Climate Change, Desertification, and Migration (TRUNCATED VERSION)

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Abstract: Climate change has far-reaching implications, with desertification being a notable consequence. This study investigates the complex relationship between desertification and human migration within the context of Syria, where a severe drought has been linked to the civil war. Utilizing albedo as a proxy for desertification and night lights for population movement, we conducted a multi-model regression analysis, including OLS, Spatially Lagged, Spatial Error, and M-Estimator. Our findings reveal a significant correlation between drought and urban migration, with an estimated one million individuals migrating to cities. The results highlight the importance of understanding environmental migration dynamics and offer valuable insights for policymakers addressing climate change adaptation and sustainable land use. This research contributes to the growing body of knowledge on climate-driven migration and provides a methodological framework for future studies.

1 Introduction

One of the most striking consequences of environmental degradation is desertification, a process that transforms fertile land into desert due to factors such as deforestation, overgrazing, and unsustainable agricultural practices, all exacerbated by shifts in climate (34; 18). This phenomenon is both an environmental issue and a human crisis, leading to the loss of livelihoods for farmers and herders and forcing them to abandon their ancestral lands.

The Syrian civil war, which began in 2011, offers a stark illustration of this crisis. Linked to a severe drought that occurred in the mid-2000s, exacerbated by climate change and unsustainable land use practices, the drought led to widespread desertification, crop failures, and livestock losses (21; 18; 25). This environmental catastrophe forced many rural populations, particularly farmers and herders, to move to urban areas in search of alternative livelihoods and better living conditions.

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This exodus from the countryside to the cities is not unique to Syria, it is a growing trend seen across various regions, reflecting a broader pattern of climate-induced migration. But what are the underlying dynamics of this migration? How does the loss of fertile land translate into a journey fraught with uncertainty and risk? And most importantly, what can be done to mitigate the effects of desertification and support those forced to leave their homes?

This paper delves into the complex relationship between desertification, and migration, with a specific focus on the farmers and herders who have lost their formerly productive lands. Through a detailed examination of Syria's changing environment, we aim to shed light on the mechanisms driving this migration and offer insights into potential methods for identifying vulnerable populations in the future. Two hypotheses are proposed:

1. Increasing desertification, as indicated by albedo changes, is positively associated with population migration.

2. This migration pattern is more pronounced in rural areas, outside of towns, due to their higher dependence on agriculture and susceptibility to desertification.

2 Climate Change, Migration, and the Syrian Conflict: A Critical Examination of Divergent Perspectives

The Syrian conflict, marked by its complexity, serves as an illustrative case study exploring the interplay between climate change and migration. An intense drought from 2006 to 2010, a subject of myriad studies, is posited by some to have been a pivotal driver of migration, potentially influencing the inception of the Syrian civil war. This section meticulously reviews the extant literature, shedding light on two contrasting narratives: firstly, the perspective connecting climate change, migration, and the Syrian conflict, and secondly, a counterpoint grounded in quantitative evidence that challenges this connection. Within this discourse, the role of drought, particularly in the lens of climate change and its implications for the Syrian context, garners significant attention (25; 21; 18; 1; 14; 18; 14; 24).

3 Theory

The Syrian context exemplifies the intricate links between climate change, desertification, albedo, drought, and migration (18). Migration, influenced by climate change, can have profound political implications. It can reshape political dynamics in destination regions and foster the dissemination of norms related to environmental management and climate change adaptation (3). Such migration, especially from rural to urban locales due to drought and desertification, can heighten existing vulnerabilities and risks, possibly leading to the emergence or intensification of conflict (33).

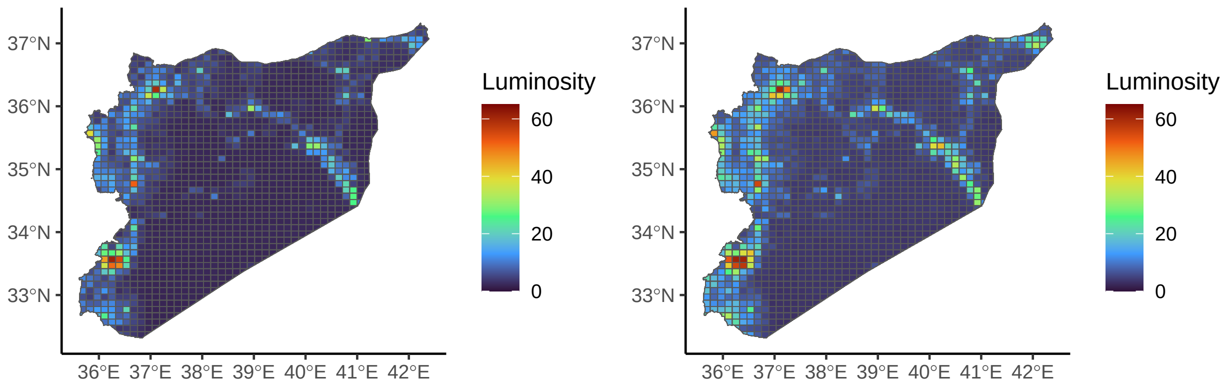
The prevailing literature on climate and conflict often delves into the association between rainfall and resource scarcity, encompassing necessities like food, water, and employment opportunities (9; 31; 32; 4; 17; 37; 20; 25; 30; 29; 23; 12; 42; 26; 18; 39; 41; 40; 8; 16; 19; 27; 28; 36; 13; 22; 2; 5; 11; 10) . Through an analysis of the relationship between changes in albedo and night lights in Syria, this study endeavors to unravel the multifaceted dynamics of environmental migration in the backdrop of desertification induced by climate change.

Individual decisions to migrate, as a response to desertification, are shaped by a myriad of elements. Factors such as information access, established social networks, available resources, and perceptions of risks and opportunities play pivotal roles (7).

4 Measures of Syria's Changing Environment

Nighttime light intensity, represented in Figure 1, serves as a proxy for population density and human activity. These anthropogenic lights indicate population distribution, economic undertakings, and urbanization levels. The DMSP-OLS composite provides monthly data from

Figure 1: Syria Night Lights Data



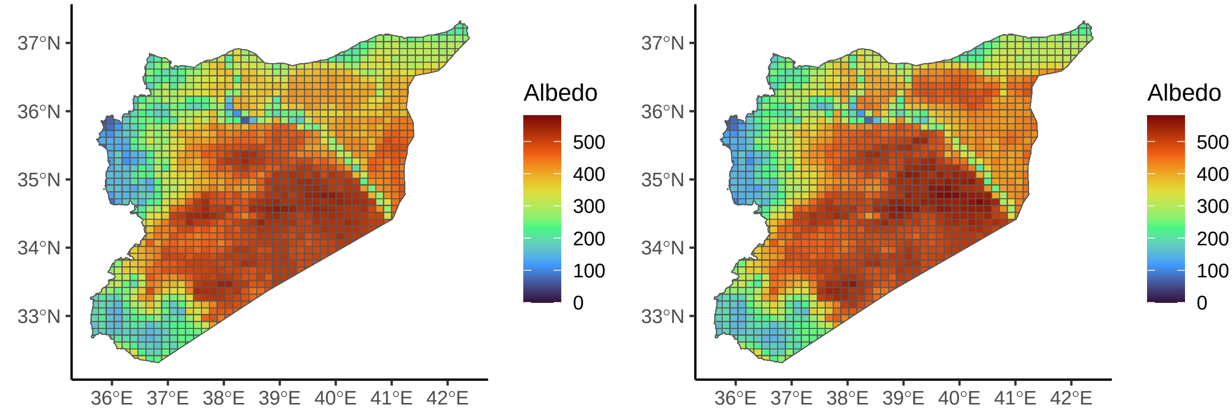
*Note: This figure depicts the average Night Lights Luminosity in Syria before and during the drought. Note that the Night Lights in the West along the Mediterranean and in the North East become brighter and more spread out during the drought. This is indicative of migration to those areas.

January 2005 to December 2010, ensuring the absence of civil unrest influences (15). For precise analysis, the data is segmented into 10km by 10km superpixels.

Albedo, indicating light reflection levels of surfaces, plays a critical role in desertification studies. High Albedo signifies barren terrains, while low values denote vegetated or urban areas. The data is sourced from the Moderate Resolution Imaging Spectroradiometer (MODIS) MCD43D58 product (35), gathered by the Terra and Aqua satellites with cloud removal. The data reveals Syria's arid nature and desertification patterns, especially towards the North East, as illustrated in Figure 2.

The dichotomous Drought variable differentiates pre and post-drought phases, marking 2006 as the drought's commencement. Alongside, the Urban/Rural metric, derived from the World Cities Dataset, demarcates urbanized regions (Figure 3). This data aligns with night lights, highlighting urban regions predominantly in the Western parts. Additionally, controls

Figure 2: Syria Albedo Data



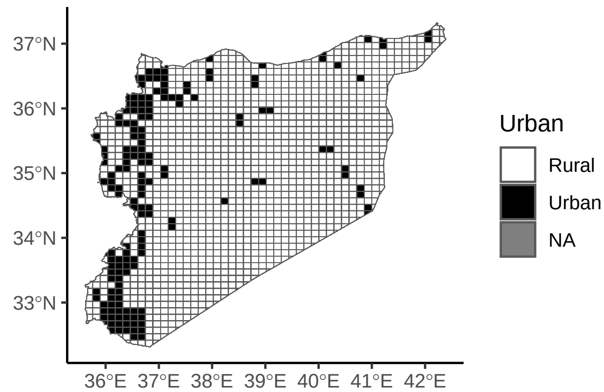
*Note: This figure depicts the average albedo in Syria before and during the drought. Much of Syria has a high albedo to begin with since much of Syria is Arid. The areas of Syria which tend to get snowfall are along the Lebanese boarder and remain about the same. The the spread of desertification can also be seen in these maps with it being most dramatic in North East.

like latitude and longitude for each superpixel adjust for temporal variations.

The Urban/Rural divide measure is generated using the World Cities Dataset by creating a buffer with a 10km radius around each city. All superpixels that touch the buffer are concerned Urban. This methodology allows for measuring the change in luminosity for cities and can capture the growth of municipalities. Figure 3 displays Syria's urban/rural data. Here we can see that urban/rural data aligns nicely with the night lights data, with most of the urbanized areas along the Western border and coastline.

In addition to these geographic variables, we will have additional controls, latitude, and longitude, which will be calculated for each superpixel and use Fixed effects to adjust for Monthly and Yearly variation.

Figure 3: Syria Albedo Data



5 Results

This section presents the findings of our exploration and evaluation of the narrative that led to the onset of the Syrian civil war. The narrative primarily revolves around two pivotal phenomena 1) the mass exodus of individuals from Syria's rural areas, largely triggered by severe droughts, and 2) the resultant swell in urban population as these individuals sought refuge in the cities . Our analysis divides Syria into two broad regions: Urban and Rural, to systematically investigate this narrative.

5.1 Urban Areas

Our multi-model regression analysis—consisting of Ordinary Least Squares (OLS), Spatially Lagged Model, Spatial Error Model, and M Estimator—reveals several key findings. In these models, we use the intensity of urban night lights as a proxy for urban migration, thus functioning as the dependent variable (38).

The Drought variable shows a consistently positive and statistically significant correlation with urban night lights across all four models. This suggests that increases in drought are significantly correlated with increased urban migration (25). An observed increase in nighttime light intensity further reinforces this association. Consequently, the hypothesis suggesting drought as a key driver for city migration in Syria is strongly supported by these findings (14; 6). Indeed, this model estimates [2] that approximately 1 million (plus or minus 500,000) individuals migrated to the cities due to the drought. This aligns with mid-range estimates from prior qualitative evidence and counters the estimates proposed by Selby et al. (38). The alternative hypothesis, which proposed a negligible impact of drought on urban migration, is thus contradicted by these findings.

The Albedo variable, which captures desertification, presents a more intricate relationship with urban night lights. The OLS model shows a marginally positive impact of albedo on urban night lights, but the Spatially Lagged and Spatial Error models suggest a significant negative effect. This is unsurprising since these models only focus on Urban areas. It would have been surprising if an increase in albedo resulted in a change in population in cities since agricultural jobs are primarily in rural areas.

The Year variable shows a positive correlation with urban night lights across all models, suggesting an annual increase in urbanization unrelated to drought or desertification. This could reflect the global trend towards urbanization and be influenced by other factors not included in the models (18).

The findings strongly support the position that drought was a key driver for city migration in Syria (25). The Albedo variable shows a complex relationship with urban night lights, indicating that desertification and potentially urbanization play a role in the observed changes (43). The Year variable suggests an ongoing trend toward urbanization, while the Longitude and Latitude variables show inconsistent significance across the models. The strong spatial autocorrelation

[2] refer to Appendix for specifics

indicated by the rho and lambda parameters suggests that the spatial aspects of the data are important to consider in the models (38).

5.2 Rural Areas

The period leading up to the Syrian civil war has been extensively analyzed, with factors such as governance issues, political unrest, and socioeconomic disparities often taking center stage. However, our findings illuminate environmental pressures' profound and potentially underestimated role.

In particular, the interaction between Drought and Albedo, as detailed in Table 2, underscores the acute vulnerability of Syria's rural regions. Our models found a consistently significant negative effect for the interaction term. This implies that areas experiencing higher Albedo values, areas with higher estimated desertification, post-drought bore the brunt of the dimming effects. The marked reduction in luminosity implies a decline in population, providing evidence of migrations during drought periods as residents sought better prospects in urban locales.

This influx of rural migrants to urban areas, driven by the combined forces of drought and increased desertification, would have contributed to the swelling of urban populations. Such demographic shifts, in turn, could strain urban resources, potentially amplifying socioeconomic tensions and discontent and setting the stage for larger conflicts.

This insight provides a plausible explanation for the apparent underestimation of migration figures by Selby et al. (38). It is possible that they did not account for the amplifying effect of desertification on population migration during droughts.

These results spotlight the complex interplay between climate variables. Moreover, the significant roles of the interaction between Drought and desertification underscore the importance of these climatic factors in rural settings.

6 Discussion

This study aimed to examine the relationship between climate change, desertification, and population movement, particularly in Syria. The main finding is that increased desertification, as indicated by changes in albedo, is associated with population migration, as reflected by shifts in night light patterns.

These findings demonstrate that drought and albedo have considerable effects on population dynamics, underscoring the importance of these factors in shaping climate-induced migration. In the context of urban environments, the models found that the population increases significantly during periods of drought. This association could indicate a migration trend from rural to urban areas when faced with adverse climate events. These observations suggest that the urban population swells during such times due to an influx of climate migrants seeking refuge from harsh rural conditions. Further research could investigate the socio-economic conditions of these migrants, including employment and housing availability, to inform urban planning and social support policies.

In rural settings, the interaction effect between drought and albedo is a significant determinant of population change. The results suggest that higher albedo, which might be indicative of specific rural characteristics or agricultural practices, can moderate the population decline associated with droughts. This novel finding opens up an interesting avenue for climate adaptation strategies in rural areas. One such avenue is exploring agricultural practices or land management techniques that could provide a potential strategy to counteract the population decline during drought. More research is needed to understand such measures' practicality, effectiveness, and environmental implications.

Temporal trends also played a significant role in our findings. The Year variable showed a consistent increase in the population of both urban and rural areas. This finding suggests a broader trend of population growth over time, which might be driven by other demographic or socioeconomic factors beyond the scope of the current study. This highlights the complex and multi-faceted nature of population dynamics and reinforces the importance of comprehensive strategies to manage climate-induced migration.

7 Conclusion

This study examines the relationship between climate change, desertification, and migration in Syria by using albedo and night lights as proxy variables. The results of the study support the idea that desertification caused by climate change, specifically drought, leads to a reduction in population density in rural areas in Syria. The results of all the models suggest that desertification can lead to migration and displacement of rural populations and that prolonged drought and desertification can have a significant impact on population density in rural areas.

The use of albedo as a proxy for desertification and night lights as a proxy for population density allows for a more comprehensive examination of the relationship between climate change and migration. Albedo, a measure of reflectivity, is a novel approach to proxy for desertification in this context. Nighttime light data, on the other hand, is widely used to measure population density, and it has been found to have a negative relationship with climate change in previous studies. The use of both variables in this study allows for a more complete subnational examination of the relationship between climate change, desertification, and migration.

Leveraging albedo estimates as an indicator of desertification presents a groundbreaking approach for identifying regions and populations most susceptible to the ravages of climate change. Albedo can provide real-time insights into the progression of desertification, a direct consequence of changing climatic patterns. As our research in Syria has demonstrated, regions with heightened albedo values post-drought witnessed significant demographic shifts, with populations moving in search of better prospects. By monitoring and analyzing changes in albedo, researchers and policymakers can pinpoint areas where desertification is intensifying, serving as early warning systems for potential population displacements.

These findings corroborate the prevailing scientific consensus that climate change acts as a catalyst for migration, especially in regions where communities heavily depend on agriculture for their livelihood. This is consistent with the argument that climate change can significantly impact agricultural productivity, thereby influencing migration patterns.

However, this study contributes to the discourse by offering a more nuanced understanding of this phenomenon. It is not solely the direct impacts of climate change, such as droughts, that instigate migration. Rather, subsequent processes, like desertification, amplify these effects and further drive migration. Furthermore, our study echoes the sentiments of other researchers who have emphasized the need to consider the complex interplay of environmental, economic, and social factors when examining climate-induced migration.

The insights gained from this study have several practical implications, particularly for policy-making. Recognizing the impact of desertification on migration patterns can inform more targeted interventions to mitigate the adverse effects of climate change. Policies focused on sustainable land use, reforestation, and water resource management could be instrumental in slowing down or even reversing the desertification process. Additionally, efforts could be made to improve the resilience of rural communities to climate change by diversifying their economies and enhancing their capacity to adapt to changing environmental conditions.

This study provides a novel and comprehensive examination of the relationship between climate change, desertification, and migration in Syria. The results of this study support the idea that desertification caused by climate change can lead to migration and displacement of rural populations and have a significant impact on population density in rural areas. The use of albedo as a proxy for desertification and night lights as a proxy for population density, in combination with multiple regression methodologies, provides a robust and comprehensive examination of the relationship. The findings of this study have important implications for policymakers and aid organizations working to address the impacts of climate change and desertification and for future research in this field.

References

[1] Ayman F ABOU-HADID. Assessment of impacts, adaptation, and vulnerability to climate change in north africa: food production and water resources. *A Final Report Submitted to Assessments of Impacts and Adaptations to Climate Change (AIACC)*, 2006.

[2] Courtland Adams, Tobias Ide, Jon Barnett, and Adrien Detges. Sampling bias in climate–conflict research. *Nature Climate Change*, 8(3):200–203, 2018.

[3] W Neil Adger, Saleemul Huq, Katrina Brown, Declan Conway, and Mike Hulme. Migration as adaptation. *Nature*, 395(6704):615–617, 2003.

[4] W Neil Adger, Juan M Pulhin, Jon Barnett, Geoffrey D Dabelko, Grete K Hovelsrud, Marc Levy, et al. Human security. In *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, pages 755–791. Cambridge University Press, 2014.

[5] Wreford Anita, Moran Dominic, and Adger Neil. *Climate change and agriculture impacts, adaptation and Mitigation: Impacts, adaptation and Mitigation*. OECD publishing, 2010.

[6] Konstantin Ash and Nick Obradovich. Climatic stress, internal migration, and syrian civil war onset. *Journal of Conflict Resolution*, 64(1):3–31, 2020.

[7] Richard Black, Stephen R G Bennett, Sandy M Thomas, and John R Beddington. Migration as adaptation. *Nature*, 478(7370):447–449, 2011.

[8] Alexander Bollfrass and Andrew Shaver. The effects of temperature on political violence: global evidence at the subnational level. *PLoS One*, 10(5):e0123505, 2015.

[9] Halvard Buhaug. Climate not to blame for african civil wars. *Proceedings of the National Academy of Sciences*, 107(38):16477–16482, 2010.

[10] Halvard Buhaug. Climate-conflict research: Some reflections on the way forward. *WIREs Climate Change*, 6(3):269–275, 2015.

[11] Marshall Burke, Solomon M Hsiang, and Edward Miguel. Climate and conflict. *Annu. Rev. Econ.*, 7(1):577–617, 2015.

[12] Joshua W Busby, Kerry H Cook, Edward K Vizy, Todd G Smith, and Mesfin Bekalo. Identifying hot spots of security vulnerability associated with climate change in africa. *Climatic Change*, 124(4):717–731, 2014.

[13] Tamma A Carleton and Solomon M Hsiang. Social and economic impacts of climate. *Science*, 353(6304):aad9837, 2016.

[14] Francesca De Châtel. The role of drought and climate change in the syrian uprising: Untangling the triggers of the revolution. *Middle Eastern Studies*, 50(4):521–535, 2014.

[15] Christopher D Elvidge, Kimberley E Baugh, Eric A Kihn, Herbert W Kroehl, Ethan R Davis, and Chris W Davis. Relation between satellite observed visible-near infrared emissions, population, economic activity and electric power consumption. *International Journal of Remote Sensing*, 18(6):1373–1379, 1997.

[16] Shuaizhang Feng, Alan B Krueger, and Michael Oppenheimer. Linkages among climate change, crop yields and mexico–us cross-border migration. *Proceedings of the national academy of sciences*, 107(32):14257–14262, 2010.

[17] Hanne Fjelde and Nina von Uexkull. Climate triggers: Rainfall anomalies, vulnerability and communal conflict in sub-saharan africa. *Political Geography*, 31(7):444–453, 2012.

[18] Peter H Gleick. Water, drought, climate change, and conflict in syria. *Weather, Climate, and Society*, 6(3):331–340, 2014.

[19] Cullen S Hendrix and Sarah M Glaser. Trends and triggers: Climate, climate change and civil conflict in sub-saharan africa. *Political geography*, 26(6):695–715, 2007.

[20] Cullen S Hendrix and Idean Salehyan. Climate change, rainfall, and social conflict in africa. *Journal of Peace Research*, 49(1):35–50, 2012.

[21] Martin Hoerling, Jon Eischeid, Judith Perlwitz, Xiaowei Quan, Tao Zhang, and Philip Pegion. On the increased frequency of mediterranean drought. *Journal of climate*, 25(6): 2146–2161, 2012.

[22] Solomon M Hsiang, Kyle C Meng, and Mark A Cane. Civil conflicts are associated with the global climate. *Nature*, 476(7361):438, 2011.

[23] Tobias Ide. Does environmental peacemaking between states work? insights on cooperative environmental agreements and reconciliation in international rivalries. *Journal of Peace Research*, 55(3):351–365, 2018.

[24] Tobias Ide. Climate war in the middle east? drought, the syrian civil war and the state of climate-conflict research. *Current climate change reports*, 4:347–354, 2018.

[25] Colin P Kelley, Shahrzad Mohtadi, Mark A Cane, Richard Seager, and Yochanan Kushnir. Climate change in the fertile crescent and implications of the recent syrian drought. *Proceedings of the National Academy of Sciences*, 112(11):3241–3246, 2015.

[26] Vally Koubi, Gabriele Spilker, Tobias Böhmelt, and Thomas Bernauer. Climate variability, economic growth, and civil conflict. *Journal of Peace Research*, 51(1):113–127, 2014.

[27] Vally Koubi, Gabriele Spilker, Lena Schaffer, and Thomas Bernauer. Environmental stressors and migration: Evidence from vietnam. *World development*, 79:197–210, 2016.

[28] David B Lobell and Marshall B Burke. On the use of statistical models to predict crop yield responses to climate change. *Agricultural and forest meteorology*, 150(11):1443–1452, 2010.

[29] Jean-François Maystadt and Olivier Ecker. Extreme weather and civil war: does drought fuel conflict in somalia through livestock price shocks? *American Journal of Agricultural Economics*, 96(4):1157–1181, 2014.

[30] John O'Loughlin, Andrew M Linke, and Frank DW Witmer. Effects of temperature and precipitation variability on the risk of violence in sub-saharan africa, 1980-2012. *Proceedings of the National Academy of Sciences*, 111(47):16712–16717, 2014.

[31] Clionadh Raleigh and Henrik Urdal. Climate change, environmental degradation and armed conflict. *Political Geography*, 26(6):674–694, 2007.

[32] Rafael Reuveny. Climate change-induced migration and violent conflict. *Political Geography*, 26(6):656–673, 2007.

[33] James F Reynolds and D Mark Stafford Smith. Desertification: a review of the concept. *Environment: Science and Policy for Sustainable Development*, 49(5):20–31, 2007.

[34] Carl Sagan, Owen B Toon, and James B Pollack. Anthropogenic albedo changes and the earth's climate. *Science*, 206(4425):1363–1368, 1979.

[35] C. Schaaf and Z. Wang. Mcd43d58 modis/terra+aqua brdf/albedo white sky albedo band7 daily l3 global 30arcsec cmg v006. https://doi.org/10.5067/MODIS/MCD43D58.006, 2015. Accessed 2023-08-23.

[36] Jürgen Scheffran, Michael Brzoska, Jasmin Kominek, P Michael Link, and Janpeter Schilling. Climate change and violent conflict. *Science*, 336(6083):869–871, 2012.

[37] Carl-Friedrich Schleussner, Jonathan F Donges, Reik V Donner, and Hans Joachim Schellnhuber. Armed-conflict risks enhanced by climate-related disasters in ethnically fractionalized countries. *Proceedings of the National Academy of Sciences*, 113(33):9216–9221, 2016.

[38] Jan Selby, Omar S. Dahi, Christiane Fröhlich, and Mike Hulme. Climate change and the syrian civil war revisited. *Political Geography*, 60:232–244, 2017. ISSN 0962-6298. doi: https://doi.org/10.1016/j.polgeo.2017.05.007. URL https://www.sciencedirect.com/science/article/pii/S0962629816301822.

[39] Ole Magnus Theisen. Climate clashes? weather variability, land pressure, and organized violence in kenya, 1989–2004. *Journal of Peace Research*, 49(1):81–96, 2012.

[40] Nina von Uexkull, Marco d'Errico, and Julius Jackson. Drought, resilience, and support for violence: Household survey evidence from dr congo. *Journal of conflict resolution*, 64 (10):1994–2021, 2020.

[41] Nina Von Uexkull. Sustained drought, vulnerability and civil conflict in sub-saharan africa. *Political Geography*, 43:16–26, 2014.

[42] Nina von Uexkull, Mihai Croicu, Hanne Fjelde, and Halvard Buhaug. Civil conflict sensitivity to growing-season drought. *Proceedings of the National Academy of Sciences*, 113(44):12391–12396, 2016.

[43] Erika Weinthal, Neda Zawahri, and Jeannie Sowers. Securitizing water, climate, and migration in israel, jordan, and syria. *International Environmental Agreements: Politics, Law and Economics*, 15:293–307, 2015.

Table 1: Urban Areas

	OLS	Spatially Lagged	Spatial Error	M Estimator
Drought	1.193***	1.221***	1.272***	1.064***
Albedo	0.002*	-0.003***	-0.008***	-0.001
Year	0.319**	0.345***	0.344***	0.242***
Constant	-597.796**	-699.763***	-1397.462***	-462.321***
Month Fixed Effects	True	True	True	True
Longitude	-0.107	0.162***	-0.742	0.089
Latitude	-0.726***	0.032	20.874***	-0.408***
rho		0.973***		
lambda			0.989***	
N	8966	8966	8966	8966
R^2	0.053			
RMSE	11.02	6.54	6.47	11.20
Std.Errors	HC4	IID	IID	IID

Table 2: Rural Areas

	OLS	Spatially Lagged	Spatial Error	M Estimator
Drought × Albedo	-0.004***	-0.003***	-0.003***	-0.002***
Drought	1.961***	1.531***	1.565***	1.151***
Albedo	-0.007***	0.001***	0.000	-0.004***
Year	0.094***	0.094***	0.095***	0.013**
Longitude	-0.231***	-0.010	-14.751***	-0.259***
Latitude	0.580***	-0.001	0.478	0.522***
Constant	-192.858***	-188.914***	427.410***	-29.652**
Month Fixed Effects	True	True	True	True
rho		0.998***		
lambda			0.999***	
N	61520	61520	61520	61520
R^2	0.182			
RMSE	3.43	2.51	2.49	3.55
Std.Errors	HC4	IID	IID	IID