WHEN THE TAPS RUN DRY: WATER STRESS AND SOCIAL UNREST REVISITED

Alfonso Sánchez, Guillermo Rylance [1]
University Loyola Andalucía

Abstract:
Water stress presents a wide range of concerns that can jeopardize international security. Neo-Malthusians scholars constantly warn of water conflicts, while institutionalists argue that possible water conflicts are the result of poor water distribution and can therefore be prevented by stronger institutions. Prima facie evidence of water-related social unrest suggests that both arguments are interrelated, not separate. We evaluate this argument statistically, by drawing on a sample of five North African countries for the 2000-2015 period. Our analysis finds robust evidence in support of institutional arguments. We also find evidence of an interaction effect between climatic variables and poor institutional water access on social unrest: positive temperature anomalies decrease the likelihood of unrest, while negative rainfall anomalies increase it.

Keywords: Climate change, water scarcity, institutions, conflict, North Africa.

***Título en Castellano**: Cuando las fuentes se agotan: estrés hídrico y agitación social. Una revisión*

Resumen:
El estrés hídrico puede suponer un peligro para la seguridad internacional en varias direcciones. Los académicos que siguen los principios neo-maltusianos ponen la atención de forma recurrente en los conflictos por recursos, mientras que los institucionalistas señalan que dichos conflictos son el resultado de una mala distribución del agua y, por lo tanto, pueden ser prevenidos mediante el fortalecimiento institucional. La evidencia prima facie de agitación social relacionada con el agua sugiere que ambos argumentos están interrelacionados. Evaluamos este argumento estadísticamente, recurriendo a una muestra de cinco países del norte de África para el período 2000-2015. Nuestro análisis encuentra evidencia sólida para respaldar los argumentos institucionales. También encontramos evidencia de un efecto de interacción entre las variables climáticas y el escaso acceso institucional al agua en los disturbios sociales: las anomalías positivas de la temperatura disminuyen la probabilidad de disturbios, mientras que las anomalías negativas de las precipitaciones lo aumentan.

Palabras clave: *Cambio climático, escasez de agua, instituciones, conflicto, Norte de África*

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[1] Alfonso Sánchez Carrasco is Assistant professor at University Loyola Andalucía. E-mail: asanchezc@uloyola.es. Guillermo Rylance González is undergraduate student at the same university. E-mail: grylancegonzalez@al.uloyola.es
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1. Introduction.

Recent popular and policy discourse have brought claims of potential 'water wars' to the forefront of the international security agenda.[2] Since 2015, the World Economic Forum's Annual Risk Report has listed 'water crises' at the top of global threats.[3] UN Secretary-General António Guterres recently urged UN Security Council members to "commit to investing in water security to ensure durable peace and security for all communities and nations."[4] Water scarcity is often portrayed as an issue that can destabilize social cohesion in developing countries**.** Since Sen's (1981) seminal work, scholars and policymakers recognize that poor distribution is the main cause behind resource scarcity. Despite an aggregate rise in access to drinking water in developing countries since the 1990s, water-related conflicts caused by poor water distribution persist. On top of this, recent multidisciplinary research and policy reports have boosted neo-Malthusian arguments cautioning that anthropogenic climate change and population growth will make scarce resources ever scarcer, fomenting competition and grievances that can trigger conflicts (World Bank 2014; Gleick 2014; Almer et al. 2017). While existing scholarship mostly threats water distribution and water scarcity as opposing theories, we recognize that both strands of literature complement each other.

This article makes two contributions. First, we assess different theoretical links between water distribution services across North African countries and their relationship to low-intensity forms of social unrest such as riots and peaceful protests. Although water distribution is often treated as a binary concept, we use the WHO/UNICEF JMP disaggregated criteria to better examine this relationship.[5] Second, while we recognize that institutional-induced scarcity is the main cause behind water scarcity, we empirically test whether climate change has begun to further constrain government's ability to supply drinking water, increasing the likelihood for social unrest. For instance, following a three-year drought, on January 2017 the government of Cape Town declared April 21 as "Day Zero" –the day when the government would have to shut off the taps due to a depletion of the city's water supply. Soon thereafter protesters chanting "water for all or the city must fall" took to the streets blaming the local government for not being able to prevent the looming crisis. In Brazil in 2017, protest and riots took place in the city of Itu after government officials tried to cut off the city's water network, due to water levels severely declined after the region experienced two of the driest seasons on record.[6] As water stress worsens in some parts of the world, it is important to examine the potential impacts that could disrupt social cohesion.

North Africa is chosen for three reasons. First, current physical water scarcity—the low availability of water resources compared to demand for water, is among the worst in the world (Figure 1). Second, over 60 percent of the population in the region lives in areas with high levels of water stress.[7] Finally, parts of North Africa are likely to experience adverse socio-economic impacts as hot temperature extremes become more frequent and rainfall more erratic.[8]

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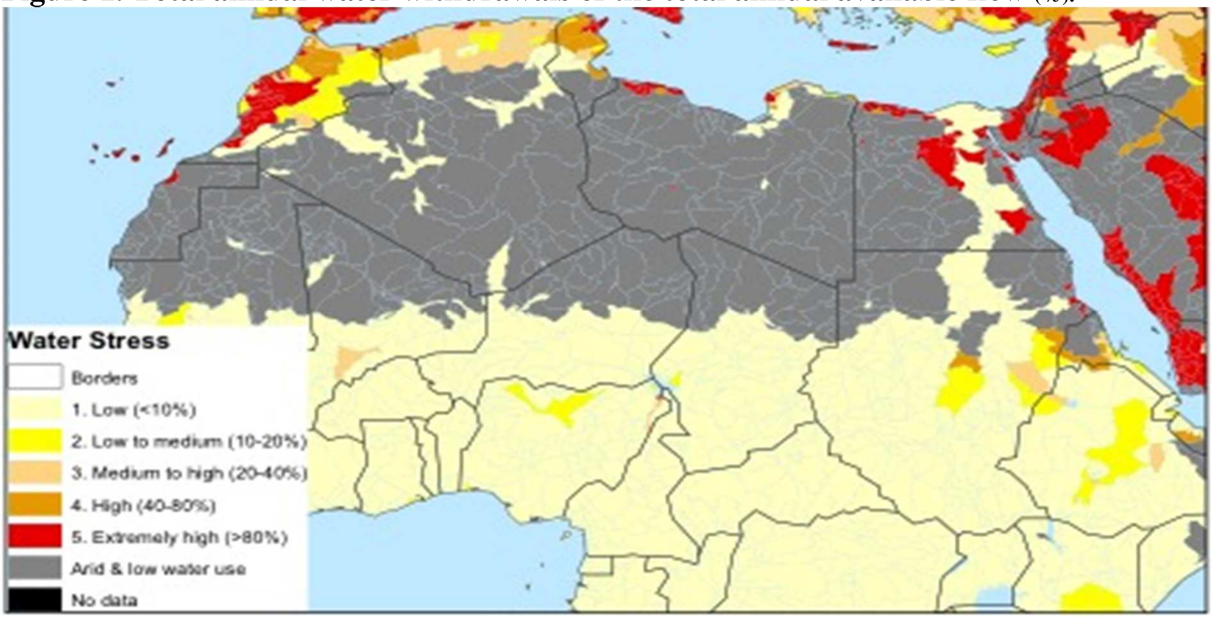
[2] Klare, Michael T. (2001): *Resource Wars: The New Landscape of Global Conflict,* New York, Metropolitan.
[3] World Economic Forum's Global Risks, at http://reports.weforum.org/global-risks-2015/
[4] UN News, at: http://www.un.org/apps/news/story.asp?NewsID=56918#.Wnre81PwbUJ
[5] The WHO/UNICEF Joint Monitoring Program for Water Supply, Sanitation and Hygiene (JMP) has reported country, regional and global estimates of progress on drinking water, sanitation and hygiene (WASH) since 1990. For more information see: https://washdata.org
[6] For more on the 2017 Brazilian water crisis, see: http://agenciabrasil.ebc.com.br/en/geral/noticia/2017-03/over-850-brazil-cities-face-major-water-shortage-issues ; for the latest updates on "Day Zero" see: https://coct.co/water-dashboard/
[7] World Bank Indicators, at: www.data.worldbank.org
[8] For robust evidence see, see Intergovernmental Panel on Climate Change (IPCC) (2014): *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II*

However, while some claim that climate change and variability is already imposing additional pressures on freshwater resources, academic consensus on the present and future impacts of climate change on water scarcity remain elusive.[9]

Figure 1. Total annual water withdrawals of the total annual available flow (%).



Data source: World Resource Institute

This article is structured as follows. Immediately below we provide an overview of the key causes for water scarcity. We then summarize the current literature climate change and conflict and present our theoretical argument and hypotheses. The section after that presents data and operationalization measures, followed by a discussion of our empirical findings. Finally, concluding remarks are offered on the implication of the findings and potential ways to move forward.

2. Causes of water scarcity

The Earth has a substantial amount of water resources. However, about 97 percent of the planet's water is salt water in the oceans and the rest is freshwater.[10] This limited amount of freshwater is mostly located in glaciers and ice caps, and only a small amount is readily available for human consumption in lakes, rivers, ground water or rainfall.[11] Furthermore, the spatial and temporal distribution of freshwater varies within regions and countries. Measuring water scarcity is a complex task. Designating a country as water "scarce" depends on several factors: a) the abundance of physical water in nature and how much of that water can be

to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, United Kingdom and New York, Cambridge University Press, Cambridge; The United Nations Economic and Social Commission for Western Asia (ESCWA) *et al.* (2017): *Arab Climate Change Assessment Report Main Report*, Beirut, ESCWA; available at E/ESCWA/SDPD/2017/RICCAR/Report; and the World Bank (2014): *Turn Down the Heat: Confronting the New Climate Normal*, Washington, DC, World Bank.

[9] For a review of the literature see: World Bank (2017): *Beyond Scarcity: Water Security in the Middle East and North Africa. MENA Development Series*, Washintong DC, World Bank; Copetti, Diego, and Luca Carniato: "Regional Assessment of Climate Change in the Mediterranean" in Navarra, Antonio and Tubiana, Laurence (eds.) (2013): *Regional Assessment of Climate Change in the Mediterranean*, *Volume 1*, Springer.

[10] Gleick, H. Peter, and Palaniappan, Meena: "Peak water limits to freshwater withdrawal and use", *Proceedings of the National Academy of Science*, Vol. 104, nº 23 (2010), pp. 11155-11162.

[11] *Ibid.,* pp. 11157

replenished by the natural water cycle; b) the current needs of the population; c) and the spatial and temporal scales used to determine scarcity.[12] At the individual level, however, water scarcity refers to the lack of safe and affordable access to water to satisfy personal needs. Therefore, governments play a crucial role in guarantying that all citizens have are water secure.

Within every country water can become scarce is three different ways. First, *demand-induced* scarcity befalls from population growth or an increase in per capita consumption.[13] So far this "doomsday" scenario has not ensued, due to a sufficient amount of water availability. Second, *supply-induced* scarcity can result from a disruption to the total quantity of production in the supply chain. This occurs by degradation or depletion caused from human activity by means of using more than its available in local ecosystem. While global water availability remains sufficient—for now—climate change is expected to intensify the water cycle, altering the availability, quality, and timing of water, which will increase short-term water scarcity in some parts of the world. In short, evidence of local supply-induced scarcity episodes are expected to occur more frequently. However, resource optimists contend that there is no inherent water scarcity, and if and when scarcity occurs, technological innovations, market forces, human ingenuity and cooperation will provide ways to overcome scarcity.[14] While there is evidence that technological innovations can reduce groundwater extraction,[15] and that cooperation between actors is likely in times of scarcity,[16] the is little support for the hypothesis that market forces improve water outcomes.[17]

Finally, *institutional-induced* scarcity occurs when political leaders do not equally distribute resources among the citizenry. This type of scarcity is the primary cause for the persistence of water and food scarcity worldwide. Political institutions are responsible for allocating water to different sectors of the economy: urban (public water supply system), industry, energy and agriculture. Therefore, distribution failures occur when lack of political will stagnates or worsens distribution efforts. This can result from ineffective policies or from old struggles among social groups over the allocation of the commodity.[18] According to a report by the World Bank (2017), some parts of North Africa and the Middle East more than half of the water consumption is unsustainable, which is leading to groundwater being abstracted faster than it can be replenished and ensuing groundwater depletion. Climate change is expected to make things worse.

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[12] For a detailed discussion, see: Rijsberman, Frank R: "Water Scarcity: Fact or Fiction?", *Proceedings of the 4th International Crop Science Congress,* nº 80 (2014), pp. 5–22.

[13] Homer-Dixon, Thomas, and Jessica Blitt. (1998): *Ecoviolence: links among environment, population, and security*, Rowman & Littlefield Publishers.

[14] Lomborg, Bjørn (2003): *The skeptical environmentalist: measuring the real state of the world*, Cambridge, Cambridge University Press.

[15] For evidence supporting cornucopian arguments, see: Ward, Frank A., and Pulido-Velazquez, Manuel: "Water conservation in irrigation can increase water use", *Proceedings of the National Academy of Sciences,* Vol.105, nº 47 (2008), pp. 18215-18220.

[16] Böhmelt, Tobias *et al.:* "Demand, Supply, and Restraint: Determinants of Domestic Water Conflict and Cooperation." *Global Environmental Change,* Vol. 29 (2013), pp 337–48.

[17] Katz, David L. (2008): *Water, economic growth and conflict: Three studies,* Doctoral Dissertation, University of Michigan.

[18] Sen, Amartya (1981): *Poverty and famines: an essay on entitlement and deprivation*, Oxford, Oxford University Press.

2. The conflict nexus: a matter of politics *and* climate.

Multidisciplinary research reveals that water misallocation, rather than scarcity per se, is what increases the likelihood of conflict. However, little research has been devoted to untangle the causal links between access to different water services and social unrest. Access to drinking water is unequivocally, an essential aspect of the social contract between constituents and political leaders. Therefore, lack of political will to improve water coverage have clear political consequences. Evidence suggests that developing countries tend develop an urban bias—the tendency to favor urban areas over rural dwellers—when allocating resources. Because city-life proximity helps spread emotions of anger and frustration and allows them to linger longer in the mind of individuals through constant reinforcement, political leaders try to prevent massive popular unrest that can result in their removal from office. Social unrest is more likely when there is space for tolerance by a polity and when individuals are neither sufficiently free to make regular claims, nor so repressed as to prevent them from trying to do so (e.g., anocracies). Polity IV data for the 2000–2015 period shows that all North African countries to fit this category—with the exception of Tunisia, which became a democracy in 2013. As such, water–related social unrest is likely to arise from horizontal inequalities—when power and resources are unequally distributed between groups based on ethnicity, culture, language or religion—that facilitate mobilization for conflict.

Available data on water management indicates that although overall water access in North Africa has increased since the early 2000s, millions of people still lack adequate water services. From 2000 to 2015 the percentage of people with access to safely managed, basic, and unimproved services improved, while access to limited services worsened and the percentage of individuals drinking from surface water stagnated. By definition, individuals with access to limited water service spend more than 30 minutes per day collecting water. Therefore, we argue that aside from the lost time devoted to collect water, these individuals are burdened with other costs associated with this practice. First, prices charged at some public points or at "neighbor's" sources may vary, which can take a toll on household finances. Similarly, these segments of the population often fall prey to opportunist "businessman" and criminal networks to unlawfully dig wells or seize water from government supplies to resell at a higher price.[19] Second, households often invest in storage containers, private well construction or the purchase of motorcycles, carts or bicycles to limit the time of water collection. Third, households are often burdened with costs related for diarrhea treatments from drinking contaminated water. Consequently, most households in rural areas boil their water to kill germs and parasites, and they are, therefore, also burdened by costs associated with water treatment such as the purchase of fuels like firewood, biomass, charcoal and electricity.[20] This is crucial given that the issue that most frequently drives Africans to militant action is the erosion of their purchasing power. Based on these assumptions we argue that those with access to limited water service are more likely to develop or intensify existing socioeconomic and political grievances towards the state, which in turn, increases their mobilization for conflict more likely. Therefore, we expect that:

H_1. High levels of limited water services *increase* the frequency and occurrence of water-related social unrest

[19] For instance, Morocco's Water Police became operational in 2018 to curve the misuse and exploitation of water resources. For more information, see: https://www.moroccoworldnews.com/2017/12/236957/morocco-water-police/

[20] For individual level analysis on the costs of water collection in Africa, see: Cook, Joseph; Peter Kimuyu, and Dale Whittington: "The Costs of Coping with Poor Water Supply in Rural Kenya", *Water Resources Research*, Vol. 52, nº 2 (2016), pp. 841–59.

Similarly, those who depend on surface water lack access to government delivery sources, forcing them to drink water directly from rivers, lakes, ponds and the like. Not only does this segment of the population fall prey to illegal service providers, they are also more likely to be burdened with costs associated with preventing and treating waterborne diseases, which ought to increase the propensity to partake in social unrest. However, we also acknowledge that: (1) this segment of the population is, in a sense, used to living without adequate water services, and (2) are more likely to be targeted by domestic and international welfare programs aimed at alleviating water stress. In other words, individuals who repeatedly lack water services have adapted to their situation and are tougher to mobilize. Therefore, we have no expectation on the directionality of the association between those who depend on surface water and social unrest. Based on the discussion presented above, we hypothesize that:

> H_2. High levels of surface water dependence are associated with the frequency and occurrence of water-related social unrest.

While we do not dispute that poor water distribution is the main cause behind water-related disputes, our second empirical contribution is to test if climate variability has begun to further constraint water distribution, which in turn, increases the likelihood of social unrest. According to the Pacific institute, there have been 400 recorded water-related conflicts worldwide from 3000 BC to 2017.[21] Thirty-two percent of these conflicts occurred over the last six years, which are among the warmest years on record. The majority of these events took place in Africa. The recent emergence of climate change has boosted neo-Malthusian hypothesis that in times of above–average–decreases in rainfall, people, communities, and nations will violently compete for even scarcer resources.[22] Freshwater is essential for survival. Therefore, the assumption is that water stress will generate grievances, frustration, which in turn, can lead to conflict.

A competing hypothesis suggest the opposite: there will be less conflict in times of above–average–decreases in precipitation, since there will be little to fight for.[23] This line of thought assumes that relative gains from engaging in conflict during drier periods are too low to justify conflict participation. Exploring this argument, Tir & Stinnett (2012) find that water scarcity does increase the likelihood of militarized conflict, but that institutionalized agreements can mitigate this effect.[24] Similarly, focusing on Central Asia's Syr Darya water allocation problems, Bernauer & Siegfried (2012) find that climate-change induced interstate conflicts over water scarcity are unlikely.

Directly challenging the neo-Malthusian premise, a cohort of conflict scholars has shifted the focus from 'scarcity' to abundance. A third causal mechanism proposes that the risk of conflict increases following wetter-than-average years given that it can prompt rent-seeking and recruitment behavior of participants.[25] A final hypothesis suggests that the probability of conflict decreases following wetter–than–average years as resources are abundant and groups

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[21] Pacific Institute, at: http://www2.worldwater.org/conflict/list/

[22] Homer-Dixon, Thomas F. (1999): *Environment, scarcity and conflict*, New Jersey, Princeton University.

[23] Raleigh, Clionadh, and Dominic Kniveton: "Come Rain or Shine: An Analysis of Conflict and Climate Variability in East Africa", *Journal of Peace Research,* Vol. 49, nº 1 (2012), pp. 51–64.

[24] Tir, Jaroslav, and Douglas M. Stinnett: "Weathering Climate Change: Can Institutions Mitigate International Water Conflict?", *Journal of Peace Research*, Vol. 49, nº 1 (2012), pp. 211–25.

[25] Hendrix, Cullen. S., and Idean, Salehyan: "Climate Change, Rainfall, and Social Conflict in Africa." *Journal of Peace Research,* Vol. 49, nº 1 (2012), pp. 35–50.

are self-sufficient. However, recent empirical research find little evidence for a direct water–conflict nexus.

Due to its geographical location, North Africa has limited freshwater sources compared to other regions. By some accounts, even before the effects of climate change "kicked-in" the world was already facing a water crisis. Gleick and Palaniappan (2010) argue that many regions in the world had already surpassed peak ecological water.[26] Most countries in North Africa depend mainly on rainfall and partially on modest groundwater reserves, making the region among the most water scarce in the planet.[27] This also makes the region more vulnerable to environmental impacts from a changing climate. As a rule of thumb, wet regions are likely to become wetter and dry regions are likely to get drier, for instance: Northern Africa has experienced an increase in heatwaves per year, while Western Africa has seen an increase in extreme rainfall and floods.[28] In a recent study, Schilling et al. (2012) forecast that rainfall in North Africa is expected to decrease between 10 and 20 percent and temperature is likely to increase by up to 3°C by 2050.[29] In Morocco alone, rainfall is prognosticated to decrease up to 40 percent by 2050. Not surprisingly, the majority Morocco's rivers are expected to suffer water shortages by 2020.[30]

The AR5 IPCC report (2014) asserts that there is strong confidence among various projection models of a decrease in surface and ground water around the Mediterranean. According to the report, decrease in water availability will be more likely from increases in evapotranspiration due to warmer temperatures, rather than from decreases in rainfall.[31] Contrary to these findings, a recent report suggests that evapotranspiration in the Mediterranean coast will only decrease a 14 percent by 2050.[32] These discrepancies in the findings are sensitive to precipitation and population projection estimates. Although lack of consensus eluded us, one scholarly article after another confirm that water availability *is* decreasing in the region.[33] For instance:

- Water availability in Morocco has dropped from 3,500m^3 per person per year in 1960 to 645m^3 per person in 2015—below the water poverty level of 1,000m^3 per person per year.[34]

- In Algeria surface water availability has declined from 13.5 billion m^3 per year at the end of the 1970 to 10 billion m^3 in the first decade of the 21st century.[35]

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[26] The authors define "peak ecological water" as the point after which the cost of disruptions that occur in the ecological services that water provides exceeds the value provided by additional increments of water use by humans for economic proposes.

[27] See: Arab Environment: Climate Change-Impact of Climate Change on Arab Countries (2009), at http://www.afedonline.org/afedreport09/Full English Report.pdf

[28] See IPCC, 2014, *op. cit,* p.251.

[29] Schilling, Janpeter *et al.*: "Climate Change, Vulnerability and Adaptation in North Africa with Focus on Morocco." *Agriculture, Ecosystems and Environment,* Vol.156 (2012).

[30] M. Ait, Kadi: "From Water Scarcity to Water Security in the Magherb Region. The Moroccan Case", en Marquina Antonio (ed.) (2004): *Environmental challenges in the Mediterranean 2000-2050*, Dordrecht, Kluwer Academic.

[31] World Bank. *op. cit*. p. 131.

[32] See ESCWA et al. *op. cit*. p. 29.

[33] Sebri, Maamar (2013): "Residential Water Industry in Tunisia – a Descriptive Analysis", *The Journal of North African Studies*, Vol.18, nº 2, pp. 305–23.

[34] For more information see: https://www.globalwaterjobs.com/News/countryinfocusmorocco.html

[35] Zareb, Djamel: "Les programmes de développement en eau dans la stratégie de développement de la sécurité alimentaire en Algérie", *Presentation at the Faculty of Political Science and Sociology*, UCM, October 30, 2012.

- In 2014 the government of Egypt reported that its per capita water resources have dropped 60 percent since 1970.[36]

The many impacts of climate variability on water scarcity are diverse and complex: warmer-than-average temperatures often increase water demand for human consumption, crops, and in some instances to cool of vulnerable infrastructure, while rainfall anomalies prevent the recharge of freshwater and damage crops. A recent estimate suggests that the continuation of current climate trends will lead to a GDP decline of 14 percent for the MENA region.[37] Given the regions arid climate, irrigated agriculture accounted and still accounts for the largest share of water withdrawals in the region (Table 1). Projected population growth and rural to urban migration are expected to further increase the demand for water, primarily in the agriculture and urban sectors. Therefore, as temperatures continue to rise, and rainfall becomes more erratic, governments will have to prioritize how to best allocate water across each economic sector. These changes can have severe economic and political impacts that will add to the region's age-old water challenges.[38]

Table. 1 Water withdrawal as % of total water withdrawal by sector in 2007

	Agriculture	*Urban*	*Industrial*
Algeria	65	22	13
Egypt	86	8	6
Libya	83	14	4
Morocco	87	10	3
Sudan	96	3	1
Tunisia	82	14	4

When water availability decreases, governments have several options available to them. First, shift water use from one sector to another with a higher social value. Though, most agricultural dependent countries in the region hesitate to implement such measure for fears of weakening the local and national economy. Second, governments can transport water from areas of scarcity to areas of abundance. Third, governments can invest in a higher priced water supply (e.g., desalination). Finally, governments can reduce demand by limiting residential water use. The latter is among the most common utilized tactics by governments in the region. For instance, Morocco has experienced below-average-rainfall since 2012. This has decimated yields in some areas and limited water availability. For instance, Morocco is one of the region's top exporters of watermelon—a substantially water demanding crop. In 2017, rather than harm watermelon farming, the Moroccan government decided to cut off the water supply to households in the rural town of Zagora, prompting peaceful protests and violent clashes with police.[39] Because water shortages have always been present throughout the region's history, "there is potential for complacency in accepting the limitations that water scarcity implies, or for dependence on incremental or traditional responses to water challenges."[40] These climatic events can further exacerbate the costs previously discussed for households in the region, and

[36] Masr, Mada: "Water resources per capita drop 60% since 1970," *MADA*, May 21, 2018.
[37] World Bank (2016): *High and Dry: Climate Change, Water, and the Economy*, Washington, DC, World Bank.
[38] Hatami, Haleh, and Peter H. Gleick: "Conflicts over Water in the Myths, Legents, and Ancient History of the Middle East", *Environment,* Vol. 36, nº 3 (1994), pp. 10–11.
[39] *Water Shortages parch Moroccan towns, prompt protests*, at https://www.news24.com/Africa/News/water-shortages-parch-moroccan-towns-prompt-protests-20171105 .
[40] See World Bank (2017), *op. cit*. p.67.

indirectly erode government legitimacy and fracture social cohesion. Based on this discussion, we postulate that:

H_3. Countries where a high percentage of the population depend on limited water service are more likely to experience social unrest in the wake of *negative* rainfall anomalies.

$H_{3.1}$. Counties where a high percentage of the population depends on limited water service are more likely to experience social unrest in the wake of *positive* temperature anomalies.

H_4. Countries where a high percentage of the population depend on surface water are more likely to experience social unrest during dryer–than–average years.

$H_{4.1}$. Countries where a high percentage of the population depend on surface water *or* limited water service are more likely to experience social unrest during warmer–than–average years.

3. Research design

Our first objective is to untangle the institutional-induced water scarcity and social unrest nexus. Because we are interested in the occurrence *and* frequency of water–related unrest, we employ a logistic regression with a binary dependent variable and a negative binomial model to account for the skewedness in our count data. Given our second objective, to examine the possible effect between climatic variables and institutional-induced scarcity on the occurrence of unrest, we also employ a logistic regression. We use robust standard errors clustered in countries in all of our models. Similarly, all models include a time trend to mitigate against possible changes in reporting on riots and protests in developing countries and a lag of our dependent variable to avoid any problems that could arise from autocorrelation.[41] Summary of sample statistics is shown in Table 2. Several test were preformed to check the robustness of our findings. For Models 1–4 two tests are performed. First, we rerun all models by replacing Polity2 by Political Rights Index from Freedom House. Second, we estimated a "sparse" model by removing all control variables. For Models 5–8 we rerun each model while simultaneously incorporating both climatic variables. None of these robustness checks altered our main results.

Table 2. Summary of main sample statistics

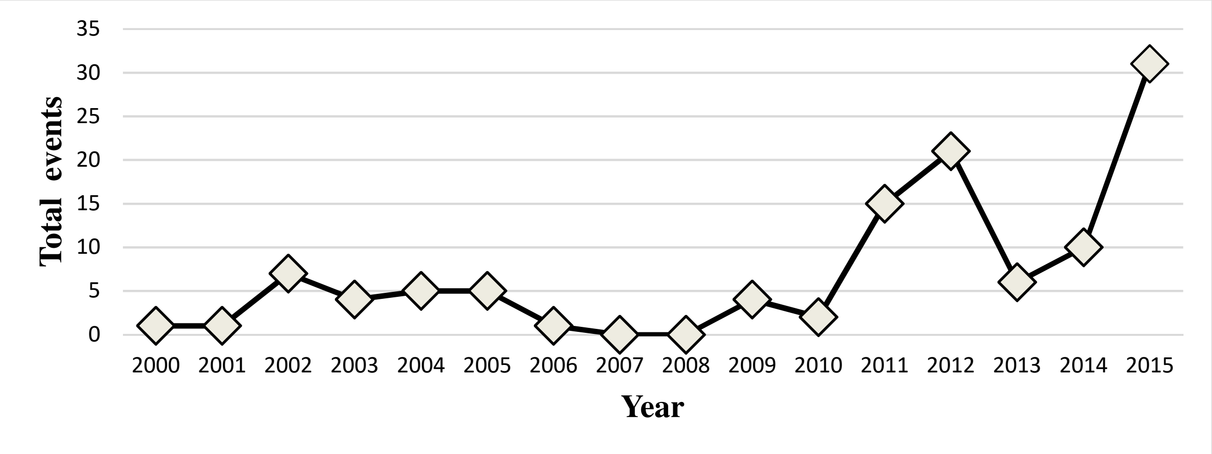
	Mean	*SD*	*Min*	*Max*
Social unrest (binary)	0.35	0.47	0	1
Social unrest (count)	1.4	2.85	0	17
Limited water service (%)	7.41	7.49	0.47	26.11
Surface water dependence (%)	2.44	3.30	0	9.31
SRA 30	-0.12	0.83	-1.58	2.01
STA 30	2.47	1.13	-2.73	6.29
Polity2	-2.82	3.41	-7	7
Log real GDP per capita	8.75	0.55	7.51	9.51
Log total population	17.25	0.66	16.08	18.35
Population growth (%)	4.23	2.23	-1.96	11.52
Civil war occurrence	0.40	0.49	0	1

[41] Hsiang, Solomon: "Climate Econometrics." *Annual Review of Resource Economics* 8, no.1 (2016), pp. 43–75.

Our main dependent variable, *social unrest,* includes all instances of peaceful protests and riots in a given year. For a more accurate measurement of the dependent variable we only include water–related events. Models 1 and 3 employ the total count of events in any given year. Models 2 and 4 use a binary variable that is coded 1 for the occurrence of an event and 0 if otherwise. Data is drawn from the Armed Conflict Location & Event Data Project (ACLED) from 2000 to 2015.[42] ACLED defines protest as "a public demonstration in which the participants do not engage in violence, though violence may be used against them. Rioting is a violent form of demonstration where the participants engage in violent acts, including but not limited to rock throwing, property destruction, etc."[43] Figure 2 displays the distribution of water-related unrest in North Africa over time.

Our independent variables measure institutional and supply–induced water scarcity/abundance. Given our theoretical assumptions we use two different forms of water access—or lack thereof. To gauge poor institutional water service, we use the percentage of individuals within a given country who depend on improved *limited water* services. This service refers to individuals whose time exceeds 30 minutes for a round trip—including queuing—to collect water from an improved distribution source.[44] To test for lack of institutional access we use the percentage of individuals who are dependent on surface water— drinking directly from a river, dam, lake, pond, stream or irrigation canal. —for their livelihoods. Variable classification and data is from the WHO/UNICEF JMP.[45]

Figure 2. Total water-related unrest in North Africa, 2000-2015.



Source: ACLED: *Armed Conflict Location & Event Data Project,* https://www.acleddata.com

Precipitation and temperature measurements are both from the Climate Research Unit (CRU) of the University of East Anglia. The data contain monthly estimates of temperature and

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[42] Raleigh, Clionadh *et al.*: "Introducing ACLED-Armed Conflict Location and Event Data", *Journal of Peace Research*, Vol. 47, nº 5 (2017), pp. 651-660.

[43] *Ibid*.

[44] Improved water sources do not take into account the quality of water delivery or water sanitation. An improved source includes piped water, boreholes and tube wells, protected dug wells and springs, rainwater, and packages or delivered water.

[45] The WHO/UNICEF JMP ladder for drinking water is defined as follows: (1) *safely managed* is drinking water from an improved source which is located on the premises, available when needed and free from fecal and priority chemical contamination; (2) *basic service* is drinking water from an improved source, provided collection time is not more than 30 minutes for a round trip including queuing; (3) *limited service* is drinking water from an improved water source for which collection time exceeds 30 minutes for a round trip including queuing; (4) *unimproved* is drinking water from an unprotected dug well or unprotected spring; (4) *surface water* is drinking directly from a river, dam, lake, pond, stream or irrigation canal. Further information is available at https://washdata.org/

precipitation for all land areas (except Antarctica) at 0.5° resolution.[46] Standardized rainfall anomalies, *SRA30*, is the total precipitation of n years (current year minus year n-1 year). Standardized temperature anomalies, *STA30*, is the yearly temperature average for a given country. We follow the approach of Hendrix and Salehyan (2012) and calculate, for each country, the deviations for the long-term mean, and divide it by the panel's standard deviation (1960-1989 baseline).[47] This varies from the percentage change in annual rainfall from a single previous year (Hendrix & Glaser 2007), the Standardized Precipitation Index (Guttman 1999) and specific temperature anomalies like ENSO because the base period for the long-term mean and standard deviation is the 30 years prior to the year of interest, rather than the total period.

The inclusion of control variables remains controversial among climate-conflict researchers. One side advocates that the inclusion of control variables may be influenced by climatic factors that can lead to biased results.[48] They argue that researchers should instead use panel fixed effects and/or time trends to identify the causal impact of contemporaneous climatic variations. The other side argues that the exclusion of variables previously identified in the literature is necessary to balance the causal weight of climatic factors.[49] To make the results comparable to the existing collective mobilization literature, several controls are included in the analysis, as well as country-specific time trends. First, we control for total population and population growth to account for the neo-Malthusian premise that more populous countries will experience stronger degradation and scarcity of natural resources.[50]
Second, we control for economic growth and level of development. The negative association between level of development and social unrest is among the most robust finding in the conflict literature.[51] Moreover, in times of water shortages, abrupt short-term declines in economic performance are likely perceived as increased deprivation for a large number of people.[52] Therefore, real GDP per capita is used to test the proposition that economic grievances are a function of income levels.[53] Data are from the Penn World Table version 9.0 and the World Bank Indicators.[54]

Third, we control for regime type. Political institutions can play an important role in the mitigation of conflict, particularly non-violent conflict. Many studies have found that social

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[46] Harris, I., P, Jones., Osborn, T, and D. H. Lister: "Updated high-resolution grids of monthly climatic observations–the CRU TS3. 10 Dataset", *International Journal of Climatology,* Vol. 34, nº 3 (2014), pp. 623-642.
[47] See Hendrix and Salehyan, *op. cit.* p.43.
[48] Burke, Marshall B, Edward Miguel, Shanker Satyanath, John a Dykema, and David B Lobell: "Warming Increases the Risk of Civil War in Africa", *Proceedings of the National Academy of Sciences of the United States of America* vol.106, nº 49 (2009), pp. 20670–74. Also refer to: Hsiang, Solomon M., and Kyle C. Meng: "Reconciling Disagreement over Climate–conflict Results in Africa." *Proceedings of the National Academy of Sciences,* Vol. 111, nº 6 (2013), pp. 2100–2103.
[49] Salehyan, Idean, and Cullen S. Hendrix: "Climate Shocks and Political Violence", *Global Environmental Change* Vol. 28, nº 1 (2014), pp. 239–50.
[50] Gleditsch, Nils *et al.*: "Whither the Weather? Climate Change and Conflict", *Journal of Peace Research,* Vol. 49, nº 1 (2012), pp. 3–9.
[51] Collier, Paul, and Anke Hoeffler: "Greed and grievance in civil war", *Oxford economic papers,* Vol. 56, nº 4 (2004), pp. 563-595.
[52] Ted R. Gurr: "A Causal Model of Civil Strife: A Comparative Analysis Using New Indices", *The American Political Science Review,* vol. 62, nº4 (1968), pp. 1104–24. Also see, Hendrix, Cullen, Stephan Haggard, and Beatriz Magaloni: "Grievance and Opportunity: Food Prices, Political Regime, and Protest", *Presentation at the International Studies Association,* New York (August 2009).
[53] Blattman, Christopher, and Edward Miguel: "Civil War", *Journal of Economic Literature,* vol.48, no. 1 (2010), pp. 3–57.
[54] Feenstra, Robert C. *et al.*: "The Next Generation of the Penn World Table", *American Economic Review*, Vol.105, nº10 (2015), pp. 3150-82.

unrest is least likely in democratic and autocratic regimes.[55] At one end of the spectrum, democratic countries have strong institutions where public officials are more likely to mitigate and respond to constituent grievances; however, when these mechanisms fail, protests, riots and demonstrations serve as counteractive responses. At the other end, autocratic regimes tend to be highly repressive and usually prevent their citizens from developing the organizational means to express their grievances.[56] Polity2 differs from Polity in the way it treats regime interruptions, replacing observations of (-66, -77, -88) with conventional Polity scores. Polity2 subtracts the Polity AUTOC score from the DEMOC score, producing a 21-point scale ranging from 10 (strong democracies) to -10 (strong autocracies). Data is from the Polity IV Project.[57]

Finally, we control for the occurrence of civil war. Armed conflict disrupts the production, trade, and access of water services. A binary variable is used to gauge the occurrence of armed conflict in any given country. The data is drawn from UCDP/PRIO Armed Conflict Dataset where armed conflict is defined as “a contested incompatibility that concerns government and/or territory where the use of armed force between two parties, of which at least one is the government of a state, results in at least 25 battle-related deaths.”[58]

4. Empirical results and discussion

Table 3 presents the coefficient effects for water services on the frequency and occurrence of water–related unrest. The results show a positive and statistically strong association between limited water services ($p<0.01$) and water surface dependence ($p<0.05$) on social unrest. The findings are consistent with previous studies linking institutional–induced scarcity to conflict.[59] These previous studies were limited to *prima facie* evidence and lack specificity by lumping all access services together, while we find specific effects. In the sample, the average predicted probability for a country to experience the occurrence of a water-related unrest is 67.6%. Our odd-numbered models report the coefficients for the occurrence of unrest. Holding all variables at their mean values, increasing the percentage of limited water services by 1SD (7.41), increases the probability of water-related unrest on average by 36%. Under the same conditions, a 1SD (3.29) increase on surface water dependence, on average, increases the probability of unrest by 49%. Similarly, our count models show an increase in the frequency of water-related unrest in counties where a high percentage of the population depend on limited water service or surface water. Therefore, we find support for hypotheses 1 and 2.

Our controls are inconsistent with previous literature. First, we find little evidence for the claim that *cetis paribus*, populous countries are more likely to experience episodes of social unrest. This finding refutes Malthusian arguments of resource scarcity being caused by either population growth or an increase in per capita consumption of a resource.[60] Finally, opposite to the overwhelming finding in the conflict literature of a negative association between per capita income and conflict, our findings supports recent research on political participation in Africa: it is not the poorest of the poor who are most likely to participate in social unrest, but rather

[55] Havard, Hegre, *et.al.*: “The Conflict Trap”, *Presentation APSA Annual Meeting*, August 2011, pp. 1–31.
[56] Goodwin, Jeff (2001): *No Other Way Out: States and Revolutionary Movements, 1945–1991,* Cambridge, Cambridge University Press.
[57] The Polity Project, at: http://www.systemicpeace.org/polityproject.html
[58] Allansson, Marie, Erik Melander, and Lotta Themnér: "Organized violence, 1989–2016", *Journal of Peace Research, vol.*54, no. 4 (2017), pp. 574-587.
[59] Brinkman, Henk-Jan, and Cullen S Hendrix: “Background Paper Food Insecurity and Conflict: Applying the WDR Framework” at: http://agris.fao.org/agris-search/search.do?recordID=US2014605804
[60] Homer-Dixon, Thomas, F. (2010): *Environment, scarcity, and violence*, New York, Princeton University Press.

those who have managed to climb the economic ladder and may fear falling back into poverty.[61]

Table 3. Coefficient effects for water services on social unrest.

	(1)	(2)	(3)	(4)
	Limited service		Surface water dependence	
Lagged DV	0.209***	0.0410	0.169***	0.0342
	(0.0344)	(0.0634)	(0.0554)	(0.0848)
Water service	0.415***	0.293***	0.917**	0.778**
	(0.129)	(0.0860)	(0.466)	(0.361)
ln population	2.004**	1.528	1.330	1.138
	(1.001)	(1.062)	(0.854)	(1.039)
Population growth (%)	-0.635	-1.798	0.0145	-1.420
	(1.466)	(1.471)	(1.093)	(1.404)
GDP growth (%)	-0.0434	0.0163	-0.0682	0.0124
	(0.108)	(0.0857)	(0.128)	(0.111)
ln Real GDP per capita	3.799***	2.418*	4.439*	3.514*
	(1.319)	(1.321)	(2.315)	(2.134)
Polity2	0.255	0.257	0.326	0.321
	(0.172)	(0.203)	(0.215)	(0.239)
Civil war occurrence (t-1)	-2.317**	-0.456	-1.378	0.106
	(1.113)	(1.243)	(1.375)	(1.195)
Time trend	-0.177**	-0.0330	-0.196*	-0.0778
	(0.0820)	(0.116)	(0.106)	(0.115)
Constant	-68.03***	-46.46***	-62.12**	-49.36**
	(16.75)	(14.85)	(25.32)	(23.57)
Number of countries?	5	5	5	5
Count model?	No	Yes	No	Yes
Observations	74	74	74	74

Models 1&3 are logistic regression and Models 2&4 are negative binomial regressions | Robust standard errors clustered in countries are in parentheses. *** p<0.01, ** p<0.05, * p<0.1

The second step in our analysis is to examine whether poor water services increase the likelihood of social unrest via climate shocks. As observed in Table 4, the effect of our four water service variables remain positive and statistically associated to the likelihood of unrest. Next, we discuss our interaction terms, which have a negative relationship to the occurrence of social unrest across models. However, in non-linear models the sign of the coefficient for an interaction term may give a misleading signal about the 'direction' of the interaction. To evaluate the substantive effect of the interaction terms we compute the average marginal effects of water services by our climatic variables (*SRA30* and *STA30*) on the probability of water-related social unrest.

We first discuss the interaction term between limited water services and standardized rainfall and temperature anomalies (Model 5 & 6). To our surprise, our interaction terms have opposite effects on the probability of unrest. In support of H_3, we find the probability of social

[61] For recent empirical evidence see, Barnes, Tiffany D, and Stephanie M. Burchard: "Engendering' Politics: The Impact of Descriptive Representation on Women's Political Engagement in Sub-Saharan Africa", *Comparative Political Studies*, vol.46, no 7 (2012), pp. 767–90. Also see, Dionne, Yi, Kris L Inman, and Gabriella R Montinola: "Another Resource Curse? The Impact of Remittances on Political Participation", *Afrobarometer Working Paper*, nº145 (2014), pp. 1-28.

unrest to be higher during lower–than–average rainfall years in countries where a high percentage of the population is dependent on limited water services. This suggests that in drier–than–average years, countries with a high percentage of individuals who spend more than 30 minutes per day collecting water will be more prone to participate in episodes of social unrest. Figure 3. illustrates the average marginal effects of limited water service by our climatic variables. At a two standard deviation bellow mean rainfall and a high percentage of limited water service increases the likelihood of water-related unrest by 7%, while a two standard deviation above mean rainfall and a high percentage of limited water service decreases the likelihood to 3.9%.

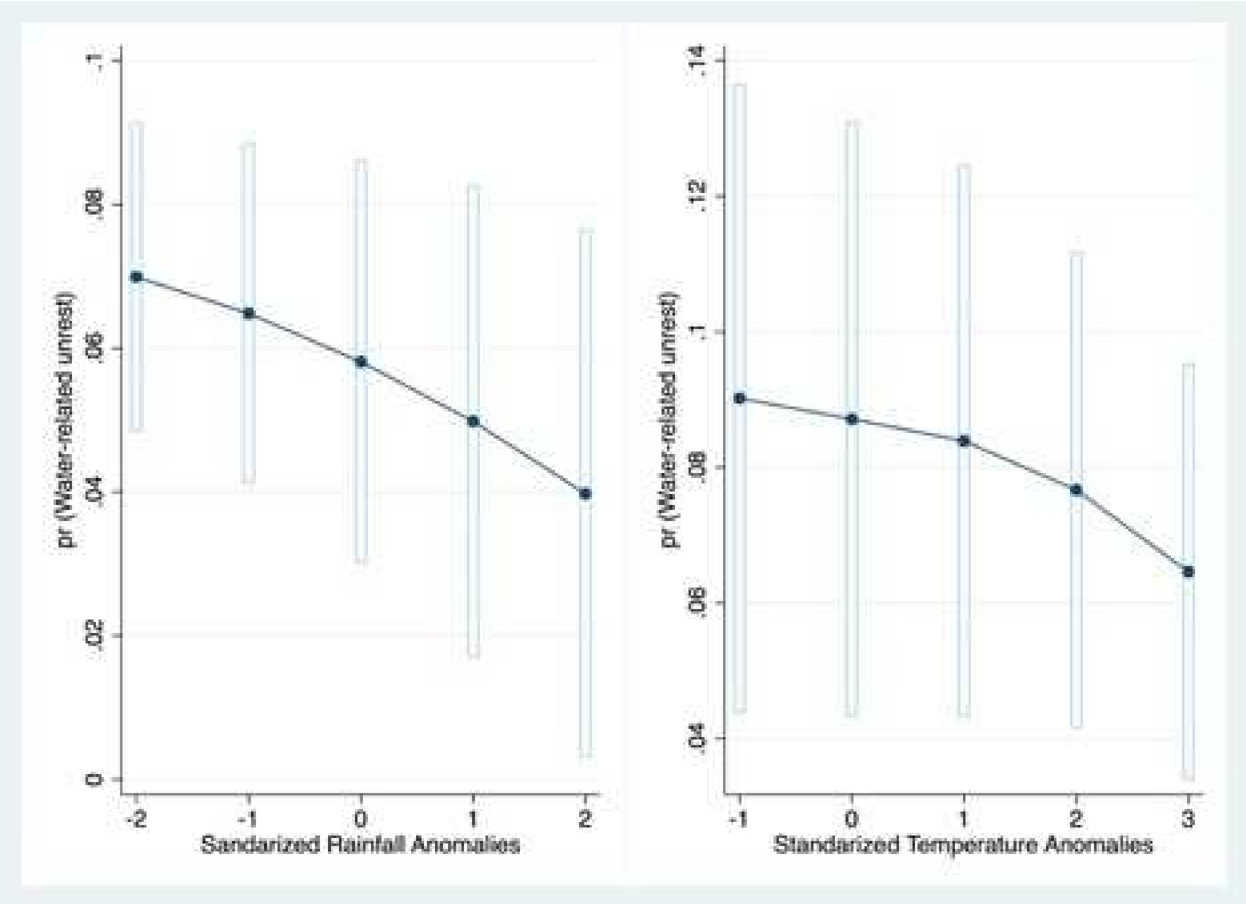
Table 4. Coefficient effects for climatic variables and water services on social unrest.

	(5)	*(6)*	*(7)*	*(8)*
	Limited service		Surface water	
	Rainfall	Temperature	Rainfall	Temperature
Lagged DV	0.203***	0.245***	0.160***	0.192**
	(0.028)	(0.059)	(0.042)	(0.077)
STA30		0.500***		0.275
		(0.176)		(0.277)
SRA30	0.219		0.00379	
	(0.544)		(0.426)	
Water service	0.395***	0.845**	0.911**	1.340**
	(0.137)	(0.345)	(0.460)	(0.652)
Climate*Water service	-0.054**	-0.120**	-0.092	-0.153**
	(0.024)	(0.047)	(0.058)	(0.075)
ln population	2.079**	2.517*	1.356*	1.329
	(1.002)	(1.347)	(0.813)	(0.858)
Population growth (%)	-0.789	-1.371	-0.0895	-0.267
	(1.374)	(1.317)	(0.960)	(0.898)
GDP growth (%)	-0.048	-0.098	-0.058	-0.129
	(0.116)	(0.115)	(0.129)	(0.144)
ln Real GDP per capita	3.641***	4.207**	4.519**	3.857*
	(1.370)	(1.699)	(2.291)	(2.072)
Polity2	0.258	0.235	0.323	0.382*
	(0.174)	(0.153)	(0.219)	(0.202)
Civil war occurrence$_{(t-1)}$	-2.140**	-2.329*	-1.290	-1.247
	(1.012)	(1.394)	(1.293)	(1.144)
Time trend	-0.163**	-0.151**	-0.188*	-0.164**
	(0.068)	(0.059)	(0.101)	(0.077)
Constant	-67.66***	-81.38**	-63.24**	-57.12**
	(17.11)	(32.83)	(24.82)	(25.58)
Number of countries	5	5	5	5
Observations	74	74	74	74

Logistic regression | Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Shifting to the interaction between temperature anomalies and limited water service, we find that warmer–than–average years decrease, rather increase, the probability of water–related unrest. At its coolest, a one standard deviation bellow mean temperature, and a high percentage of limited water service increases the likelihood of water-related unrest by 9%. Opposite to this, at the warmest, a three-standard deviation above mean temperature, and a high percentage of limited water service decreases the likelihood of water–related unrest to 6.4%. As we expected our temperature interaction term to have the opposite effect on the onset of social unrest we find no support for $H_{3.1}$. Our results are opposite to Burke et al. (2009) who find that warmer years significantly increase the likelihood of conflict, and more in line with Buhaug (2010) find little support for the alleged positive association between above-average-temperatures and conflict.[62]

Figure 3 Average marginal effects of limited water service by climatic variables with 95% Cis



(pr probabilities)

Next, we discuss the interaction coefficients effects for climatic variables and surface water dependence on social unrest. While in Model 7 we find no effect on the interaction between rainfall anomalies and surface water on social unrest, in Model 8 we find a statistically significant association between our interaction term and social unrest. The average marginal effects suggest a similar pattern as before: a decrease in the likelihood of unrest has temperatures increase. However, the results from this final model did not pass our robustness tests. Furthermore, opposite to our institutional scarcity models, we find that populous countries to more prone to water-related social unrest. We believe that this discrepancy in results is explained by the notion that climate shocks multiply and enhances horizontal grievances towards the state.

[62] Burke, Marshall B, *et al.*, *op. cit.*, pp. 20670–74. See also, Buhaug, H. *et al.*: "Sensitivity Analysis of Climate Variability and Civil War", *PRIO Papers* (November 2010).

5. Conclusion

Our research answers two relevant questions about water stress in the region. First, we demonstrate that limited water distribution and surface water dependence (lack of institutional distribution) are strong determinants of water-related social unrest in North Africa. While overall access to drinking water has improved, policymakers in the region must continue to further increase water services to the millions of individuals who spend more than 30 minutes per day collecting water, and to those who depend on surface water for their livelihoods to mitigate social unrest.

Second, we find that negative rainfall shocks have begun to impact the likelihood of water-related social unrest via poor water distribution. Worsened institutional water scarcity may indeed multiply horizontal grievances that incentivize militant action towards the state. This is in contrast with recent literature that finds wetter-than-average years to be associated with peaceful protests and riots.[63] While rainfall shocks increase the likelihood for unrest, we also find that hotter than average years decreases the likelihood for water-related unrest. This is in line with the notion that during times of environmental stress, individuals are more likely to 'hunker down' as a mitigation strategy and have little appetite to participate in episodes of social unrest.[64]

Despite the robustness of our results, we realize that they are sensitive to other factors such as different measurements of our key independent variables, model specifications and our limited sample. Such sensibilities should be taken into account when interpreting our empirical results. Despite these limitations, our results reveal the importance of expanding our understanding of the different ways by which the interaction between climate variability and water security can disrupt social cohesion.

What do our findings suggest about the impacts of climate change on water scarcity in North Africa? The future climate scenarios by the IPCC and many independent researchers agree that North Africa and the Middle East will become significantly drier and hotter. Some research findings even suggest that the region may inhabitable by 2050 due to the effects of a changing climate.[65] Therefore, policymakers should focus on: (1) investing in initiatives such as water recycling technologies and desalination; (2) shift agricultural focus towards less water dependent crops, and (3) continue the expansion of improved water services in the region. Future research should continue to focus on capturing the motivation and opportunity to participate in water-related unrest, rather than capturing deterministic relationships between environmental conditions and conflict.

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[63] See Hendrix and Salehyan, *op. cit.*. p.46.

[64] Salehyan, Idean, and Hendrix, Cullen: "Climate shocks and political violence", *Global Environmental Change*, Vol. 28, no. 1 (2014), pp.239-250.

[65] Pal, Jeremy S., and Elfatih AB Eltahir: "Future temperature in southwest Asia projected to exceed a threshold for human adaptability", *Nature Climate Change,* Vol. 6, nº 2 (2016), pp. 197. See also, Lelieveld, J, Y Proestos, and P, Hadjinicolaou: "Strongly Increasing Heat Extremes in the Middle East and North Africa (MENA) in the 21st Century", *Climatic Change*, Vol. 137 (2016), pp. 245–60.

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