742; 0.897]	[0.351; 0.851]	[0.366; 0.874]				
Temperature (°C)	0.002	0.001	0.004	0.01				
	[–0.000; 0.004]	[–0.002; 0.003]	[–0.007; 0.015]	[–0.001; 0.022]				
Spatial lag (a)	0.490*		1.162*					
	[0.452; 0.528]		[1.079; 1.244]					
Prior events (a)	0.197*		0.293*		0.158*		0.277*	
	[0.141; 0.254]		[0.017; 0.569]		[0.132; 0.183]		[0.231; 0.324]	
Spatial lag (b)		0.220*		1.395*				
		[0.167; 0.272]		[1.319; 1.471]				
Prior events (b)		0.197*		0.294		0.125*		0.223*
		[0.132; 0.261]		[–0.005; 0.592]		[0.092; 0.157]		[0.219; 0.227]
SPI3 ≤ –1.0 SD					0.014*	0.002	0.101*	0.056*
					[0.002; 0.025]	[–0.009; 0.013]	[0.055; 0.146]	[0.001; 0.111]
R^2	0.470	0.468	0.723	0.669	0.401	0.408	0.579	0.515
Adj. R^2	0.389	0.387	0.548	0.459	0.386	0.393	0.547	0.478
No. obs.	24,206	24,206	8,246	8,246	10,765	10,765	3,735	3,735

OLS regression; growing season models use subdistrict-month and year fixed effects; SPI3 models use month-province, subdistrict, and month fixed effects; district clustered standard errors; * zero effect is outside the 95% confidence interval; ‘a’ and ‘b’ designate events initiated by the government and non-government actors, respectively; observation N changes between ICEWS and ACLED models because the ACLED time-series is shorter; Models 3-4 have fewer observations than Models 1-2 because the test is for SPI3 effects during the growing season months.

Table III. Effects of growing season and SPI3 upon the (logged) number of conflict events in the ICEWS (Models 1 and 3) and ACLED (Models 2 and 4) datasets

	Model 1: Growing season (ICEWS 2011–18)		*Model 2: Growing season (ACLED 2017–19)*		*Model 3: SPI3 ≤ –1.0 (ICEWS 2011–18)*		*Model 4: SPI3 ≤ –1.0 (ACLED 2017–19)*	
	a.	*b.*	*a.*	*b.*	*a.*	*b.*	*a.*	*b.*
(Intercept)	–0.090*	–0.077	–0.272	–0.39	3.574*	3.442*	1.717*	1.175*
	[–0.177; –0.004]	[–0.196; 0.041]	[–0.695; 0.151]	[–1.033; 0.253]	[3.481; 3.666]	[3.326; 3.558]	[1.527; 1.907]	[1.098; 1.252]
Growing season month	3.477*	3.174*	1.418*	0.569*				
	[3.363; 3.592]	[3.026; 3.322]	[1.050; 1.786]	[0.017; 1.120]				
Temperature (°C)	0.004*	0.002	0.004	0.017				
	[0.000; 0.007]	[–0.003; 0.006]	[–0.012; 0.020]	[–0.007; 0.040]				
Spatial lag (a)	0.550*		5.766*					
	[0.470; 0.629]		[5.584; 5.948]					
Prior events (a)	0.341*		0.590*		0.292*		0.770*	
	[0.254; 0.427]		[0.167; 1.013]		[0.240; 0.344]		[0.639; 0.900]	
Spatial lag (b)		0.482*		4.997*				
		[0.365; 0.600]		[4.866; 5.127]				
Prior events (b)		0.351*		0.448		0.276*		0.413*
		[0.232; 0.469]		[–0.195; 1.091]		[0.203; 0.350]		[0.403; 0.422]
SPI3 ≤ –1.0 SD					0.020*	0.003	0.105	0.128
					[0.001; 0.040]	[–0.016; 0.021]	[–0.043; 0.252]	[–0.011; 0.267]
R^2	0.633	0.605	0.810	0.690	0.625	0.591	0.672	0.539
Adj. R^2	0.577	0.545	0.689	0.494	0.615	0.580	0.647	0.503
No. obs.	24,206	24,206	8,246	8,246	10,765	10,765	3,735	3,735

OLS regression; growing season models use subdistrict-month and year fixed effects; SPI3 models use month-province, subdistrict, and month fixed effects; district clustered standard errors; * zero effect is outside the 95% confidence interval; 'a' and 'b' designate events initiated by the government and non-government actors, respectively; observation N changes between ICEWS and ACLED models because the ACLED time-series is shorter; Models 3-4 have fewer observations than Models 1-2 because the test is for SPI3 effects during the growing season months.

Table IV. Effects of SPI1 and SPI6 upon conflict events in the ICEWS (Models 1 and 3) and ACLED (Models 2 and 4) datasets

	Model 1: SPI1 ≤ –1.0 SD (ICEWS 2011–18)		*Model 2: SPI1 ≤ –1.0 SD (ACLED 2017–19)*		*Model 3: SPI6 ≤ –1.0 SD (ICEWS 2011–18)*		*Model 4: SPI6 ≤ –1.0 SD (ACLED 2017–19)*	
	a.	*b.*	*a.*	*b.*	*a.*	*b.*	*a.*	*b.*
(Intercept)	0.842*	0.875*	0.569*	0.464*	0.841*	0.875*	0.564*	0.458*
	[0.797; 0.887]	[0.824; 0.926]	[0.501; 0.638]	[0.416; 0.512]	[0.796; 0.886]	[0.824; 0.927]	[0.497; 0.630]	[0.409; 0.507]
SPI1 ≤ –1.0 SD	–0.003	0.003	0.003	0.009				
	[–0.015; 0.009]	[–0.008; 0.013]	[–0.039; 0.046]	[–0.048; 0.065]				
Prior events (a)	0.158*		0.288*		0.158*		0.276*	
	[0.132; 0.185]		[0.242; 0.335]		[0.132; 0.183]		[0.230; 0.322]	
Prior events (b)		0.125*		0.227*		0.125*		0.220*
		[0.092; 0.157]		[0.222; 0.232]		[0.092; 0.157]		[0.212; 0.228]
SPI6 ≤ –1.0 SD					0.005	0.000	0.117*	0.078*
					[–0.007; 0.016]	[–0.011; 0.012]	[0.069; 0.164]	[0.027; 0.128]
R^2	0.401	0.408	0.575	0.514	0.401	0.408	0.581	0.516
Adj. R^2	0.385	0.393	0.542	0.477	0.385	0.393	0.548	0.479
No. obs.	10,765	10,765	3,735	3,735	10,765	10,765	3,735	3,735

OLS regression; month-province, subdistrict, and month fixed effects included; district clustered standard errors; * zero effect is outside the 95% confidence interval; ‘a’ and ‘b’ designate events initiated by the government and non-government actors, respectively; observation N changes between ICEWS and ACLED models because the ACLED time-series is shorter; Models 3-4 have fewer observations than Models 1-2 because the test is for SPI3 effects during the growing season months.

Table III shows that dry conditions do not increase the *intensity* of rebel-initiated conflict. It is possible that ICEWS results do not support H4 because the dataset covers earlier years of the war that are not available in ACLED.

In summary, we find strong and consistent support for H1 and H2. There is some evidence supporting H3, but the results are less consistent across models. The agreement among some precipitation models is worth reviewing. Using ACLED data, H3 is supported with multiple measurement windows for SPI3. Including our Online appendix analysis, H3 has support in the majority (five of seven) of our ACLED results. There is less support for H3 in the ICEWS analysis, but three of seven models suggest that dry conditions increase government-initiated conflict. Overall, we find little support for H4. Only three of seven models support H4 using ACLED. None of the ICEWS models support H4.

Conclusion

Many accounts of *violence to destroy Syrian agriculture* appeared in the international media during 2019. These reports implicate the Assad regime and rebel groups alike. *Violence to capture agriculture* has received less attention in the international media but is also a common strategy of all sides in the conflict. Beyond journalistic accounts and individual examples of violent incidents, our analysis suggests that these forms of conflict have occurred with regularity since the civil war began.

Conflict initiated by both the Syrian government and rebels is most common during local growing seasons when crops and farmland are most valuable. Additionally, there is evidence that dry conditions during the growing season further elevated the risk of government and rebel-initiated attacks. This effect of rainfall deficits is strongest using the ACLED dataset, which covers later years of the war. In our ICEWS analysis of all war years, the precipitation effect is sensitive to the duration of the rainfall deficit measurement and model specification.

We believe that dry conditions could elevate the risk of conflict as a result of harmful livelihood losses that follow droughts (Vestby, 2019; Buhaug et al., 2020). Existing research similarly found that rainfall deficits were associated with conflict in Indonesia when irrigation is lacking (Gatti, Baylis & Crost, 2020), violence across Africa when agricultural shortages raised the price of food in local markets (Raleigh, Choi & Kniveton, 2015), and communal attacks when groundwater supplies are insufficient (Döring, 2020).

Addressing calls for more detailed investigations of strategic violence over food resources (Koren, 2019), our findings are important for academics and policymakers alike. For those Syrians who remained on farms to tend crops during the war, the growing season was a particularly dangerous time. This violence occurred when the average farming Syrian could least afford to incur additional losses. By studying who fights over land (government or rebel actors), when the attacks take place (during important times for crops), and under what weather conditions (unusually low rainfall), our work is a logical extension of the existing literature that focused on environmental factors leading into the Syrian war.

Manipulating food supplies and damaging agricultural resources is not a new war fighting tactic. The Russian revolution, Spanish and Chinese civil wars, Japanese occupation of China, and the Serbian Siege of Sarajevo are all well-documented examples of this practice (Oberschall & Seidman, 2005). Government and rebel forces have targeted agricultural resources in African conflicts as well (Koren, 2019). Our study is most readily generalized to current events in Yemen and Iraq. The Saudi coalition has repeatedly attacked agricultural resources in its war to oust Yemen's Houthi-controlled government: 'as devastating as these strikes have been, more deadly to the Yemeni people overall are the coalition strikes targeting farms, fishing boats, food storage sites and transportation networks' (Sowers, 2018). As in Syria, ISIS in Iraq has also capitalized on agricultural strife; '[w]hen a particularly vicious drought struck in 2010, the fifth in seven years, they doled out food baskets' (Schwartzstein, 2017).

In ongoing research, we will further investigate several research themes that are beyond the scope of this article. First, one limitation of our analysis is the coarse aggregation of the rebel actor category. The ideological and strategic differences between Islamists, secessionist Kurds, and other opposition fighters are considerable, warranting more detailed analysis of violence initiated by each group. Also beyond the scope of this article, future research should use vegetation health metrics for wheat-producing farms derived from fine-resolution remote sensing data. Rainfall is commonly used as proxy for farmers' experiences, but the influences of land management and irrigation are recorded in greater detail by satellite data.

The security implications of our findings are clear. There is robust evidence that both government- and rebel-initiated conflict were most likely during important months in Syria's crop calendar. This trend has had dire implications for food security in a context where effective responses from international agencies are unlikely. Conflict also often occurred along with precipitation deficits, a worrisome finding because greater weather variability will accompany global warming (Giorgi, 2006; Dai, 2013) and could make serious ongoing violence even more intense.

Replication data

The dataset, codebook, and do-files for the empirical analysis in this article, along with the Online appendix, are available at https://www.prio.org/jpr/datasets/.

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