The infertile crescent: Water scarcity and conflict intensity in the Syrian civil war
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Master Thesis International Politics

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Abstract: *Due to climate change and rising temperatures, the world is more often facing extreme weather conditions like drought. Such conditions of water scarcity especially cause problems in countries dependent on agriculture, where failed harvests can cause negative income shocks and grievance development, influencing conflict. Focusing on the relationship between conflict intensity and water scarcity, this research explores the case of the Syrian civil war from 2011-2017, finding that over-time differences in temperatures can explain monthly variations in number of deaths. This research thereby confirms the fact that rising temperatures can lead to more intense conflict and concludes with brief discussion of policy recommendations to tackle drought-related conflict.*

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13.06.2022

Wordcount: 8549

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Introduction

The recent publication by the Intergovernmental Panel on Climate Change has painted a troubling picture: the impact of climate change today is already more widespread than first expected, and more extreme weather is yet to come (IPCC, 2022). With a global rise in temperatures, more often will humanity have to endure extreme weather such as heatwaves, floods, wildfires, storms and drought. Even when limiting global warming to 1.5 degrees C, as set in the Paris Climate Agreement, populations exposed to extreme floods will increase by 24% and nearly 1 billion people will suffer from drought (IPCC, 2022; Levin, Boehm & Carter, 2022). Apart from massively harming ecosystems, these events come with destructive political and social consequences (Hendrix & Salehyan, 2012; ICPP, 2022). Temporary shocks in rainfall and temperature – anomalies that connect to floods and droughts – are harmful to agriculture, causing harvests to fail and insecurity and poverty among farming societies to rise (Allouche, 2011; Hendrix & Salehyan, 2012; McLaughlin Mitchell & Pizzi, 2021). This often feeds into already existing social and political inequalities, impacting migration flows, affecting political behavior and increasing the likelihood that groups engage in riots, conflict and anti-governmental violence (Hendrix & Salehyan, 2012; De Juan, 2015; Ash & Obradovich, 2020).

One of the resources that seems to play a key role in all these extreme weather conditions is water. Be it in abundance or scarcity, water is causing problems all over the world. It is the key ingredient to human survival and a lack of rainfall, in combination with high temperatures, can cause destructively dry conditions, impacting a country's soil and its population (NIDIS, 2022). Scholars have found that countries that are suffering from drought are more likely to experience civil war (Percival & Homer-Dixon, 1996; Maxwell & Reuveny, 2000; Allouche, 2011; Couttenier & Soubeyran, 2013; Hsiang et. al, 2013), though not everyone agrees (Slettebak, 2012; Koubi, et. al, 2012; Salehyan & Hendrix, 2014). A topic that has received less scholarly attention is the effect that drought can have on the intensity of ongoing conflicts. Going beyond the debate of drought and conflict onset, this research uses the case study of the Syrian civil war to explore the relationship between water scarcity and conflict intensity. It finds that water scarcity cannot explain differences in conflict intensity between areas, but it does explain differences over-time, showing that there is significantly more violence in hotter months than in colder months. It identifies agricultural output as the underlying mechanism in this relationship, recognizing that opportunity costs decrease and grievances develop in times of unsuccessful harvests due to water scarcity (Percival & Homer-

Dixon, 1996; Maxwell & Reuveny, 2000; Salehyan & Hendrix, 2014; Gawande, Kapur and Satyanath, 2017; Crost et. al, 2018).

Located in the once fertile crescent, Syria is becoming more and more vulnerable to drought due to decreasing rainfall and ground water levels. Geographers have pointed to soil erosion in the Syrian coastal area, and the few projects that were conducted by the Syrian government raise great concerns about the damages of water erosion and Syrian ecosystems (Mohammed, et. al, 2020). Scholars have argued that the years-long drought preceding the Syrian civil war had a role in the onset of the conflict (Selby, 2019; Ash & Obadovich, 2020). But what do the conditions of water scarcity mean for its ongoing civil war? By analyzing data on terrestrial rainfall, air temperature and fatalities of the Syrian civil war, this research tries to answer the question: *What is the effect of water scarcity on the intensity of conflict in the Syrian civil war?*

While environmental effects always go hand in hand with political, economic and social factors of conflict (Allouche, 2011; Koubi et. al, 2014), research on water scarcity and conflict intensity is pressing. As global climate change accelerates, extreme weather becomes more common and societies become more vulnerable to conflict (Hendrix & Salehyan, 2012; IPCC, 2022). Furthermore, research has found that the effects of climate change interact with social, economic and political conditions that are known to influence conflict (Theisen, et. al, 2013; Detges, 2017). Therefore, by exploring the case of Syria, this research adds to the body of knowledge on water scarcity and conflict intensity, as well as the broader debate about how the depletion of natural resources influences conflict. It shows how climate change can manifest itself in civil conflict, which is something that will likely happen more in the near future due to the acceleration of global warming (Hendrix & Salehyan, 2012; ICPP; 2022). The findings of this research can be used as an incentive for international organizations and policymakers to reduce the impact drought can have on crops, in order to increase societal resistance of climate-related conflict (Crost et. al, 2018).

This thesis is structured in five sections. Firstly, this research presents an overview of the literature on resources and conflict, showing that findings on the topic of water scarcity remain inconclusive and inconsistent. It then sets out the theory of this thesis, focusing on agriculture as a mechanism of grievance development in dry areas like Syria. After that the empirical approach is explained, including a motivation for the case-selection, followed by the empirical results of the statistical analysis. This research concludes with a summary of the main findings, a brief discussion of policy recommendations, limitations and suggestions for further research.

Literature

Climate change and resource depletion

Global warming is affecting the world as we know it, making dry areas drier and wet areas wetter (Crost et. al, 2018; IPCC, 2022). Studies indicate that more than 30% of the world will experience different kinds of soil degradation, ranging from erosion to aridity and drought (Cerretelli, et. al, 2018; Mohammed, et. al., 2020). These changing weather and ground conditions do not just destroy livelihoods, but also bring about resource depletion, increasing the possibility of various forms of conflict (Delina & Cagoco-Guiam, 2018; IPCC, 2022).

The literature on resources and conflict intensity distinguishes between renewable and non-renewable natural resources. Renewable natural resources, like water, are often believed to connect to conflict via resource depletion or scarcity, while non-renewable natural resources, like gold and diamonds, are often hypothesized to lead to conflict via abundance (Homer-Dixon, 1999; Koubi, et. al, 2014). Especially the effects of the latter have been examined by research on conflict intensity, arguing that there is more violence in sub-national regions that are rich in such resources (Rigterink, 2020). Ways in which such an abundance in resources can relate to conflict include the selling of these resources, of which the economic gain can be used to finance getting weapons and soldiers; the formation of separatist movements to create their own state in resource rich areas; the development of grievances of ordinary citizens due to land exploitation and environmental degradation caused by resource mining; and an increase in fighting due to high pay off-value when conquering part of a resource-rich area (Fearon, 2004; Ross, 2004; Rigterink, 2020).

Resource depletion relates to conflict in other ways. The main argument is that people will have to compete over the little resources that are left (Homer-Dixon, 1994, 1999; Kahl, 2018). Especially now that the effects of climate change are accelerating, it seems important to understand how resource scarcity relates to conflict intensity. One of the key resources that seems to be affected by climate change is water (IPCC, 2022) – be it in the form of groundwater levels, rivers, lakes, rainfall – and thus it is of great importance to establish how water scarcity can influence conflict.

Water scarcity and conflict

In recent years, water scarcity has been one of the main challenges for countries in the Middle East, among which is Syria (Mourad & Berndtsson, 2011). From 2006 to 2010 the country saw one of its worst multiyear droughts, which was followed by a civil war since 2011. It is therefore not surprising that many scholars argue that the Syrian civil war was partly rooted in the effects of climate change (Selby, 2019; Ash & Obradovich, 2020; Holleis, 2021). Many studies on other conflicts have also identified an effect of water scarcity on conflict onset, stressing that these effects are stronger in agriculture dependent countries (Percival & Homer-Dixon, 1996; Maxwell & Reuveny, 2000; Couttenier & Soubeyran, 2013; Hsiang et. al, 2013). In countries where citizens' livelihoods are dependent on the land and the success of harvests, drought can have immense effects on their economic wellbeing, leading to conflict through migration (De Juan, 2015; Ash & Obradovich, 2020), the development of grievances (Homer-Dixon, 1991; Collier & Hoeffler, 2004; De Juan, 2015) or an interaction between water scarcity and bad political, economic and environmental policies to tackle these problems (Selby, 2019; Mohammed et. al, 2020). Not everyone agrees on what effect water scarcity has on conflict onset, as some scholars argue that water scarcity can actually have a pacifying effect (Salehyan & Hendrix, 2014), where others do not find any evidence of a relationship between water scarcity and conflict at all (Slettebak, 2012; Koubi, et. al, 2012).

While much research has been done on the relationship between water scarcity and conflict onset, results are inconsistent (Percival & Homer-Dixon, 1996; Maxwell & Reuveny, 2000; Slettebak, 2012; Koubi, et. al, 2012; Couttenier & Soubeyran, 2013; Hsiang et. al, 2013; Salehyan & Hendrix, 2014; De Juan, 2015; Selby, 2019; Ash & Obradovich, 2020; Holleis, 2021). A topic that has gotten less attention is how water scarcity can affect other conflict dynamics, such as intensity. When going beyond civil war and taking a wider scope on violence – including demonstrations, riots, strikes, communal conflict and anti-governmental violence – Hendrix Salehyan (2012) find that extreme deviations in rainfall, especially in very dry or wet years, have a positive relationship with all forms of political violence. Other studies consider the effect of weather shocks and agricultural successes on conflict. They show that weather shocks during the growing season in Africa caused more conflict incidents than weather shocks outside of the growing season (Harari & La Ferrara, 2014) and that more rainfall in the wet season in the Philippines was associated with more civil conflict in the following year, while more rainfall in the dry season showed a decrease in civil conflict in the following year (Crost, et. al, 2018). A study that focusses on land productivity as an indicator for water supply finds that one standard deviation decrease in land productivity increased killings by 60 percent in the Maoist conflict in India (Gawande, Kapur & Satyanath, 2017). While these studies shed a light on the relationship between deviations in weather conditions and conflict intensity, they do not provide conclusive answers about the effect water scarcity or drought can have on conflict intensity. This research aims to bridge this gap in literature by looking at how water scarcity relates to conflict intensity in the Syrian civil war.

Theory

As we have seen, shocks in rainfall can produce destructive crop conditions, relating to more conflict (Harari & La Ferrara, 2014; Gawande, Kapur & Satyanath, 2017; Crost, et. al, 2018; Roche, et. al, 2020). Not just rainfall, but also temperature influences crop conditions, where excessive heat can reduce crop supply (Bollfrass & Shaver, 2015). Little rainfall in combination with high temperatures causes a destructive combination for agriculture, causing harvest to fail, food to become scarcer and food prices to rise (Bellemare, 2012). Such higher food prices and resource scarcity have been shown to lead to social instability, group violence and civil conflict (Bellemare, 2012; Gawande, Kapur & Satyanath, 2017; Kahl, 2018). The effect of weather conditions on harvests are thus key in determining the relationship with violence, which is why this research identifies agricultural dependence as the underlying mechanism through which water scarcity connects to conflict intensity (Percival & Homer-Dixon, 1996; Maxwell & Reuveny, 2000; Salehyan & Hendrix, 2014; Gawande, Kapur and Satyanath, 2017; Crost et. al, 2018).

When a large part of the population relies on work and income through the agricultural sector, many farming families experience negative income shocks when drought destroys the harvest of the year (Roche, et. al, 2020). Not only do many people lose their income, the decreased output of agricultural goods also increases nation-wide food prices (Bellemare, 2012). This causes troubling situations for many people, giving rise to grievances over the unequal distribution of resources and general social instability (Bellemare, 2012; Roche, et. al, 2020). Important in this grievance development is blame attribution. Grievances due to scarcity can be developed towards fellow communities (Gawande, Kapur & Satyanath, 2017), but also against the state (Homer-Dixon, 1994, 1999; Percival & Homer-Dixon, 1996; Kahl, 2018). While problems with water scarcity are caused by climate change, the effects can be mitigated by government policy (Selby, 2019). When governments ignore issues of water availability, society will most likely feel the effects of scarcity, often playing into already established social and economic cleavages in society (Selby, 2019). For example, economic reform policies in Syria significantly disadvantaged farmers, causing them to lose ownership of farmland and making groundwater irrigation for crops more expensive (Selby, 2019). Thus, when Syria was hit by drought, farmers were the ones who struggled with water scarcity the most, losing crops, livestock, and their main source of income. In this way, government policy that disadvantages farmers, in combination with water scarcity, can cause grievances towards the state (Homer-Dixon, 1994, 1999; Percival & Homer-Dixon, 1996; Kahl, 2018; Selby, 2019).

When negative income shocks and grievance development are included into a cost-benefit calculation of violence, the cost of violence decreases (Roche, et. al, 2020). Unemployment reduces opportunity costs of joining an insurgent group as people have fewer economic alternatives (Salehyan & Hendrix, 2014; Crost et. al, 2018). With more people joining, insurgent groups build strength and tend to become more active in times and areas of water scarcity (Crost et. al, 2018; Hussona, 2020). Additionally, during bad harvest years, there is little to lose but much to gain. Next year the harvest can be better, and thus being in control over more land may offer a better shot at crop productivity and increased income the next year. This leads to increased violence during times of drought (Gawande, Kapur & Satyanath, 2017). Therefore, agricultural dependent countries are likely to experience an increase in violence in areas and periods of water scarcity. This research proposes the following hypotheses about the relationship between water scarcity and conflict intensity:

H1 (Scarcity hypothesis)
There is a positive relationship between water scarcity and conflict fatalities.

H2 (Spatial hypothesis)
The Syrian civil war is more fatal in areas with more pressing water scarcity.

H3 (Temporal hypothesis)
The Syrian civil war is more fatal in months with comparatively more pressing water scarcity.

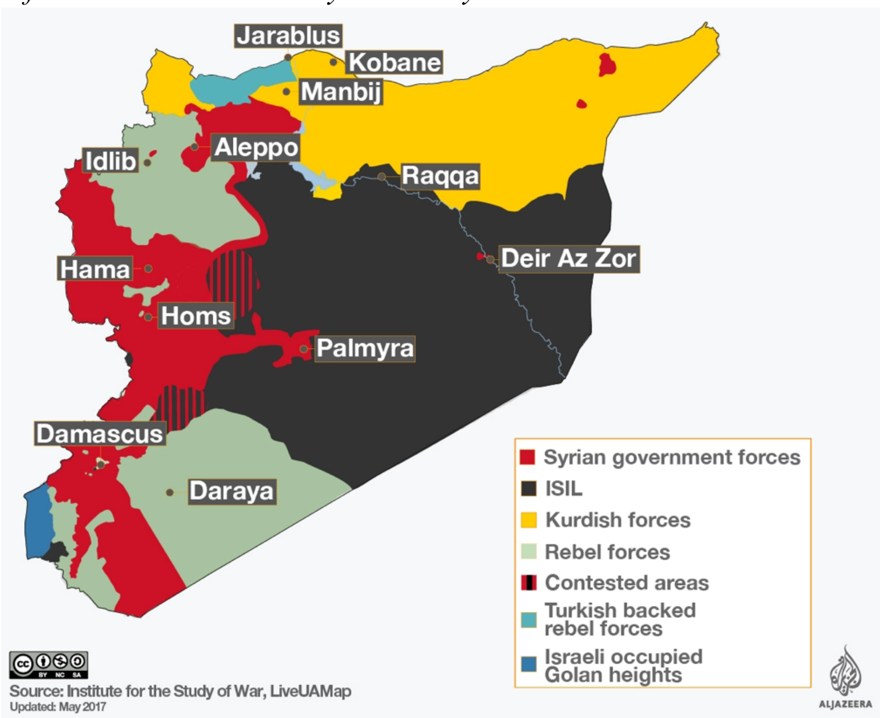
Empirical design

Dependent variable

The dependent variable for this research is conflict intensity. To measure intensity, I will use the number of deaths per governorate in Syria between 2011 and 2017, using the UCDP Georeferenced Event Dataset. This dataset contains detailed information on the location of battles and attacks, giving specific coordinates as well as the names of the town and political administrations. It includes a best estimate of the number of fatalities per attack, which is the total sum of all types of violence within one battle or attack. The UCDP distinguishes between three types of violence: state-based violence (use of force a between state and another actor), one-sided violence (use of force by a state or armed group against civilians) and non-state violence (use of force between non-state actors) (UCDP, 2022a). In order to have balanced and clean panel data, the different observations of battles or attacks are combined, giving a sum value of all fatalities per governorate in a specific year and month.

As this research argues that grievances and reduced opportunity costs may give some people more reasons to fight, it would be interesting to look at one-sided violence and non-state violence. However, one of the main characteristics of the Syrian civil war is that there has not been a clear-cut confrontation between rebels and state forces. Violence came from many sides and territorial control has changed significantly throughout the conflict (see Figure 1 for the situation in 2017). Several insurgencies have fought government forces, but later more radical rebel groups such as Jabhat Fateh al-Sham and Islamic State of Iraq and the Levant (ISIL) joined the fight, as well as the Russian army (UCDP, 2022b). Figure 1 shows that the contested territories between these actors do not keep to governorate borders, and sometimes the territories are very small. As the data of this research are structured in panels per governorate, the differences in territories between and within governorates cannot be accounted for. Looking at solely one type of violence would thus be insufficient to understand the entire scope of the conflict's intensity. Therefore, the analysis will include all three kinds of violence to determine conflict intensity, accounting for how rebels react to droughts, but also accounting for the violent counter-reaction of the other forces involved in the conflict.

Figure 1: Map of territorial control in Syria in May 2017



Source: Al Jazeera (2017)

Independent variable

The main independent variable of this research is water scarcity, which will be measured by using data on rainfall and air temperature, which are both important indicators for monitoring drought (NIDIS, 2022). Where rainfall indicates scarcity or abundance of water, air temperature is important for determining drought as it gives an indication of how much (ground)water evaporates (NIDIS, 2022). The data on terrestrial rainfall and air temperature come from the geographical department of the University of Delaware (Matsuura & Willmott, 2018a; 2018b). The data is aggregated in 0.5 by 0.5-degree grids of longitude and latitude, taking the monthly average of air temperature (in degrees Celsius) and the monthly total of precipitation of rain in mm, thereby also mapping out the seasonal variations in weather conditions. As these grids are quite small, the data is well suited for analysis on water scarcity at a regional level. For this analysis, the data is transformed from grid-level into political administrations, aggregating the monthly data on temperature and rainfall on the level of the 14 governorates of Syria. Where different data points fall within the same governorate, the average of these data points were taken as the monthly average for that governorate.

Estimation and measurement

The timeframe of this research is 2011-2017[1], turning the data into time-series cross-sectional panel data. The analysis will start with linear regressions, after which these results are compared to fixed effects models that control for the differences between governorates and months. The coefficients for fixed effects are determined with two methods: the dummy method and the within estimation method. The dummy method creates a dummy variable for every unit of the time-invariant subject, in this case governorates and months of the year. The within estimator fixes the effects of governorates and months by running the regression with demeaned variables.

Furthermore, the models include a series of relevant controls. First, the population size of the governorates, noting that governorates with a larger population will most likely have a higher number of fatalities. For this, I use the OCHA Syrian population census of 2004 (OCHA, 2004). Unfortunately, this is the most recent census that is available. It is important to note that the population numbers of the governorates, as well as Syria as a whole, have changed drastically since the beginning of the war due to many internally- and externally displaced people, as well as the casualties that the war has caused. Therefore, the population numbers per

[1] The civil war started in 2011, and the datasets on climatic factors end in 2017.

governorate might not be accurate, but they still give an indication of population size and density. Second, the size of the agricultural sector in each of the governorates, as it is expected that governorates that are more dependent on agriculture will experience more fatal conflict in the case of water scarcity. To do so, data on barley and wheat production (per '000 tonnes) are used, as well as data on livestock farming (per '000 heads) from the Food and Agriculture Organization of the United Nations (FOA, 2021). Barley is a crop that is mostly rainfed, so a lack in rainfall will have a direct effect on its production (FOA, 2021). Wheat farming on the other hand is mostly irrigated with the use of groundwater, thus being more dependent on the interplay of rainfall and temperature (FOA, 2021; NIDIS, 2022). These data cover the crop years of 2019/2020 and 2020/2021. While these data may not fall within the timeframe of this research, they are still useful as the numbers of agricultural production between the two years differ quite drastically, showing production in a 'good' and 'bad' year. Therefore, the average output of these two years is taken as the value for each of the governorates in Syria. Finally, the urban/rural divide. Cities are struck by droughts in different ways than rural areas, as agricultural work is less prevalent amongst city populations. It is therefore good to differentiate between fatalities that were caused by violence within cities and outside of cities. This can be done by means of a dummy variable, that codes urban fatalities as 1 and all other fatalities as 0. However, as this research works with governorate panels, cities within governorates cannot be accounted for. Nevertheless, the city of Damascus has its own governorate, and thus fatalities within this urban governorate are coded as 1, where all other governorates are coded as 0. Table 1 shows the descriptive statistics of the dependent, independent and main control variables per governorate.

Table 1: descriptive statistics of dependent and independent variables

	N	Mean	Std. Deviation	Minimum	Maximum
Best estimate of fatalities	1010	261.13	341.75	0	2389.00
Air temperature	1010	18.55	8.14	1.55	36.88
Precipitation	1010	25.81	42.26	0	358.90
Population	1010	1,352,684.28	935,393.70	66,627	4,045,166
Urban	1010	0.08	0.27	0	1
Wheat production	1010	172.55	165.25	0	507.40
Barley production	1010	92.60	139.87	0	481.30
Livestock	1010	417.05	288.65	0	797

Case selection

Before moving into the analysis, a word on the selected case is due. Syria is an appropriate case as it meets all the requirements for this study: it has a civil war, it has a large agricultural industry and has problems of water scarcity. The agricultural sector is a source of livelihood opportunities for half of the Syrian population, making up more than one fifth of their GDP[2] (Tull, 2017; Alloush, 2018). Syria saw one of its worst multiyear droughts from 2006 to 2010, which had a huge impact on harvests and economic conditions of Syrians. 800,000 people lost their income and 85% of the country's livestock died (Holleis, 2021). The drought amplified the already ongoing problem of ground water depletion that started due to the huge expansion of irrigated farming since the late 1980s (Selby, 2019; FAO, 2021). This agricultural dependence makes the Syrian population more volatile to climatic changes and water scarcity. Therefore, I expect to find the theorized relationship between drought and conflict intensity in Syria, making Syria a most-likely case.

One of the main limitations of doing a single case study is the external validity. As it focusses on one case, some may argue that the results cannot be generalized to other countries. However, water scarcity is a challenge for most Middle Eastern countries, as well as conflict. Therefore, the findings of this research can be applied to most countries in the region. Furthermore, scholars have already found similar relationships in other parts of Asia (Gawande, Kapur & Satyanath, 2017; Crost, et. al, 2018), showing prospects for also generalizing the results outside of the Middle East. Additionally, while we should not forget the importance of social, economic and political forces in shaping war dynamics, research into the effects of climate change is more pressing than ever, as extreme weather conditions are becoming more common (IPCC, 2022). Being located in the once fertile crescent, Syria is now battling long-term droughts, environmental degradation and civil war, showing that global warming can transform any ecosystem into one that is more vulnerable to conflict (Hendrix & Salehyan, 2012). Therefore, the Syrian civil war may be setting a precedent for other cases that are yet to come, and this research offers insights into what can be expected when that happens.

Analysis

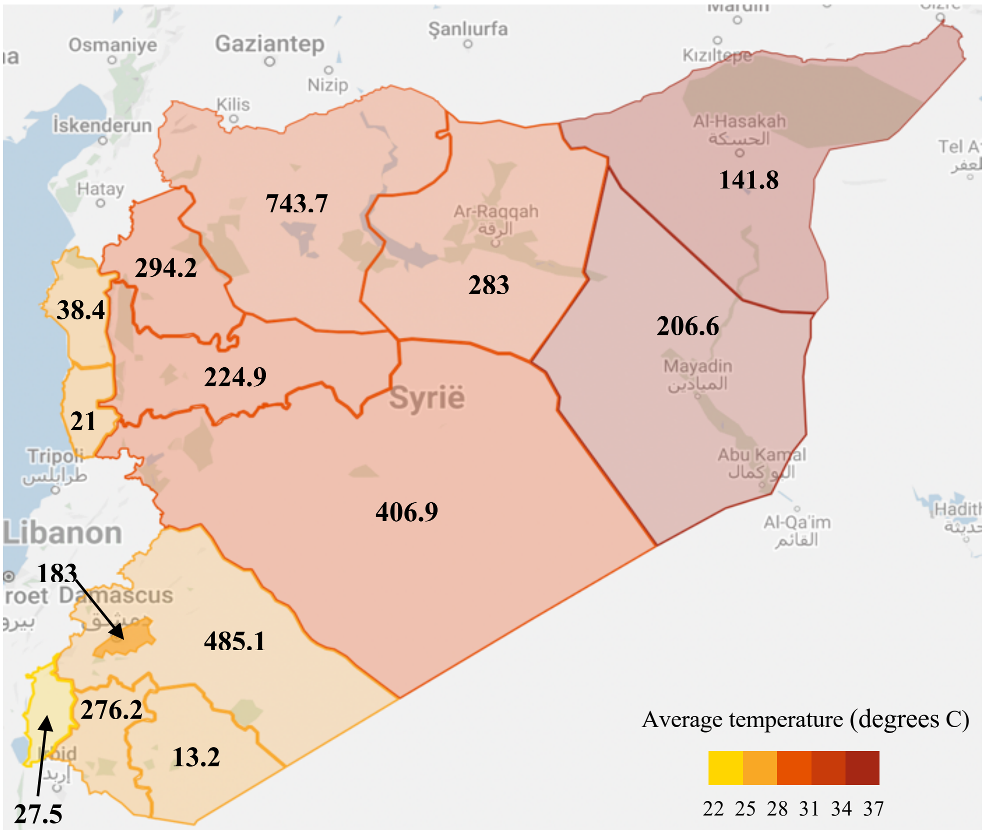
Data exploration

To get an idea of how conflict is dispersed throughout Syria, this analysis starts off by checking the total sum of fatalities per governorate and per month (Table A1 & A2 in Appendix). It

[2] Numbers from before the start of the war in 2011

shows that the bulk of all violence in the Syrian civil war between 2011 and 2017 is perpetrated in Rif Dimashq and Aleppo governorate (Table A1). The highest count of fatalities can be found in Aleppo governorate, accounting for almost one fourth of all fatalities in Syria from 2011-2017. Other governorates that have seen a larger share of fatalities are Homs, Idlib and Daraa governorate. Governorates that seem to be spared excessive violence are the smaller ones located in the West of the country, As Suwayda, Latakia, Quneitra and Tartus. When looking at the dispersion of fatalities among months, we find August as the month with most fatalities, accounting for 9.8% of all fatalities in the Syrian civil war. As this is a hot summer month, this could indicate a positive relationship between water scarcity and conflict intensity. March was the month with the least violence, accounting for 7.4% of all fatalities (Table A2). This indicates that there may be a difference in intensity of violence between summer and winter months, however the differences are quite small.

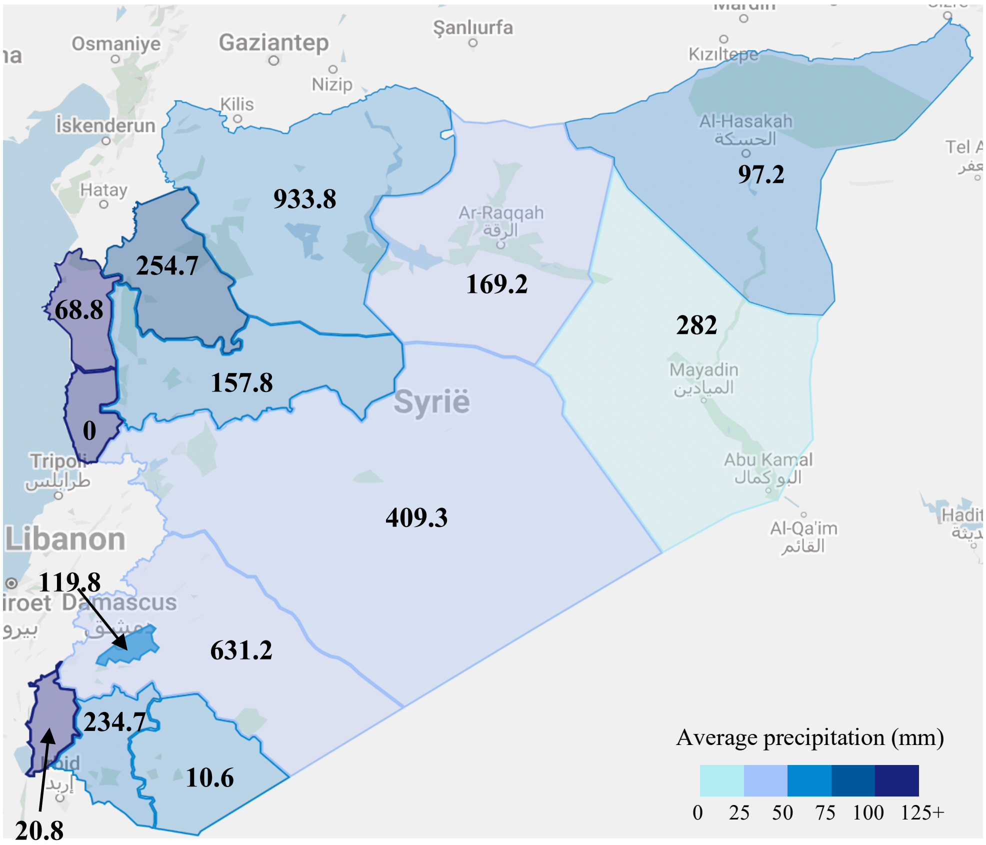
Figure 2: Average fatalities in a heat map of July, per governorate



Note: average fatalities and temperatures of July, 2011-2017. Colors indicate temperatures; bold numbers indicate average fatalities within each governorate.

Figures 2 and 3 visualize the numbers of fatalities in each governorate on climatic maps. Figure 2 shows the fatalities and temperatures in the month of July, one of the hottest and driest months of the year. Figure 3 shows the fatalities and precipitation in the month of January, one of the wettest and coldest months of the year. When comparing the two maps, it becomes clear that the four smaller governorates in the West that have seen relatively little violence – As Suwayda, Latakia, Quneitra and Tartus – have more moderate temperatures in summer and higher amounts of rainfall in winter (also see Figure A1 & A2 in Appendix). This suggests that there may be a relationship where a regional abundance of water would have a pacifying effect. When turning to the bigger governorates with higher numbers of fatalities, this relationship seems less prominent. While seeing large numbers of violence in most of the warmer governorates (Figure 2), the two hottest governorates in the East (Al Hasakah and Deir ez Zor) have less fatalities than the somewhat more moderate governorates in the middle of the country (Idlib, Aleppo, Ar Raqqah, Hamah and Homs). And while the large governorates in the middle of the country see quite a high number of fatalities and not so much rainfall (Homs and Rif Dimashq), the wetter governorate in the North (Aleppo) has the highest number of fatalities of all governorates (Figure 3).

Figure A2: Average fatalities in a rain map of January, per governorate



Note: average fatalities and precipitation of January, 2011-2017. Colors indicate mm of precipitation; bold numbers indicate average fatalities within each governorate.

This quick exploration shows that there are some interesting correlations, but no clear relationship is identified yet. Aleppo has seen the highest number of fatalities in the Syrian civil war, and while it is one of the warmer governorates, it also has a decent amount of precipitation with over 300mm of rain each year (Figure A1 & A2 in Appendix). The governorate that has seen the second highest number of fatalities, Rif Dimashq, is not necessarily one of the hottest governorates, but it is one that yearly gets very little rainfall (Figure A1 & A2 in Appendix). Latakia, Tartus and Quneitra are by far the wettest governorates of Syria (Figure 3), and together they account for only 3.5% of all fatalities (Table A1 in Appendix). These observations suggest that there might be a relationship between water scarcity and conflict intensity, where higher temperatures would lead to more fatalities and higher levels of rainfall would decrease the number of fatalities. However, following this line of reasoning, the two hottest and driest governorates Ar Raqqah and Deir ez Zor should be the most violent, yet they only account for 5.7% and 7.9% of all fatalities in the Syrian civil war. Thus, further investigation is necessary. Some simple correlations between precipitation, temperature and fatalities, indicate that temperature might not have a significant effect on number of fatalities ($r = 0.035$, $p = 0.284$) but precipitation does ($r = -0.099$, $p = 0.002$). This gives an indication of the relationship between the variables on water scarcity and fatalities, but to determine more accurate results this research now turns to linear regressions and panel linear regressions using fixed effects.

<u>Linear modelling</u>

Table 2 shows the results of several linear models, presenting how temperature and precipitation relate to the number of fatalities in the Syrian civil war. The individual effects of temperature and precipitation on fatalities were first run separately in M1 and M2. This found a positive effect for temperature, meaning that higher temperatures would lead to more deaths. This effect is however not statistically significant at conventional levels ($p = 0.201$). As can be seen from M2, precipitation has a negative and statistically significant relationship with fatalities ($p = 0.004$), indicating that less rainfall is associated with more fatalities. These results are similar to the results of the bivariate correlations, offering support for H1: There is a positive relationship between water scarcity and conflict fatalities.

However, these results change when the predictors are put in a model that does not only consider water scarcity, but also controls for (urban) population and agriculture (M3). The effect for temperature remains positive, however it decreases in size and remains statistically insignificant ($p = 0.494$). Precipitation not only loses its statistically significant effect ($p = 0.652$), but the direction also changes, indicating that more precipitation would lead to more fatalities. Yet the large standard errors for these coefficients suggest that no meaningful conclusions can be drawn from it.

Table 2: Linear models for fatalities in Syria

	M1	M2	M3
Intercept	229.813***	279.806***	-0.458
	(26.75)	(12.558)	(0.355)
Air temperature	1.688		0.880
	(1.321)		(1.288)
Precipitation		-0.724**	0.116
		(0.254)	(0.278)
Total population			0.000***
			(0.000)
Urban			-160.500***
			(38.330)
Wheat production			0.585**
			(0.186)
Barley production			-0.975***
			(0.220)
Livestock			0.057
			(0.045)
Adjusted R^2	0.001	0.007	0.375
N	1010	1010	1010

Note: p < 0.01, p < 0.001 **, p < 0.000***, numbers in parentheses are standard errors*

When comparing the adjusted R^2 for the different models, we do see that more variation in the number of fatalities is explained in M3. This increase in explained variance can mostly be attributed to the control variables. First, as expected, population size has a positive and statistically significant effect ($p < 0.000$). There is a negative and statistically significant effect for the urban dummy ($p < 0.000$), indicating that, on average, there is less death in the urban governorate of Damascus than in other governorates. There is a positive and statistically significant effect for wheat production ($p = 0.002$) but a negative and significant effect for barley production ($p < 0.000$). The holding of livestock has a positive effect, but it is small and insignificant ($p = 0.200$). Interesting here is that the effect for rainfall is positive and statistically insignificant, but the effect for barley production is negative and highly significant, while barley is a rainfed crop. This shows that rainfall itself may not have a direct or large effect on fatalities, but its effects on agricultural production does. The effect for barley tells us that there is less violence in governorates with a higher barley production, which highlights the explained theory that successful harvests limit conflict intensity (while unsuccessful harvests spark more conflict).

Thus, while taken as the only predictor, precipitation significantly influences the number of fatalities, increasing deaths as precipitation goes down, thereby explaining 0.8% of the variance in the number of deaths. While the effect for temperature is not statistically significant, it is positive, indicating that fatalities increase by 1.688 for every degree C increase in temperature. Together this offers support for H1, showing that water scarcity can increase number of fatalities – even if the explained variance of these two predictors is quite low. The control variables in M3 therefore take away significance of the variables for temperature and precipitation, showing that population demographics and agricultural production are stronger predictors for the number of fatalities in Syria than precipitation and temperature.

Fixed-effects modelling

While the linear models give an indication of the effects of temperature and precipitation, they do not take into account the panel character of the data. It could be that the linear regression has cancelled out the effects per governorate and changes the effects that temperature and precipitation have on fatalities. To account for these potential differences per governorate, this analysis now turns to model with fixed effects. For $M1_{fe}$, this is done for every governorate within Syria, resulting in a coefficient for the independent variables that holds true over the differences per governorate. Table 3 shows the results of these fixed effects models.

Taking the individual effect for temperature in a fixed effects model shows a positive, but statistically insignificant relationship with fatalities (b = 0.745, p = 0.485, Table A2 in Appendix). The effect for precipitation is negative (b = -0.010, p = 0.965), but very small and statistically insignificant (Table A2 in Appendix). $M1_{fe}$ in Table 3 on the page below runs the fixed effects model including the control variables, but neither of these effects are statistically significant. These results proved to be stable after running a similar model with a within estimator regression. Both temperature and precipitation have a positive effect on fatalities, which means that an increase in both temperature and precipitation could be related to an increase in fatalities across governorates. Most control variables also have a positive relationship with fatalities, showing there would be more fatalities in more densely populated governorates, as well as more fatalities in densely populated urban areas like Damascus. The effects for wheat and barley production have changed direction. Wheat production now has a negative coefficient, meaning that there is less violence in governorates with more wheat production, while the coefficient for barley production tells us there is a slight increase in fatalities in governorates with more barley production. The coefficient for livestock farming shows that in governorates with 1000 more head of livestock, there are 1.098 more fatalities.

Table 3: fixed-effects analysis on fatalities

	$M1_{fe}$	FE1	FE2	$M2_{fe}$
Fixed effects	governorate	month	month	month
Air temperature	1.067	16.208***		18.076***
	(1.418)	(2.574)		(4.298)
Precipitation	0.115		-1.025***	-0.177
	(0.196)		(0.338)	(0.273)
Total population	0.000			0.000***
	(0.000)			(0.000)
Urban	112.300			-180.760
	(83.722)			(28.472)
Wheat production	-2.188			0.461*
	(1.315)			(0.129)
Barley production	0.163			-0.966***
	(26.907)			(0.136)
Livestock	1.098			0.006
	(0.695)			(0.045)
Adjusted R^2	0.615	0.004	-0.001	0.383
N	1010	1010	1010	1010

Note: $p < 0.01$, $p < 0.001$ **, $p < 0.000$***; numbers in parentheses are heteroscedasticity consistent standard errors (HC1)*

Judging from these results, controlling for differences in governorates does not seem to be very productive for explaining the variation in the number of fatalities, thus failing to find support for H2. None of the predictors in $M1_{fe}$ significantly affect fatalities and the individual effects of temperature and precipitation even have a negative adjusted R^2 (Table A2 in Appendix). Yet, even when there are no significant predictors, $M1_{fe}$ has an adjusted R^2 of 0.615, meaning that this model would explain 61.5% of the variance in fatalities. This leads us to believe something is not right in the model, which could be attributed to over-time trends that are not included in the model (Frost, 2018).

Now turning to temporal effects (H3), I ran several models that fix the effects per month of the year (FE1, FE2 & $M2_{fe}$ in Table 3). FE1 shows the individual relationship between temperature and fatalities, having a positive and statistically significant effect ($p < 0.000$). It shows that fatalities increase by 16.208 with a monthly temperature increase of 1 degree C. FE2 shows that precipitation has a statistically significant and negative effect on fatalities ($p < 0.001$), holding that fatalities decrease with 1.025 for every mm of increase in rain. Taken together, these models offer support for H3, showing that for any month that is hotter and/or drier, fatalities will go up. $M2_{fe}$ (Table 3) includes the control variables in the model, but in this instance these must be interpreted with caution as they are coded as time-invariant variables in this research. The effects for temperature and precipitation however do change per month, and the effect for temperature remains statistically significant and even increases in size ($p < 0.000$). Precipitation no longer has a significant effect ($p = 0.499$), but the effect remains negative, indicating an increase in fatalities with little rainfall. Thus, while only one of the two predictors of water scarcity is significant, the model still shows support for H3: The Syrian civil war is more fatal in months with comparatively more pressing water scarcity. There is a clear relationship between temperature and fatalities, showing that there are far more fatalities in hotter months than in cold months. And while the effect of precipitation is not significant, it is negative, pointing to an increase in fatalities during drier months. This shows that the Syrian war was indeed more fatal during months with more water scarcity.

Conclusion

Global warming has caused the average global temperature to rise, resulting in more extreme weather all over the world. Even when we manage to keep to the Paris Climate Agreement, 30% of the world will experience different kinds of soil degradation and nearly 1 billion people will suffer from drought (Cerretelli, et. al, 2018; Mohammed, et. al., 2020; IPCC, 2022; Levin, Boehm & Carter, 2022). These changes in climate massively harm ecosystems and can bring about resource depletion (IPCC, 2022). The resource that becomes more and more important as the world is suffering from the effects of climate change is water. In countries where citizens' livelihoods are dependent on the land and the success of harvests, drought can have immense effects on their economic wellbeing. When harvests fail, farmers experience negative income shocks, which can lower the opportunity costs of joining an armed group (Crost et. al, 2018; Roche, et. al, 2020). Additionally, when the problems of water scarcity and the effects of drought are not well governed, grievances are likely to develop against the state (Homer-Dixon, 1994, 1999; Percival & Homer-Dixon, 1996; Kahl, 2018). These two processes can increase the occurrence of violence, thereby linking water scarcity to conflict intensity in agricultural dependent countries.

By taking Syria as a most-likely case to find this theorized relationship, this research conducted a variety of different models to investigate the relationship between high temperatures and low precipitation on the number of deaths in Syria. This analysis has shown that while water scarcity does not explain differences in fatalities per region, it does explain the variation in fatalities over time. It has shown that there is a significantly higher number of fatalities in warmer months than there is in colder months. Heat can cause crops to fail, ground water to evaporate and soil to deteriorate. In combination with a negative (yet statistically insignificant) effect for rainfall, these predictors show that in months of more water scarcity, the conflict in Syria tends to be more violent.

These results add to the debate on climate change and conflict, showing that warmer and drier circumstances can increase violence within an established conflict. This supports the literature that argues that drought influences conflict (Percival & Homer-Dixon, 1996; Maxwell & Reuveny, 2000; Couttenier & Soubeyran, 2013; Hsiang et. al, 2013). It shows the importance for the world to understand the effects that climate change can and will have on conflict. Governments and international organizations should take these results as an incentive to make society and agriculture more drought resistant by drafting extensive plans for water control. This can include control of groundwater levels, investments in irrigation, effective methods for catching rainfall, crop diversification and shielding land from the direct heat of the sun to avoid crop failure, groundwater evaporation and soil depletion. The Syrian civil war may just be one case, but the effects of drought will not stay limited to Syria alone. Therefore, it is of the utmost importance to protect populations across the world from drought and its violent effects.

Limitations

The original datasets on fatalities, temperature and precipitation were suited for grid-analysis. However, for this research, these were aggregated to the level of political administration (governorates), which has likely caused many finer details to be lost and obscured some relevant local variation. This might explain, for example, why no evidence was found for the spatial hypothesis of this thesis. Unfortunately, this research was not fit for a grid-analysis due to time and technical constraints. The data of the control variables had a panel structure, which made it hard to match with grid-level data. Therefore, the decision was made to aggregate all data of this research into panel data. Furthermore, there are some limitations due to the timeframe of certain data. For example, the Syrian civil war has created more than 12 million internally- and externally displaced persons (UNHCR, 2021), making the population consensus of 2004 outdated. Additionally, numbers on agricultural production were only available for 2019-2021, while it would have been more interesting to compare yearly numbers of agricultural output with yearly numbers of fatalities. Unfortunately, the lack of accurate and timely data is not uncommon for countries at war, which explains the missing data on population- and agricultural censuses in Syria from 2011-2017.

Other scholars are encouraged to conduct further research on the topic of water scarcity and conflict intensity, this time using grid-data and grid-analysis to investigate local variation in fatalities. Furthermore, instead of considering all types of violence, it would be interesting to disaggregate between the different forms of violence that the UCDP distinguishes, in order to test if the theory of grievances and opportunity costs holds for state-based violence, one-sided violence and non-state violence individually. Finally, while the causal mechanism of agricultural dependence explains the effects that were found in the analysis, the theory is not actually tested. It would be interesting for further (qualitative) research to investigate how drought can lead to more intense conflict, and why it is that temperature has a stronger effect than rainfall.

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Appendix

Table A1: dispersion of conflict in Syria, per governorate

Governorate	Sum of fatalities	% of all fatalities
(A)Aleppo	64194	24.3%
(B)Al Hasakah	8843	3.3%
(C)Ar Raqqah	15100	5.7%
(D)As Suwayda	654	0.3%
(E)Daraa	18332	7.0%
(F)Damascus	11492	4.4%
(G)Deir ez Zor	20826	7.9%
(H)Hamah	16957	6.4%
(I)Homs	27784	10.5%
(J)Idlib	24142	9.2%
(K)Latakia	5825	2.2%
(L)Quneitra	2655	1.0%
(M)Rif Dimashq	46224	17.5%
(N)Tartus	714	0.3%
Total	*263,740*	*100%*

Table A2: dispersion of conflict in Syria, per month

Month	Sum of fatalities	% of all fatalities
January	20063	7.6%
February	23662	9.0%
March	19629	7.4%
April	21033	8.0%
May	21382	8.1%
June	21424	8.1%
July	22537	8.6%
August	25768	9.8%
September	22607	8.6%
October	23464	8.9%
November	21408	8.1%
December	20673	7.8%
Total	*263,740*	*100%*

Figure A1: average monthly air temperature per governorate

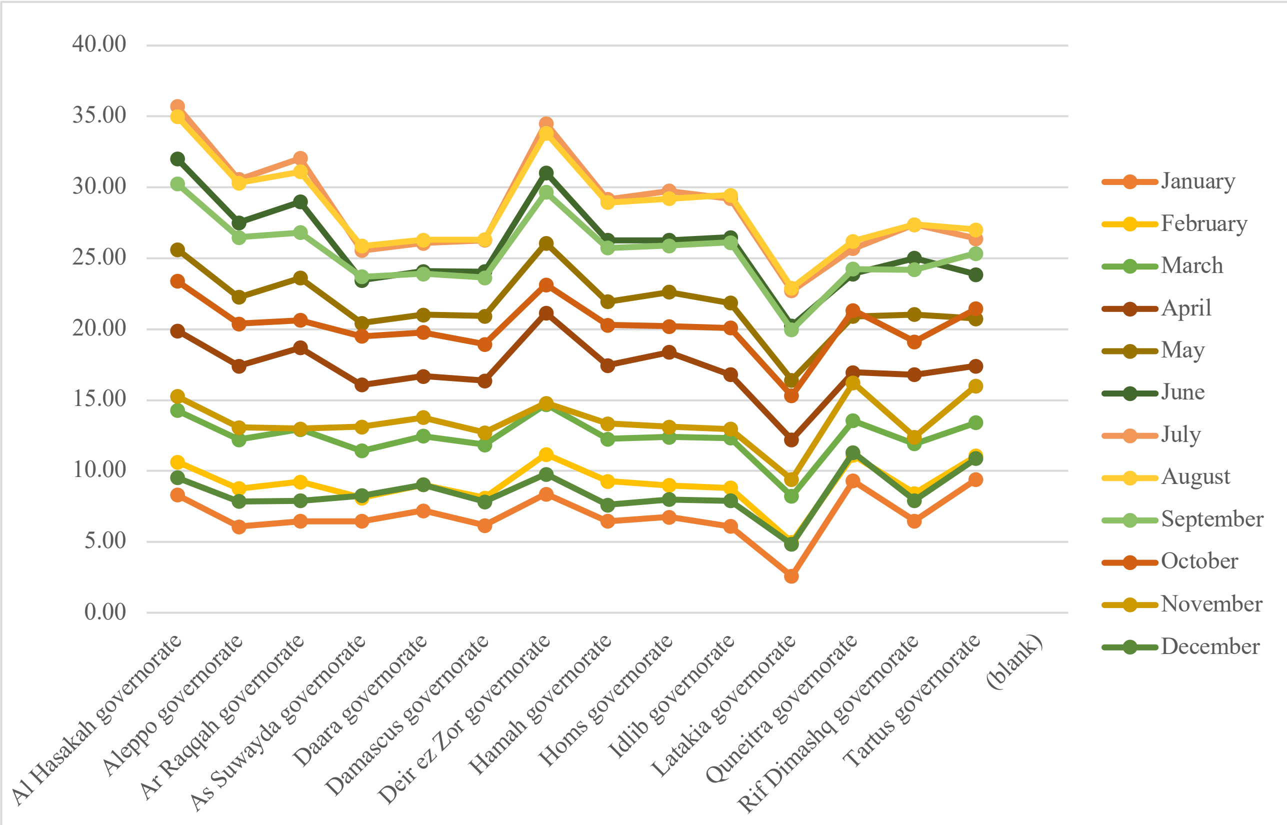

Figure A2: average monthly rainfall per governorate, together making up yearly average

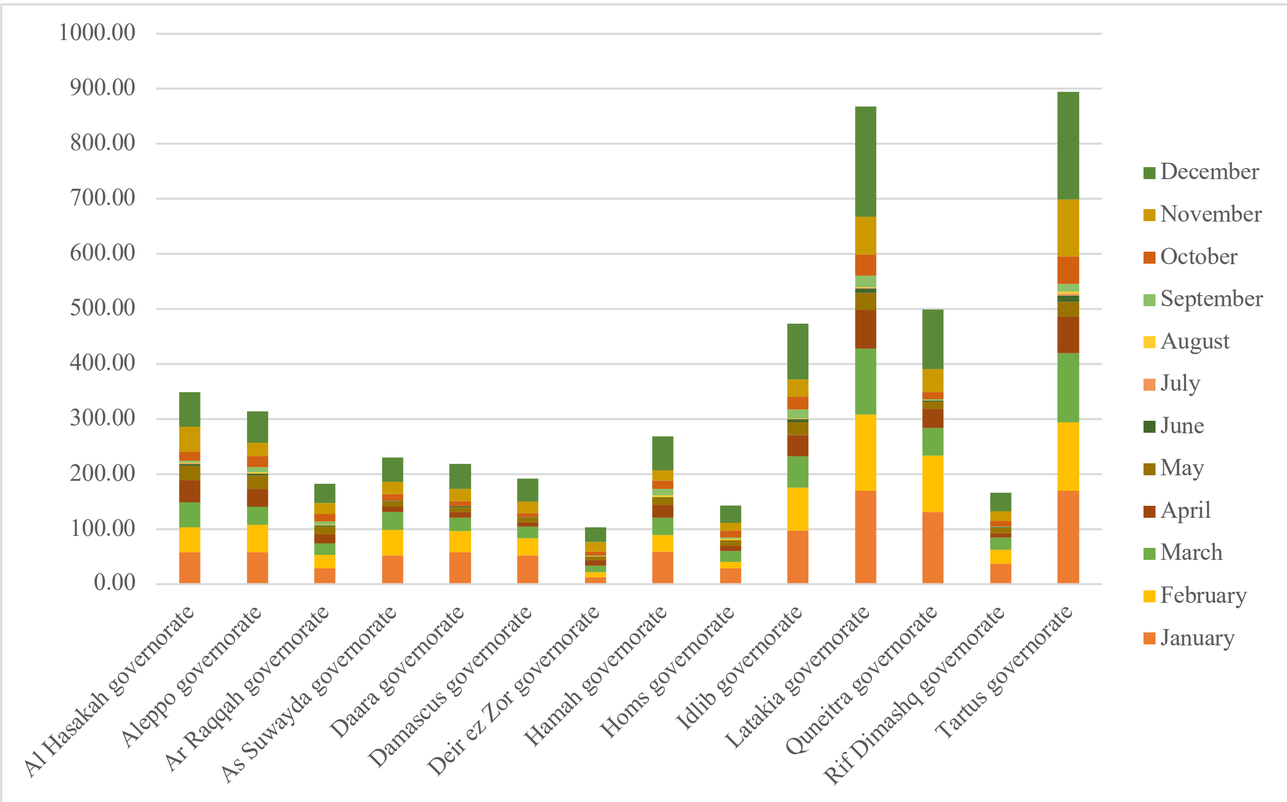

Table A3: governorate fixed-effects models for individual predictors

	A1	A2
Fixed effects	governorate	governorate
Air temperature	0.745	
	(1.242)	
Precipitation		-0.010
		(0.091)
Adjusted R^2	-0.014	-0.014
N	1010	1010

Note: p < 0.01, p < 0.001 **, p < 0.000***; numbers in parentheses are heteroscedasticity consistent standard errors (HC1)*