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Review

A Systematic Literature Review of Quantitative Studies Assessing the Relationship between Water and Conflict on the African Continent

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Abstract: Since the seminal 2012 Special Issue of the Journal of Peace Research about climate change and conflict, at least 35 review papers on the topic have been published. To our knowledge, none of these reviews focused on water and conflict specifically. In order to address this research gap, the present article conducts a systematic review of scholarship examining the linkages between water and conflict, focusing on quantitative studies using secondary data sources. This review focuses on the African continent given projections about the intersection between water issues and conflict in this region, as well as the popularity of this portion of the world in studies of climate change and conflict. We discuss the findings of papers reviewed and propose six avenues for future research. As research about this topic advances, it will require attention to nuances in data processing, integration, and modeling across spatial and temporal scales, if the outcomes of this body of scholarship are to be leveraged to guide the decision making of governing bodies.

Keywords: Africa; climate change; water; conflict; environmental change

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1. Introduction

Climate projections indicate continued future increases in temperature, precipitation, and extreme weather events [1–3]. Impacts of the anticipated changes are likely to be both patchy in space and variable over time [4]. These impacts linked with other forms of anthropogenic environmental change, such as toxic emissions and effluents, are increasing environmental risks while degrading the capacity of households, communities, and governments to deal with these risks [5–8]. A vital question concerns the range of human responses to these changing conditions, particularly the potential for increased violence. Members of the research community have noted that these changes could give rise to greater intensity and frequency of conflict as people compete over increasingly scarce resources [9–11].

Recently, the Sixth Assessment Report of Working Group II's chapter on Africa included several references to conflict and environmental change [3]. Language from this report noted "There is substantial evidence that climate variability influences human security across Africa." [3] (p. 1394). The report acknowledged the complexities behind this relationship for both violent and civil conflict related to institutions and socioeconomic conditions, among other factors. What is certain, however, is an expectation of increased rates of environmental change globally, which includes disturbances in water systems across Africa [1,3,12]. These changes may bring abrupt and dramatic changes in the distribution of resources and people, especially for fresh water and environmental services. The redistribution of these resources will likely pose challenges for societies in the medium and long term. While cooperation is a more efficient means of resolving resource disputes [13–18], it may not always be possible, particularly if a place has preconditions that make peaceful resolution less likely (e.g., racial/ethnic divisions, weak or otherwise non-functioning institutions, history of conflict). While there is no consensus on the climate-conflict nexus—as reviews of recent scholarship have made clear [19,20]—most experts generally agree that "intensifying climate change is estimated to increase future risks of conflict" [21].

At this juncture, several review studies have attempted to synthesize the growing body of work on climate and conflict [22–26]. As von Uexkull and Buhaug [19] noted, since the 2012 Special Issue on "climate change and conflict" in the Journal of Peace Research, which then represented the largest collection of peer-reviewed journal articles on the subject, 35 quantitative review articles have been published on the topic. Collectively, scholarship has made several research advances, particularly with respect to the use of fine-grained disaggregated data, as well as the acknowledgement of the diversity of conflicts that may result from climate change [19]. Linkages between climate change and confict are mediated by a variety of contextual factors [20], which helps to explain the diversity of findings in the growing body of research on this topic [27]. Here, we have hypothesized that part of the variations in research findings may arise from the range of environmental changes induced by a changing climate (e.g., temperature changes, extreme events, changes in precipitation), as well as the range of study areas used in prior investigations and reviews on the topic [25,28].

The review that follows is the result of a series of meetings between researchers engaged in environmental research and/or peace studies convened at the Socio-Environmental Synthesis Center (SESYNC) at Annapolis, Maryland. The team consisted of people from multiple disciplines: geography, peace studies, climate science, remote sensing, land change science, urban planning, and economics The purpose of the meetings was to engage in interdisciplinary research on the specific theme of water and conflict on the continent of Africa. To understand the state of science related to this topic, the team sought out review papers. We did find several articles dealing more broadly with climate change and conflict, including a prior review focused on East Africa [26]. No review articles were found dealing with water and conflict on the African continent; thus, we sought to produce a systematic review.

This review makes new contributions to the literature on water resources and also climate change and conflict, more broadly. First, our review focuses on water and conflict, and this focus on water opens up the possibility for studies that move beyond an investigation of linkages between precipitation variability, drought, and/or conflict. The broader scope of "water" means we capture articles dealing with transboundary water issues, land disputes that may have been an effort to access water resources, water access and security, water quality and quantity, and conflicts that occur while fetching water. Second, our review focuses on the entire continent of Africa, not just Sub-Saharan Africa, and is therefore distinct from prior reviews examining climate change and conflict around the world [20,22,29,30], and reviews focused on one portion of the continent [26].

The focus on the entire African continent is important for several reasons. One, prior work frequently analyzed the entire continent as a whole [31–33], including studies of climate change and conflict [34–36]. Two, the focus on the entire continent makes physiographic sense which allows for the inclusion of a range of major water bodies and water issues. For instance, Africa's longest river, the Nile, is a major transborder water resource that transverses ten countries in northern, central, and eastern Africa. Third, the continent is already experiencing the negative effects of climate change, which are projected to continue in the future [3]. In the most recent IPCC reports, climate scientists have projected more heatwaves (high confidence) and drying trends in the west and southwestern portions of the continent (high-confidence) [3]. These changes in climate intersect with numerous vulnerabilities (e.g., population growth, poor institutions, high poverty, limited finances) [3,13,37,38] and a legacy of conflict in many African regions that are connected to ethnic and political dynamics (e.g., Rwanda, Darfur, Somalia) [29].

2. Materials and Methods

A systematic review implements a rigorous methodology for locating and synthesizing the analytical results of research on a particular topic [39,40]. The goal of a systematic review is to provide a comprehensive overview of a particular topic and highlight gaps for future work, while striving to minimize selection bias that may occur with descriptive narrative reviews that do not have an a priori article identification and selection plan [41]. Systematic reviews may or may not involve meta-analyses, which are a summary of the statistical findings of studies on a particular topic [39]. The systematic review conducted here is designed to synthesize the findings of prior work on water and conflict across the African continent; it does not include a meta-analysis.

To compile a list of published, relevant works, we conducted a search for peer-reviewed journal articles published between January 2012 and December 2021. This time frame was selected for two reasons. One, it includes, but also moves beyond the 2012 Special Issue of the Journal of Peace Research, which captured a large number of articles that dealt with water and conflict [19]. Two, the endpoint of 2021 is the most recent year for which we have an entire calendar year of peer-reviewed articles.

We conducted three different searches within the Web of Science and EBSCO databases using the following words: (1) “water” and “conflict” and “Africa”, and (2) “climate” and “conflict” and “Africa.” Our search focused on finding these keywords in the title, abstract, or keyword lists of articles. As mentioned previously, there are a variety of ways to operationalize “water” (e.g., water security, rainfall, precipitation). The use of broad terms is an effort to capture articles dealing with water issues, but also articles that deal with water issues that may not use the term “water” specifically. It is for this reason that we broadened our search to incorporate articles about climate and conflict; articles from this body of work may operationalize water using the terms precipitation or rainfall. We also elected to use the broad term “Africa” to capture any articles that may deal with conflict on the continent.

Figure 1 contains the list of search terms and the number of articles associated with the set of search terms from each database.

Our initial search produced 506 papers. Of this initial list, we removed 121 articles according to the criteria outlined in Figure 1 (e.g., duplicates and/or non-peered reviewed articles). The remaining 385 articles required further review by members of the research team.

Only original research papers were included in this review. Thus, we excluded from the analysis review papers, meta-analyses, book reviews, and introductions to Special Issues. To code the peer-reviewed articles from scholarly journals, members of the research team populated a form for each paper in Qualtrics that contained questions about the methods used, data sources, definition of conflict, spatial scale of the analysis, and time period of the analysis (see Figure 2). Prior to analyzing the articles, the team coded a subset of articles together to ensure consistency in coding across team members. These articles were then analyzed using a double review process to ensure the articles met the study criteria. To be included in the subsequent analysis, the study must have been geographically situated in Africa. It must also have analyzed the relationship between conflict and water, thereby eliminating articles that focused on just one of the topics. Furthermore, articles analyzing an aspect of climate change other than water (e.g., vegetation dynamics, temperature trends) were eliminated from the analysis.

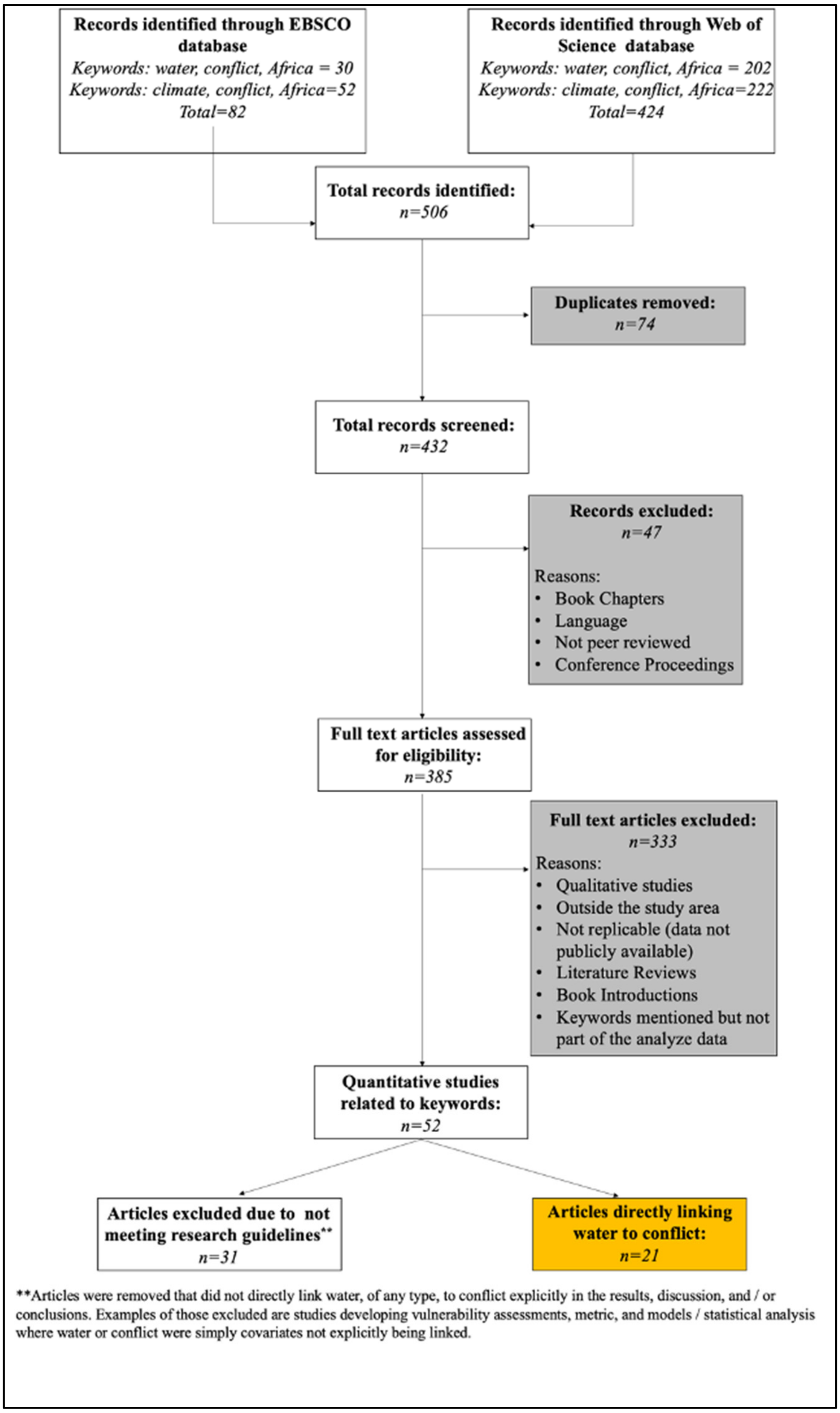

Figure 1. Article Review Process.

Question	Coder Options
What type of quantitative methods were used?	ANOVA (e.g., ANCOVA, repeated measures ANOVA, MANOVA); correlation analysis; descriptive statistics; difference in means (e.g., Mann-U, t-tests, propensity scores); regression analysis; spatial analysis (e.g,. geographically weighted regression; nearest neighbor analysis; hotspots, spatial regression, spatial autocorrelation); other
What type of qualitative methods were used?	Interviews (unstructured and semi-structured); text analysis; focus groups; document analysis (includes archival work); other
How did the study operationalize water?	Drought, floods, rainfall, precipitation, water stress, water infrastructure, quality/pollution, water access, water cost; other
Did the paper analyze the impact of water on a particular phenomenon and if so what kind?	Crops/irrigation; energy; food security; women (inequality; time spent getting water; household dynamics; health disease; livelihood development (income, jobs, education); migration; pollution; soil moisture; vegetation; other
What type of conflict did the paper analyze[i]?	Protests/Unarmed social conflict (non-violent); strategic development (typically non-violent; e.g., land acquisitions); violence against civilians (violent, outside force, e.g., government, initiated); riot (violent); explosion/remote violence (e.g., kidnapping, abductions, car bombs); armed conflict/battles; civil war; conflict (generic); Other
Which conflict data set was used?	ACLED, correlates of water, global terrorism database; SCAD; SIPRI (specify dataset used); UCDP (specify dataset used); Other (please specify)
What was the year or time period that the article was analyzing?	1970-1975;1976-1980;1981-1985;1986-1990;1991-1995;1996-2000;2001-2005;2006-2010;2011-2015; 2016-2019; No Specific Timeframe Given (Generalizations about time, e.g., recent trends, modern times); Other
What was the geographical extent of the water data used in the paper?	Continental; Regional; Country; Local; Other
What was the temporal resolution of the water data?	Day; Month; Year; Other
Did the paper provide policy implications?	Coder explanation
Do you have any information to share about the article? Was this article central to this Pursuit and why? What stood out the most about this article for you?	Coder explanation

Figure 2. Coding Criteria for Articles.

In our analysis of search results, we focused on quantitative studies using publicly available secondary data. We defined quantitative as using one or more of the methods outlined in Figure 2. These criteria excluded quantitative studies using survey data that are not available for public use and qualitative papers using interview data. Although qualitative studies are valuable, they do not lend themselves to systematic assessments of sources of variation in study design and results, due to sampling bias or sampling error in survey data. Interview data are also prone to variation in interpretation, a potential source of uncertainty in study findings. Lastly, we excluded vulnerability studies that identify places that could be susceptible to conflict. Although these studies identify place characteristics that increase vulnerability to conflict, they did not take the next step of evaluating the strength of the linkages between water and existing conflict, if any.

3. Results

Ultimately, just 21 articles of the 385 coded met all study criteria. Figure 3 contains a list of these articles as well as information about the geographic extent, spatial scale of the analysis, and time period of interest for each study. Based on the information in this table, it is evident that three journals were key outlets for this research topic during the period of interest: Journal of Peace Research (n = 8), Political Geography (n = 3), and Environmental Research Letters (n = 3). Several articles are from the 2012 Special Issue of the Journal of Peace Research entitled "Climate Change and Conflict" [42].

Authors	Year	Full Title of Article	Journal	Geographic Extent	Spatial Scale of Analysis	Time Period
Almer et al.	2017	Water scarcity and rioting: Disaggregated evidence from Sub-Saharan Africa	Journal of Environmental Economics and Management	Sub-Saharan	raster (0.5° x 0.5° gridded)	1990-2011
Anderson et al.	2021	Violent conflict exacerbated drought-related food insecurity between 2009 and 2019 in sub-Saharan Africa	Nature Food	Sub-Saharan	polygon (country)	2009-2019
Buhaug et al.	2015	Climate variability, food production shocks, and violent conflict in Sub-Saharan Africa	Environmental Research Letters	Sub-Saharan	polygon (country)	civil conflict (1962-2009); social unrest (1991-2009); non-state conflict (1990-2009); coup (1962-2009)
Detges et al.	2016	Local conditions of drought-related violence in Sub-Saharan Africa: The role of road and water infrastructures	Journal of Peace Research	Sub-Saharan	polygon (admin. units)	1990-2010
Di Falco et al.	2020	Property rights, land disputes and water scarcity: Empirical evidence from Ethiopia	American Journal of Agricultural Economics	Country (Ethiopia)	raster (0.1° x 0.1° gridded)	2005, 2007
Fjelde and Uexkull	2012	Climate triggers: rainfall anomalies, vulnerability and communal conflict in sub-Saharan Africa	Political Geography	Sub-Saharan	polygon (admin. districts)	1990-2008
Harari and La Ferrara	2018	Conflict, Climate and Cells: A Disaggregated Analysis	The Review of Economics and Statistics	Continent	raster (1° x 1° gridded)	1997-2011
Helman et al.	2020	Climate has contrasting direct and indirect effects on armed conflicts	Environmental Research Letters	Continent	raster (0.5° x 0.5° gridded)	1992-2012
Hendrix and Salehyan	2012	Climate change, rainfall, and social conflict in Africa	Journal of Peace Research	Continent	polygon (country)	1990-2009
Hoch et al.	2021	Projecting armed conflict risk in Africa towards 2050 along the SSP-RCP scenarios: a machine learning approach	Environmental Research Letters	Continent	polygon (subnational water provinces)	2015-2050
Jones et al.	2017	Food scarcity and state vulnerability: Unpacking the link between climate variability and violent unrest	Journal of Peace Research	Country (countries with a population of > 1 million)	polygon (country)	1991-2011
Koubi et al.	2012	Climate variability, economic growth, and civil conflict	Journal of Peace Research	Continent	polygon (country)	1980-2004
Landis et al.	2017	Fording differences? Conditions mitigating water insecurity in the Niger River Basin	Political Geography	Regional (West)	raster (0.5° x 0.5° gridded)	1997-2012
Mack et al.	2021	Conflict and its relationship to climate variability in Sub-Saharan Africa	Science of the Total Environment	Continent	raster (0.5° x 0.5° gridded)	1997-2018
O'Loughlin et al.	2012	Climate variability and conflict risk in East Africa, 1990-2009	Proceedings of the National Academy of Sciences	Regional (East)	raster (1° x 1° gridded)	1991-2009
Papaioannou	2016	Climate shocks and conflict: Evidence from colonial Nigeria	Political Geography	Country (Nigeria)	polygon (provinces)	1912-1945
Price and Elu	2017	Climate Change and Cross-State Islamist Terrorism in Nigeria	Peace Economics, Peace Science and Public Policy	Country (Nigeria)	polygon (Nigerian states)	2005-2009
Raleigh et al.	2012	Come rain or shine: An analysis of conflict and climate variability in East Africa	Journal of Peace Research	Country (Uganda, Kenya, and Ethiopia)	polygon (town / village)	1997-2009
Theisen	2012	Climate clashes? Weather variability, land pressure, and organized violence in Kenya, 1989-2004	Journal of Peace Research	Country (Kenya)	raster (0.25° by 0.25° gridded)	1989-2004
van Weezel	2019	On climate and conflict: Precipitation decline and communal conflict in Ethiopia and Kenya	Journal of Peace Research	Country (Ethiopia and Kenya)	polygon (administrative districts)	1999-2014
Witmer	2017	Subnational violent conflict forecasts for sub-Saharan Africa, 2015-65, using climate-sensitive models	Journal of Peace Research	Sub-Saharan	raster (1° by 1° gridded)	2015-2065

Figure 3. Geographic and Temporal Information for Core Articles [34,37,43–61].

Figure 3 contains information about the geographic extent and spatial scale for each article. Extent refers to the area of interest for the study, whether that is the entire continent of Africa, a specific country, or a region within a country. Six studies analyzed the relationship between water and conflict across the entire continent of Africa. Six studies also analyzed this relationship focusing only on Sub-Saharan Africa (SSA). Another six articles focused on specific countries within SSA. Two articles covered either Eastern or Western Africa. One article focused on countries with a population of greater than one million. No articles focused exclusively on the Northern, Southern, or Central regions of the continent. Five articles focused on one country specifically, of which Kenya and Ethiopa were the more popular focal countries. Nigeria is also notable in this group of articles. While it is difficult to say why the authors selected the countries listed in Figure 3, one potential explanation is that English is the official language of Kenya and Nigeria [29]. Another potential explanation is that data are more readily available for these countries than others [29]. A third potential explanation is that some countries are noted for violence related to ethnic and religious expression [62]. For example, Kenya has a history of ethnic rioting following elections, and the northern part of Nigeria has a history of religion-associated terrorism [62].

The column in Figure 3 referring to the spatial scale of the article provides information about the units of analysis used in the study. For example, some studies used grid cells or raster data [43,44], while others used country-level information [37,45]. An advantage of using higher resolution spatial data is that it can better capture within-country variations in conflict, such as higher conflict rates around major cities and lower rates of conflict in less densely populated areas. Higher-resolution data can also capture important rainfall and temperature gradients within countries. A disadvantage of using high-resolution gridded data is that they limit the number of control variables that are available for statistical modeling.

Figure 3 also contains the study period for all articles included in this review. All articles cover at least two years in their analysis and several studies span multiple decades. The majority of studies (n = 12) focus on the 1990s and the 2000s. Two articles span the 1980s, 1990s, and early 2000s [44,46]. Two articles make projections about the relationship between water and climate [47,48]. One article uses data covering the years 1912–1945 [49]. There are many potential reasons for the trends in study periods, but data availability is the most likely explanation. Several of the conflict databases originate in the 1980s or 1990s and provide the first point-level accounts of conflict, by type, across the African continent. The most commonly used precipitation datasets have varying time frames. For instance, data from the Global Precipitation Climatology Project (GPCP) starts in 1979 because it uses remote sensing data; whereas, the Global Precipitation Climatology Center's (GPCC) data originates in 1901 because it relies on station data.

3.1. Conflict Dataset and Measures of Conflict

Figure 4 contains information about the secondary conflict datasets used in the articles selected for this review. Three main sources of data are notable among these studies. The first source is the Uppsala Conflict Data Program (UCDP) curated by the Department of Peace and Conflict Research at the University of Uppsala, Sweden [63], which is widely viewed as the gold standard for quantitative research about armed conflict [64]. This data source contains information about multiple types of organized violence; events in this dataset are defined as "instances of fatal organized event violence" [64]. Examples of the types of information about conflict contained in the UCDP data include (Figure 4): civil conflict, communal conflict, any type of conflict that resulted in at least 25 deaths, and state based armed conflict. A second major source of data is the Armed Conflict Location & Event Data Project (ACLED), which is curated by a non-profit organization within the United States [65] and is considered to be "the highest quality and most widely used real-time data and analysis source on political violence and protest around the world" [66]. Examples of conflict types extracted from this dataset include (Figure 4): battles, explosions/remote violence, riots, and violence against civilians. The third major source of data is the Social Conflict Analysis Database (SCAD) curated by the Robert S. Strauss Center for International Security and Law at the University of Texas, Austin [67]. This database contains information about social and political unrest for the continent of Africa [67]. Events included in this database range from protests, riots, strikes, to communal violence [67].

Based on the twenty-one studies included in our review, six used the UCDP data, six used the ACLED data, two used the SCAD data, two used both the UCDP and SCAD data, and one used both the UCDP and ACLED data. Of the two data sets focused on Africa, ACLED and SCAD, ACLED is used more frequently. Four papers used information about conflict from other sources. One paper used information from The Religion of Peace dataset (TROP), which contains event data derived from news and media sources about acts of terrorism committed by Muslims [50]. The second paper used data from the Kenyan press and Factiva to gather information about the first conflict event that generated 25 deaths or more [44]. The third paper took a historical approach and used information from the National Archives in London to gather information about court cases, homicides, and admitted prisoners between 1912 and 1945 [49]. The fourth paper extracted information about land disputes from the Sustainable Land Management Survey [51].

Even though the data used by these studies came from publicly available sources, it is possible that the choice of dataset could affect model results. This possibility is raised by studies noting differences between the datasets utilized most frequently in the corpus of papers covered by this review: SCAD, ACLED, and UCDP. For example, Demarest and Langer [68] note that databases such as ACLED and SCAD are more likely to contain larger scale violent events meritorous of international news coverage. This bias means small-scale local events not receiving international press coverage (e.g., small scale riots and protests) are less likely to be included in SCAD and ACLED. They found that this bias was more likely to be the case with SCAD, which uses international news sources to compile data, than ACLED. Eck [69] compared the UCDP and ACLED data and noted three important differences between the databases. One, ACLED does not provide information about actors, which makes it problematic for studies of civil war. Two, ACLED uses event based data, which treats the incidence of conflicts equally, irrespective of their magnitude. Three, UCDP is restricted to events resulting in fatalities, while ACLED is not restricted in this way.

Authors	Year	Water Measure	Water Data Source	Conflict Type	Conflict Data Source	Method	Key Finding	Relationship between Water and Conflict
Almer et al.	2017	Monthly Measure (Standardized Precipitation-Evapotranspiration Index)	Global Precipitation Climatology Center	Point data and summary statistics on: (1) number of days with riots (2) binary variable that gets a 1 if at least one riot is observed during the month (3) binary variable that gets a 1 if there is at least one riot in a particular month but none in the month prior	Social Conflict Analysis Database (SCAD)	Panel regression model with fixed effects	A one-standard deviation fall in the index or drier conditions, raises the likelihood of riots in a given cell and month by 8.3%. The impact of dry weather conditions on riots is larger in cells with lower availability of water resources (rivers and lakes)	Drier conditions increase conflict
Anderson et al.	2021	Z-scores of Annual Precipitation and Soil Moisture	Climate Hazards Group Infrared Precipitation (CHIRPS), Soil Moisture (Global Land Evaporation Amsterdam Model (GLEAM))	Frequency of deaths, frequency of events for the following types of conflict: battles, explosions/remote violence, riots, violence against civilians	Armed Conflict Location & Event Data Project (ACLED)	Maximum covariance analysis	Drought related food insecurity is related to violent conflict	Drier conditions increase conflict
Buhaug et al.	2015	Annual Measure (Precipitation variability)	National Oceanic and Atmospheric Administration (NOAA)	Point data of conflict stratified by: armed conflict, social unrest, severe inter-communal violence, attempted coups	Uppsala Conflict Data Program (UCDP), Social Conflict Analysis Database (SCAD)	Ordinary least squares regression (OLS)	At the country level, no link between drought and crop failures and conflict	No link
Detges et al.	2016	Monthly Measure (Standardized Precipitation Index over a 6 month period (SPI6))	Global Precipitation Climatology Center	Point data stratified by: civil conflict and communal conflict	Uppsala Conflict Data Program (UCDP)	Logit model	Road infrastructures influence the risk of civil conflict incidence in connection with precipitation shortall. The availability of alternative water sources influences the risk of communal conflict events related to drought.	Wetter conditions increase conflict
Di Falco et al.	2020	Monthly Measure (Standardized Precipitation-Evapotranspiration Index)	African Rainfall Climatology Version 2	Land disputes	Sustainable Land Management Survey	Panel logit model	Droughts during the rainy season increase the likelihood of conflict. Land certification decreases the probability of conflict during the rainy season.	Drier conditions increase conflict
Fjelde and von Uexkull	2012	Annual Measure (Precipitation deviation), (Standardized Precipitation Index over a 6 month period (SPI6))	Global Precipitation Climatology Project	Point data of events that resulted in at least 25 deaths	Uppsala Conflict Data Program (UCDP)	Logit regression	Large negative deviations in rainfall from historical mean are associated with increased incidence of organized violence; this relationship is amplified in regions with "politically excluded ethno-political groups"	Drier conditions increase conflict
Harari and La Ferrara	2018	Monthly Measure (Standardized Precipiation-Evapotranspiration Index)	ERA Interim dataset from the European Centre for Medium-Range Weather Forecasts	Point data on conflict stratified by: all conflict, battles, violence against civilians, riots and protests, nonviolent rebel activities	Armed Conflict Location & Event Data Project (ACLED)	Logit regression	(1) A 1 std. deviation shock to SPEI during the growing season is associated with a 1.3% point increase in conflict likelihood in the next year. (2) High persistence in space and time; when a cell experiences conflict, it is 12% more likely to experience conflict in the next year; neighboring cells have a 2.3% probability of conflict in the following year as well (3) Climate changes outside the growing season have no effect on conflict; suggests agricultural yields the mechanism in the climate-conflict link (4) Spillovers across national borders are likely-ethnicity is tied to spillovers	Relationship varies
Helman et al.	2020	Annual Measures from 1992-2012 (Precipitation deviation calculated from z-scores)	Climate Hazards Center Infrared Precipitation with Stations (CHIRPS)	Point data of conflict events that resulted in at least 25 deaths	Uppsala Conflict Data Program (UCDP)	Structural equation modeling	Higher temperatures and lower rainfall have direct linkages with conflict. Higher temperatures and lower rainfall patterns have weaker linkages with indirect factors associated with conflict such as food and water supplies.	Relationship varies
Hendrix and Salehyan	2012	Annual Measure (Standardized rainfall deviation from the long-term mean of rainfall for a given country)	Global Precipitation Climatology Project	Counts of the following types of conflict stratified by region: total conflict events, nonviolent events, violent events, government-targeted events, nongovernmental events, and civil conflict	Uppsala Conflict Data Program (UCDP), Social Conflict Analysis Database (SCAD)	Logit regression models; negative binomial regression	Increased rainfall increases the probability of conflict	Wetter conditions increase conflict
Hoch et al.	2021	Precipitation, evaporation, flood volume	Simulated environmental variables using PCR-GLOBWB (Sutanudjaja et al., 2018)	Binary indicator of conflict incidence (state-based armed conflict and non-state conflict events)	Uppsala Conflict Data Program (UCDP)	Machine learning (CoPro ML Model)	The link between water-related indicators of climate change varies regionally across the African continent	Relationship varies
Jones et al.	2017	Monthly Measure (Monthly deviation in rainfall from long-term monthly average)	Global Surface Summary of the Day (GSOD) project at the Global Observing System Information Center	Dichotomous measure of conflict that takes on a value of "1" if there is at least one violent event and "0" otherwise	Social Conflict Analysis Database (SCAD)	Logit regression	Finding related to water: (1) state vulnerability moderates the impact of rainfall on conflict and (2) in both high and low vulnerability states, especially dry months are associated with a higher likelihood of violence.	Drier conditions increase conflict
Koubi et al.	2012	Monthly Measure (Deviation of current precipitation from long run mean)	Global Precipitation Climatology Centre of the World Meteorological Organization, Climatic Research Unit	Point data of events that resulted in at least 25 deaths	Uppsala Conflict Data Program (UCDP)	Logit regression	Climate variability does not impact conflict through economic growth	No link
Landis et al.	2017	Monthly Meaure (Trend in precipitation, positive or negative)	Climate Research Unit of the Universtiy of East Anglia	Point data on conflict stratified by: all events, battles, civilian riots and protests, remote violence and violence against civilians	Armed Conflict Location & Event Data Project (ACLED)	Zero-inflated negative binomial model	Negative precipitation variability increases the risk of political violence	Drier conditions increase conflict
Mack et al.	2021	Montly and Annual Measure (Monthly and annual deviation of rainfall from 22-year mean)	Climate Hazards Group Infrared Precipitation (CHIRPS)	Transition of a grid cell from below average levels of conflict to above average levels of conflict for all conflict event types and the following types of conflict: battles, explosions and remote violence, protests, riots, strategic development, violence against civilians	Armed Conflict Location & Event Data Project (ACLED)	Markov chain, Logit panel model	Seasonal and regional effects in the probability of a transition from peace to conflict	Relationship varies
O'Loughlin et al.	2012	Monthly measure (Standardized Precipitation Index over a 6 month period (SPI6))	Climate Research Unit of the Universtiy of East Anglia	Point data of conflict stratified by: battle–government regains territory, battle–no change of territory, battle–rebel control of territory, riots/protests, and violence against civilians	Armed Conflict Location & Event Data Project (ACLED)	Negative binomial model	Wetter deviations from precipitation norms decrease the risk of violence. Drier and normal periods have no relationship with violence.	Wetter conditions decrease conflict
Papaioannou, K.	2016	Monthly and Annual measure (Standardized rainfall deviation from long-term mean)	Administration Annual Reports which contain data from 36 metereological stations across Nigeria	Index of soco-poitical conflict and tablular data on number of prisoners admitted during the year, the number of court cases, the number of homicides	Books of statistics, administrative reports and session papers from the National Archives in London	Panel regression model	U-shaped relationship between rainfall and conflict. Large negative deviations from normal associated with conflict as are large positive deviations. In the middle of the U is where there is little deviation from normal.	Relationship varies
Price and Elu	2017	Annual Measure (Mean maximum temperature and total rainfall)	Annual Abstract of Statistics 2012 for the Federal Republic of Nigeria	Point data with two measures: (1) Islamist terrorist incidents (2) Islamist terrorist incidents targeting Christians	Religion of Peace (TROP)	Probit model; zero-inflated Poisson; zero-inflated negative binomial	Increases in temperature and decreases in rainfall increase the likelihood of Islamist terrorism in Nigeria	Drier conditions increase conflict
Raleigh et al.	2012	Monthly Measure (Positive or negative monthly deviations from monthly rainfall average)	NOAA Climate Prediction Centre Merged Analysis of Precipitation (CMAP)	Counts of total conflict events, rebel actions, and communal violence	Armed Conflict Location & Event Data Project (ACLED)	Negative binomial regression; composite analysis	Both extreme wet and dry conditions are associated with an increased incidence of conflict.	Relationship varies
Theisen, O.	2012	Annual Measure (Rainfall operationalized as the percent deviation from mean rainfall and standardized precipitation index)	Global Precipitation Climatology Center	Point data of conflict events that resulted in at least 25 deaths	Kenyan press and Factiva	Logit regression	Wetter years are associated with more conflict	Wetter conditions increase conflict
van Weezel	2019	Long Term Measure (Precipitation shift measured as the difference in the average anomaly, subtracting the benchmark period (1981–98) average from the 1999–2014 average)	Centennial Trends Greater Horn of Africa Precipitation Dataset (Funk et al.., 2015)	Point data on communal conflicts	Uppsala Conflict Data Program (UCDP)	Negative binomial model	Precipitation decline leads to an additional 1.3 conflict events per district.	Drier conditions increase conflict
Witmer	2017	Monthly Measure (Standardized Precipitation Index over 6 months (SPI6))	Climate Research Unit from the University of East Anglia	Point data on conflict stratified by: violence against civilians, riots/protests, battle events	Armed Conflict Location & Event Data Project (ACLED), Uppsala Conflict Data Program (UCDP)	Poisson multilevel model with country-level random effects	No relationship between conflict, climate and precipitation anomalies	No link

Figure 4. Information about Water, Conflict, Methods, and Results for Core Articles [34,37,43–61].

3.2. Water Data

Figure 4 also contains information about measures of water and the associated source of data. Studies used a variety of data including the Annual Abstract of Statistics for the Federal Republic of Nigeria, the National Oceanic and Atmospheric Administration (NOAA) Climate Prediction Centre Merged Analysis of Precipitation (CMAP), and the Global Observing System Information Center. A common data source (n = 5) is the Global Precipitation Climatology Project's gridded monthly precipitation dataset that, in its current version, has a temporal extent from 1979–2022 and a spatial resolution of 2.5° × 2.5° [70]. Most studies used a metric of precipitation deviation from a long term average. Precipitation was incorporated in analyses in one of four ways: (1) the Standardized Precipitation Index (SPI); (2) the Standardized Precipitation and Evapotranspiration Index (SPEI); (3) annual deviation from the long-term mean; and (4) monthly of deviation from the long-term mean.

For studies of precipitation in Africa, monthly precipitation metrics are preferred to annual metrics because of seasonal variations across the continent, particularly across southern Africa. For example, Campo-Bescos et al. [71] used monthly climate data to illustrate key drivers of landscape productivity across large portions of southern Africa. Waylen et al. [72] highlighted extreme variability in daily and monthly precipitation, which further illustrates the need for a careful consideration of the types of climatic data and associated time steps used in analyses of conflict. From this perspective, the temporal flexibility of precipitation indices such as SPI and SPEI offer the advantage to calculate the metric at a variety of time scales [73,74]. Commonly used temporal windows (or lags) include 1 month, 3 months, and higher multiples (e.g., 6, 9, 12, 18, and 24 months).

Each index has its particular drawbacks. SPI only tracks precipitation and indicates the number of standard deviations that observed accumulated precipitation deviates from long term trends. Thus, SPI is not helpful in arid to hyper arid landscapes, e.g., [75], because the absence of precipitation is not tracked. In contrast to SPI, SPEI aims to measure water availability, drought, and soil moisture content by including both precipitation and potential evapotranspiration (PET). SPEI is a relatively new index [76] developed to better understand water availability characteristics in semiarid regions around the world. SPEI is based on the difference between precipitation and PET, and PET can be calculated in a couple of different ways. There are conflicting opinions over the best approach to calculate PET, but the Penman-Monteith equation is most common in SPEI calculations.

3.3. Synthesis of Study Findings

Figure 4 presents a summary of each article's findings about water and conflict. The figure classifies the findings of these studies into six categories:

1. Wetter conditions are associated with less conflict;
2. Wetter conditions are associated with more conflict;
3. Drier conditions are associated with less conflict;
4. Drier conditions are associated with more conflict;
5. The relationship between climate and conflict varies with the amount of rainfall;
6. No relationship between water and conflict.

Across these categories, there are few clear trends between the temporal scale used, data sources used, and analytical results. Spatial scale may impact study findings however. Two of the three studies finding no link between water and conflict used country level data [37,46]. All papers that found nuanced, varying relationships between water and conflict used subnational data. Three of these studies used grid-cell-level data [52–54]. This trend suggests studies using country level data may not contain sufficient spatial resolution to capture all of the nuances between water and conflict, particularly across a continent with a lot of heterogeneity between and within countries with respect to dry and wet seasons, as well as conflict incidence and conflict types.

Of the 21 studies listed in Figure 4, four of them noted that wetter conditions were linked with conflict incidence, albeit in opposing directions. Three studies found wetter conditions were associated with increased levels of conflict [34,44,55]. In times of wetter conditions, though not floods, there is potentially an abundance of natural resources and overall higher level of landscape productivity. The link between wetter conditions and conflict occurrence could thus be associated with groups of people striving to obtain resources—i.e., conflict driven by abundance rather than scarcity [77]. Alternatively, if there are wetter conditions and there are more resources available, then groups may choose not to engage in conflict as there may be sufficient resources for everyone.

Eight studies found drier conditions were associated with more conflict [43,45,50,51,56–59]. These studies found evidence of this relationship across a range of geographic settings: Nigeria, Ethiopia, Kenya, Western Africa, and SSA. Diverse definitions of conflict were also used in each of these studies, ranging from Islamist terrorist incidents [50], riots [43], land disputes [51], and communal conflicts [59]. The findings of these studies support the idea that people are more likely to compete for resources in times of scarcity [78,79], particularly in places such as SSA, where people's livelihoods depend on more predictable rainfall patterns [56]. The importance of rainfall is echoed in the findings from several studies. For example, DiFalco et al. [51] found that droughts during the rainy season, when water is anticipated, creates conflict over land. Both Jones et al., [57] and Anderson et al. [45] found a link between water and conflict through the mechanism of food security. In particular, Anderson et al. [45] found that drought conditions increase food insecurity and that it is this rise in food insecurity that contributes to violent conflict. An interesting aspect of this group of studies are findings that indicate the characteristics of places that amplify or attenuate the linkage between water and conflict. For example, Almer et al. [43] indicated diminished water availability can magnify the impact of drier conditions on the incidence of riots. Political exclusion is another factor noted to amplify the relationship between dry conditions and conflict [56]. Conversely, Jones et al. [57] noted that higher quality institutions can attenuate or diminish the likelihood that dry conditions lead to conflict.

A third group of studies (n = 6) finds that the relationship between water and conflict varies [47,49,52–54,60]. Many of these studies found deviations from normal—whether too wet or too dry—drives conflict. For example, Raleigh and Kniveton [60] found that the frequency of rebel and communal conflicts increase during periods of extreme variation, irrespective of the direction of the extreme. Helman et al. [53] found that the direct effects from extreme climate, temperature or precipitation, on conflict were stronger than indirect effects. Papaioannou [49] also found evidence of a U-shaped relationship between rainfall and conflict, suggesting that extreme deviations from normal drive conflict; thereby supporting the argument that wetter conditions are worse than drier, because conflict was worse in wetter years. Their explanation for this conclusion was twofold. First, crop losses for farmers in extremely wet periods is much faster than the slower onset impacts of a prolonged drought, where farmers may delay conflict as they wait for rain. Another explanation is that very wet periods destroy infrastructure needed for the police and military to respond to conflict. Thus, conflicts last longer because the parties that prevent them are unable to get to conflict locations. The fourth study in this group is more specific about the timing of the linkage between conflict and water. Harari and Ferrara [52] found that even one standard deviation in climate regimes, as measured by the SPEI, resulted in a higher susceptibility to conflict, both in the immediate future and within the following 12 months. They also found that climatic changes during the growing season are linked to conflict, but changes outside of the growing season were not.

The last two studies within this group found regionally and seasonally varying relationships between water and conflict. Mack et al. [54] found that above average rainfall in SSA during the dry season placed grid cells at a higher probability of transitioning into conflict. This pattern was particularly notable for Western and Southern Africa when households are likely to migrate to cities in search of employment opportunities. In Central Africa, however, above average rainfall at any time was more likely to lead to conflict. This result is perhaps related to the area's wetter climatic conditions, which make food stores and crops susceptible to rotting. The Hoch et al. [47] study found that the links between water and conflict will vary across the African continent in the future. They projected for areas already prone to conflict in Northern and Eastern Africa, that changes in climate related to water will increase the risk of conflict. The study also projected that in some parts of the Sahel and Western Africa, changes in climate related to water will actually reduce conflict risk.

The fourth group composed of three studies found no relationship between conflict and water [37,46,48]. These studies differed in terms of the temporal resolutions and measures of water, suggesting no clear trend in drivers of findings. Witmer [48] used a 6-month SPI to measure water; Koubi [46] used a monthly based deviation from the long-term mean precipitation measure; and Buhaug et al. [37] used an annual measure of precipitation. However, two studies used country-level data [37,46], suggesting this spatial scale may be insufficient to unpack locally varying relationships between conflict and water.

4. Discussion

Our analysis of peer-reviewed research papers analyzing the linkages between water and conflict on the African continent produced several findings. The first and perhaps most notable finding is the relatively small number of studies (n = 21) dedicated to this specific topic. This finding was surprising given the growing body of work about conflict and climate change [19,25,27] and the popularity of Africa as a focal point for these studies [29]. A second finding of this review is the focus of studies on measures of water related to rainfall and precipitation. While this result may be related to the search terms used for the present review, it does suggest that there is room for future research related to water that is not measured using rainfall or precipitation. A third finding is the variation in linkages described in the studies. While most of the articles we reviewed found a link between water and conflict, the direction and magnitude of these linkages were not consistent across the studies. As noted previously, some of this variation may be related to the datasets utilized to operationalize conflict [68,69]. This finding also coincides with prior work on climate change and conflict more broadly [20,23,27,80,81] and suggests that narrowing the focus of climate change and conflict studies to water does not produce clearer findings. Finally, spatial scale may impact study results, particularly studies using country level data that find no linkages between water and conflict. Spatial scale is a particularly important consideration on the African continent because of the heterogeneity between and within countries with respect to dry and wet seasons, as well as conflict incidence and conflict types.

It is important to note, however, that these findings are based on a small group of papers that were selected based on the search parameters specified for this review. While systematic reviews strive to be as comprehensive as possible, they will not capture every single article that was ever published on this topic. The goal of systematic reviews is to be comprehensive and practical, which means that there must be some limits placed on search parameters or the number of potential papers to be reviewed becomes impractical. Thus, our review may not have captured every peer-reviewed article published about water and conflict on the African continent. For example, articles that refer to specific locations or water bodies (e.g., Nile, Zambezi, streams of local importance) may not been included in the present review. It also means that papers referring to specific countries on the continent and that do not reference Africa in the keywords, abstract or title may also be excluded from the present review. A second limitation of the present review is its mix of studies that contain some papers focused on one country and other papers that analyze the relationship between water and conflict across the African continent. A third and related aspect of this paper is the choice to make the review a longitudinal study covering vastly different types of societies. These two limitations were unavoidable given the limited number of studies meeting the criteria for this review (n = 21). Had further parameters been added, even fewer papers would have been included in the review. Lastly, the findings of this review may be related to the focus on English language papers. Had searches been conducted for articles in languages other than English, our corpus of papers and results may have been different.

Despite these limitations, the group of papers analyzed in this review points to six avenues for future research. Before elaborating upon each of these six areas, it is important to state the following discussion does not include a call for research examining various indirect impacts of climate change on conflict via mechanisms such as agriculture, food security, institutional quality, and livelihoods. We do not include them here because this fruitful line of inquiry has already been noted in prior work [25,82].

4.1. Using Mixed Methods Approaches

One area for future research noted in prior reviews of climate and conflict more broadly [23,27,80,81]—but which is also relevant for papers focused on water and conflict—is work that builds on a large body of qualitative studies, which provide important information about specific communities and their experiences with conflict [83–85]. Our review of the literature indicated that social scientists have conducted several localized and relevant case studies to explain the rise or the mediation of conflict [86–89]. Although important, these studies are also difficult to replicate, which is why this review focused only on quantitative assessments using secondary data sources. That said, quantitative studies tend to overlook or are unable to capture more nuanced origins of conflict, the conditions that make particular locales susceptible to conflict, or to characterize the trigger events of specific conflicts. Qualitative studies provide rich detail about local sociocultural contexts that affect the suppression or facilitation of conflict, and they investigate how these local contexts interact with local, national, and transcontinental trends—be they economic, ecological, or political—to understand the entanglement of exogenous factors with local ones. Qualitative data and analyses are particularly useful to contextualize, ground-truth, and add nuance to location and time specific measurements and empirical model predictions [25,26].

Therefore, future research that couples and leverages the replicability of quantitative work using secondary data with the rich contextual information from qualitative studies could reap the benefits of both analytical approaches. To accomplish such synthesis, we suggest bottom-up studies that take site-specific information about conflicts and then use this information to construct, test, and refine quantitative models. Specifically, meso-level analyses (either within a particular country or between countries) are likely to benefit from this type of analysis where rich contextual information about conflict initiation and its spillover into other regions can inform the quantitative modeling of conflict spread. For example, the 1994 conflict in Rwanda spilled over into neighboring countries, which remain conflict hotspots to this day (e.g., Democratic Republic of Congo). Although this example is not specific to water, instances of conflict related to water may be a source of conflict in neighboring regions. Qualitative studies could help pinpoint these instances, which could then be evaluated empirically. To examine spillover dynamics at various spatial scales, it will be critical to use models that incorporate spatial effects [52].

4.2. Expanding the Scope of Vulnerability Assessments

A second area for future work is an expansion on existing studies where water is identified as a driver of vulnerability. We encountered three vulnerability studies in our review [90–92]. However, they were excluded from our analysis because, while they indicated the potential for conflict, they did not take the next step to link the identified vulnerabilities to actual occurrences of conflict. Vulnerability studies can provide valuable information about the conditions that render places susceptible to conflict. Thus, when paired with secondary data about conflicts, these studies offer the potential to use forecasting models to assess if historical vulnerabilities render places more susceptible to conflict in the future, with attention to trigger events. In conducting these assessments, an interesting line of work might compare locations at peace and those in conflict despite projections to the contrary. Such comparative analyses of counterfactuals could provide valuable information about why some places remain peaceful despite their potential for conflict.

4.3. Studying Peace Persistence and Conflict Mitigation

Rescoping vulnerability studies brings up a third area for future research: investigating peace persistence and conflict mitigation. The papers analyzed here note a variety of conditions that make places vulnerable for conflict due to water issues (e.g., scarce water resources, drought, inequalities, social fracturing or strong ideological divides), but analyses and discussion of peace persistence were nonexistent. In part, this bias may reflect how our systematic search was structured; specifically, the search terms we employed. Yet, this finding is still surprising because studies have noted that conflict is a last resort for allocating resources in the presence of ineffective institutions [93]. They also noted that cooperation, not conflict, is the more efficient and more likely response to water issues [13–18,94,95]. Furthermore, a desired outcome of conducting analyses of conflict is to identify and provide information that may be useful to mitigate future conflicts and enhance the adaptive capacities of communities, societies, and nations. Investigating conditions that promote peace persistence and promote conflict mitigation—which may not be the simple inverse of the conditions that facilitate conflict [96]—could provide critical information that helps advance our understanding of the link between water and conflict. Empirical research about peace persistence and conflict mitigation would make a useful contribution to a budding line of research about environmental peacebuilding, which is composed primarily of qualitative studies [97–100]. Two key questions include: (1) Which areas that experience deviations from normal climate conditions do not experience conflict? and (2) What are the regional characteristics—environmental and otherwise—that promote long-term peace? Efforts to answer these questions could compare and contrast institutional differences to illuminate potential conflict mitigation strategies. Here, databases dedicated to conflict mitigation (e.g., the Peace Accords Matrix, IPI Peacekeeping Database) could prove particularly useful. Future research could also identify and analyze points of peace preservation, especially in areas experiencing high rates of environmental change, to learn how to effectively grow or develop peacebuilding programs, and to understand how these programs can be fostered in areas where conflict arises over complex water issues.

4.4. Evaluating Environmental Migration

Another area of future research is the investigation of responses to water scarcity related conflicts. One response is the migration of people to alternative locations. In 2018 and 2019 in SSA alone, 2.6 million and 3.4 million people were displaced by natural disasters [3]. The latest IPCC Working Group II report suggests that by 2050 between 17.4 and 85 million people could relocate due to environmental changes impacting water availability [101]. Although research on the topic is growing, we do not yet understand the underlying mechanisms behind migration as a response to environmental change [102,103]. A link between environmental migration and conflict is anticipated because of the potential for stressors in receiving locations, including ethnic tensions, competition for resources, additional burdens on services and infrastructure, and dysfunctional institutions [103,104].

Figure 5 details some of the events on the continent of Africa with environmental migration linkages. One of these events is the historic 1984–1985 drought in the Awash River Basin in Ethiopia, which is home to several million people [105]. In this time period, a series of failed rainy seasons and poor harvests left millions without food [106]. The drought and associated famine, combined with ongoing border conflict in northern Ethiopia, created a perfect storm of events that left one million people dead [107]. These conditions forced many people to migrate and take up residence in refugee camps. Many more people died in these camps when rains arrived in the spring of 1985, spreading cholera and other diarrheal diseases [106]. The scale of this humanitarian crisis, and the ongoing vulnerability of Eastern Africa and other parts of Sub-Saharan Africa to food insecurity because of a reliance on rain-fed agriculture, led to the development of early warning systems to take proactive steps against famines (e.g., FEWS NET) [108]. These conditions and history suggest an increased likelihood of conflict related to environmental migration as global climate conditions continue to evolve.

Origin	Time Period	Environmental push factors	Conflict at Destination (Y/N)
Ethiopia (Awash River Basin)	1984-1985	Drought, famine, forest fires, locust invasion	Y
Rwanda	early 1990s	Arable land/water scarcity, land degradation, deforestation	Y
Ethiopia/Eritrea	1960s-1980s	Droughts, famines	Y
Mauritania	1980s-1990s	Drought, soil erosion, desertification, deforestation, water scarcity	Y
Somalia	1970s	Arable/grazing land degradation, water scarcity	Y
South Africa	1970s-1980s	Land degradation, deforestation, subsistence crisis, water scarcity	Y
Sahel	late 1960s-1980s	Droughts, famines, land scarcity	Y
Sudan	1970s-1980s	Droughts, famine, desertification, deforestation, erosion	Y
Ethiopia	late 1970s	Grazing/arable land degradation, deforestation	Y
Nigeria, Jos Plateau	1970s-1990s	Soil/water/air pollution, silted rivers, land scarcity/degradation	Y
Somalia	late 1980s-mid 1990s	Drought, erosion, deforestation	N
Kenya (Northern and Western)	1960s-1990s	Drought, land degradation, land scarcity, famine	N
Burkina Faso (Mossi Plateau)	1960s-2000s	Drought	N
Zimbabwe (Southern lowland)	1980s-	Drought	N
Tanzania (Southern, Northeast)	1950s-1990s	Land scarcity/ degradation	N

Figure 5. Historical Environmental Migration Examples from Africa. Source: Adapted from Reveny (2007) [104] pp. 663–667.

As work progresses on this topic, there are several considerations to bear in mind. First, distinctions between slow onset and rapid onset environmental change are critical. Studies suggest rapid onset events (e.g., flooding, mudslides) are more likely to trigger migration than slow onset environmental change, where it may be easier to cope and then adapt over time [104]. From this perspective, studies may want to focus attention on particular types of events (e.g., flooding, landfall of tropical cyclones, mudslides, locust outbreaks, or rapid-onset drought). A second consideration is the type of conflict that could take place in the destination location (e.g., violent or social). The assessment of multiple types of conflict is necessary since the impact may vary depending on the number and type of migrants, and also the characteristics of the receiving location. A third consideration is the characteristics of the migrants and people in the receiving country, with a focus on racial/ethnic/cultural differences. Conflict may be more likely when a large number of racially/ethnically different migrants enters a receiving area. Smaller groups of racially/ethnically different migrants may not be perceived as a threat and may not provoke conflict. Differences in institutional capacity need to be controlled for, since these alone may drive conflict rather than the peaceful integration of new migrants. A fourth consideration is the scope of migration in question (e.g., international vs. internal migration). In Africa alone, studies find substantial variation in migration behavior across countries in response to climatic changes at various spatial scales [3].

4.5. Characterizing Water Stress Quantitatively

Work is needed on the relative strengths and weakness of characterizing water stress through alternative metrics and models. Researchers can choose among many different variables that measure basic elements of weather and climate (e.g., temperature, precipitation, wind speed, relative humidity, soil moisture, etc.) or derived metrics (e.g., SPI, SPEI). Some articles addressed the (mis)use of point-source climate data as important considerations in characterizing climate change, including drivers of climatic variation, data development approaches, and pre-processing techniques [109,110]. There are also useful comparisons of precipitation datasets that can guide data selection [111]. One consideration are the tradeoffs between station-based data, remotely sensed data, reanalysis data, or some combination. Weather station data can provide fine-grained information, but may be destroyed during conflict, producing missing data for the time period of interest [112]. The availability of gauge data is also endogenous to conflict, which makes it unsatisfactory for studies seeking clear causal linkages between water and conflict [52].

Remotely sensed data provide more stable but perhaps coarser meteorological data and climate information. For example, nearby station data may be more accurate than a gridded climate model product at 10km resolution for a local study of drought-resistant crops. The scale of conflict data and the particular research question should help guide the selection of weather and/or climate data. If one is trying to run an analysis of climate and conflict related to agricultural yields, then certain agro-climatic metrics (e.g., growing degree days, seasonal length, precipitation anomaly) may be more germane than others.

In addition to data sources, integration of climate data needs to consider the spatial and temporal scales, and the purpose for which the data were collected, to avoid integration of dissimilar data. This caveat is particularly true for derived metrics of climate conditions (SPI or SPEI) that have a temporal lag or averaging/compositing window incorporated into their calculation. For example, SPI-3 measures precipitation deviations within a 3-month window. However, if one does not know the proper window associated with this measure then information at the same spatial scale, but different temporal window may be integrated incorrectly with SPI-3 data. Another key consideration when using derived metrics are the baseline data used in their calculation. For example, the SPEI is an indirect measure of soil moisture and employs both temperature and precipitation baseline data into the index calculation.

Outside of the sources of data used to characterize climate change, studies can also expand upon how water is conceptualized in analyses. Measures of precipitation, drought, and evapotranspiration have dominated in the water-conflict literature, and given the agricultural orientation of livelihoods on the African continent, this is reasonable. However, other issues related to water may be sources of conflict. Thus, in future work scholars may wish to consider issues pertaining to including water quality, water access (physical, legal, and financial access), and water rights, including mediating and regulating institutions.

4.6. Characterizing Conflict Quantitatively

A sixth avenue for future work is how conflict is quantitatively characterized. In our review of studies, a common strategy was to analyze the link between water and the presence or absence of conflict using binary choice models (see Figure 4). This approach treats small and large occurrences of conflict similarly. It also does not consider the historical level of conflict within study areas. Moving forward, studies should consider whether the level of conflict is above average for that region. Another strategy would be to examine conflict counts above a particular threshold. This step would avoid treating one conflict event the same as several conflict events, which is unavoidable in binomial and logit regression models.

More work is also needed to assess the different types of conflicts most likely to arise from water-related issues. While work has largely debunked the possibility of interstate conflict over water [18,99,113] and a large chunk of work has devoted attention to violent conflict [13,17,55,114], comparatively less work has been devoted to the link between water and social conflict, particularly interpersonal conflict. Social unrest is important to consider because it may render a place unstable and less attractive to attract tourists and foreign direct investment. In extreme cases, social unrest can also lead to widespread instability and regime changes, as was the case with the Arab Spring in 2010 when social unrest in Tunisia spread to other countries including Bahrain, Egypt, Jordan, Morocco, Syria, and Yemen [115]. Sensitivity analyses that consider the linkages between water and different types of conflict within the same study area are also critical. This practice would follow the example of some of the studies profiled in this review [34,37,48,52,54].

5. Conclusions

Our recommendations for future research may help reduce the manifold uncertainties in the climate-conflict nexus. If the outcomes of this scholarship are to be leveraged to guide the decision-making of governing bodies and their national and international security interests, then greater consistency in findings and higher confidence in results are required. Correspondingly, these decisions and resulting actions will likely affect the lives and livelihoods of most peoples. Gleditsch [116] aptly characterizes this reality: "while the structure of this debate has remained relatively similar, the stakes seem higher." The onus is thus on the research community to identify constructive solutions.

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