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Climate Adaptation, Water Governance & Conflict

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School of Business & Economics

Discussion Paper

Economics

2026/10

Climate Adaptation, Water Governance & Conflict*

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Abstract

This paper estimates the causal effect of renewable water conditions and water use on violent conflict in rural agrifood systems. We implement a fixed-effects instrumental variables strategy that uses plausibly exogenous temperature and precipitation shocks to instrument multiple water outcomes. Annual specifications are imprecise, but five-year aggregations yield sharper inference and show that higher renewable freshwater availability significantly reduces conflict risk. Water use margins are central: freshwater withdrawals are associated with lower conflict, whereas higher aggregate water-use efficiency is associated with increased conflict risk. Overall, the results indicate that climate-driven water shocks operate through distinct channels—stocks, withdrawals, and efficiency—and that empirical conclusions depend critically on time aggregation and the definition of water being instrumented. The findings imply that climate adaptation and water policy should be paired with conflict-sensitive governance and improved measurement of local water use and access.

Keywords: agrifood systems, hydro-climatic shocks, violent conflict, water-use efficiency, instrumental variables.

JEL Codes: Q25, Q15, D74, Q54, C26

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1 Introduction

Since the conclusion of the Second World War, violent conflict has persistently obstructed global development by eroding physical capital, undermining state capacity, and fracturing the social infrastructure essential for long-run growth. A robust literature in political economy and development argues that such violence is rarely the product of primordial ethnic or cultural animosities. Instead, conflict is more accurately understood as a contestation over rents, resource rights, and institutional enforcement—particularly where high-value resources interact with unequal access and fragile governance (e.g., the “greed vs. grievance” tradition).

More recently, climate change has been underscored as a multiplier of these tensions. Anthropogenic environmental changes can increase the magnitude of ecological constraints, aggravate the insecurity of livelihoods—particularly in developing economies—and increase the importance of distributional struggles over land and water (ESCWA, 2023). Yet the empirical record remains fragmented. A key reason is measurement and aggregation: water scarcity is often proxied by slow-moving national indicators, while conflict is inherently localized and responds to high-frequency shocks and context-dependent governance structures. Climate adaptation strategies frequently emphasize the role of water productivity and hydraulic infrastructure in mitigating crises. However, these interventions may produce adverse political effects by reshaping the distribution of resource rents within rural economies. When governance institutions are weak, the economic gains from adaptation may increase competition over resources rather than mitigate conflict.

This paper contributes to the literature on the resources-conflict nexus by shifting the analytical focus from aggregate scarcity to the political economy of water as a set of channels—availability, withdrawals, and efficiency. A central challenge in this setting is the endogeneity of water outcomes: conflict risk and water use are jointly affected by migration, investment, infrastructure, and policy responses. We address this concern using an instrumental variables strategy that exploits plausibly exogenous climate variability as a source of within-country variation in water use, allowing us to identify the causal impact of water-related constraints on violence in rural agrifood systems.

It is important to note that both the sign and the magnitude of water’s effect on conflict are linked to governance institutions. In environments where the rights of actors to resources are inherently unclear and where there is weak enforcement of rights, the expansion of access to a resource can alleviate insecurity for some actors while simultaneously creating conditions of increased competition for others. Changes in the efficiency of the use of a resource can also lead to grievances among existing actors in those environments. Thus,

while the security and climate change literature has largely focused upon the biophysical elements of climate change, these factors are actually only part of a framework that can be used to understand how environmental changes can lead to the emergence of conflict among the actors within those environments.

The remainder of the paper is organized as follows. Section 2 reviews the related literature, while Section 3 presents the policy framework that will be applied to examine the relationship between climate-related security issues and competition for water resources. Section 4 presents the theoretical mechanisms for the relationship between water and conflict. Section 5 describes the data and identification strategy. Section 6 discusses the results of testing those mechanisms, and Section 7 draws conclusions from those results.

2 Literature

Climate change is increasingly recognized as a threat to national security created through the resulting violent conflict that can emerge as a result of these climatic shifts. The link between these two factors has been analyzed throughout history, revealing the ways in which climatic shifts have led to conflict and the decline of various civilizations over time. Authors such as [McNeily \(2011\)](#) have explored the relationship between climate change and conflict in the past, revealing that the main conflicts that emerged from climate change were localized to regions experiencing scarcity of the resources those regions relied upon for survival. This has been particularly the case in regions with developing economies in which conflict between pastoralists and farmers was common. In these ecologically sensitive regions, the violence that emerges from climate change threatens food security for those who are undernourished, as there are currently an estimated one billion undernourished individuals in the world ([FAO, 2018](#)). These various impacts of climate change can be analyzed through three primary ecological channels: shifts in precipitation levels, shifts in extreme weather events, and shifts in the planet's thermal levels. Each of these factors can contribute to the development of a comprehensive strategy for the adaptation of the planet's nations and their governments, especially in relation to the legislation that they pass and the methods that they utilize to finance any proposed measures.

Another area of study that relates to these impacted regions is that of natural resource management. Many of these rural areas of the planet are without power to manage the land within their region, leading to the development of conflict between those individuals who rely upon these natural resources for survival. The exact relationship between these two factors is poorly understood by researchers in the field, regardless of the number of research studies that have been performed on the topic. Resources vary in their type of

creation (renewable or traditional), the needs of the individuals within those societies for which those resources are critical, and the type of value that those resources provide (from water to rare earth elements).

While conventional wisdom from authors such as [Koubi et al. \(2013\)](#) suggests that the scarcity of renewable resources such as water and land, and the abundance of non-renewable resources like oil, gas, and minerals, is the major driver of violence within the planet's regions, others suggest the opposite. For instance, authors such as [Brown \(2010\)](#), [Hendrix & Salehyan \(2012\)](#), and [Theisen \(2012\)](#) have reported that regions with an abundance of renewable natural resources experience more violent conflicts than those with fewer of those resources. The reason for these different findings is due to the different variables that were analyzed within each study.

While the link between natural resources and conflict has been studied for decades, the relationship between those two factors can be analyzed through two main theoretical frameworks. Each framework analyzes the link between scarcity of natural resources and the increase in the probability of violent conflict between individuals within those regions, or the link between the resource curse (abundance of one type of natural resource) and the resulting conflicts between those areas and their natural resources. Each framework has been studied throughout history through authors such as (e.g., [Koubi et al., 2013](#)) who found that the most profitable, non-renewable natural resource within a region was associated with the curse or abundance framework, while those that contained more renewable resources were related to the scarcity framework. Each theoretical interpretation of the link between natural resources and conflict has been connected to different schools of economic thought. For instance, Neo-Malthusians tend to focus on the link between the scarcity of those natural resources and the resulting conflicts between individuals, while neoclassical economists focus on the link between the abundance in natural resources and the resulting conflicts between the governments of those regions, the natural resource owners, and the peoples of those regions who are required to contribute to the management or exploitation of those abundant natural resources. Finally, political ecologists ecological economists focus on both of those frameworks, suggesting that the link between natural resources and conflict is actually a result of the power relationships between those groups, rather than the link between the resource itself and the conflict.

The relationship between natural resources, climate change, and the 2030 Agenda for Sustainable Development and its goals (SDGs) are, therefore, interconnected issues that must be addressed in the development of effective strategies for the planet. The planet's agendas recognize that many of those issues impact marginalized groups on the planet (such as women, youth, and persons with disabilities), leading to the understanding that any

strategies for those issues must also be gender-sensitive and inclusive of the marginalized groups and their needs (ESCWA, 2024). The relationship between natural resource management and conflict emerged as a multi-faceted relationship between those two factors. For instance, the degradation of renewable natural resources due to mismanagement of those resources, environmental shifts, and increasing demand for those resources can lead to violent conflicts. These factors can be analyzed through three primary channels that link natural resource conflicts with the resulting violence, especially within those fragile regions of the planet that lack the governmental power to manage their natural resources.

The most prominent manifestation of this dynamic is the connection between water scarcity and hydrological stress. Most regions of the planet have unequal access to the water resources that it requires to sustain itself, leading to conflicts between those regions (especially between those that have an abundance of water and those that have none) and the link between those conflicts and the natural resource within the region. Additionally, regions such as the Sahel region and Sudan have an abundance of livestock herds that rely upon water resources to survive. This directly bolsters competition between sedentary agriculturalists and mobile pastoralists. Therefore, conflicts over access to water points and grazing land can be deadly and self-perpetuating.

These dynamics are particularly salient in the context of climate change and its impact upon the planet through droughts and desertification. These climate change-related shocks often lead to the displacement of populations and the forcing of conflict parties to live in closer proximity to one another. The presence of high-value natural resources within a region can often lead to the development of hostilities within those areas. The resource curse theory posits that the discovery and abundance of natural resources often produces economic growth. At the same time, this wealth can be used to purchase weapons, which can then be used to trigger conflicts. This competitive environment is increasingly being shaped by external actors who often claim the raw materials that are mined from those resource-rich regions of the planet.

Beyond the discussion on biophysical and economic drivers, another factor that often relates to instances of violence and conflict is the marginalization of communities and territories within the region that contains these natural resources. The general lack of benefits returned to marginalized groups creates horizontal inequalities, which facilitate armed insurgencies. Furthermore, many of these conflicts within resource-rich regions are established due to failures of existing institutions. Many of those areas have had non-existent land tenure systems, experience corruption in permitting mining activities as well as a lack of methods to resolve any land-related disputes. Additionally, those governments often establish policies that offer commercial land concessions to those who

may have certain land-related rights, but fail to provide land concessions to the traditional groups that utilize the land. Finally, customary systems for managing natural resources within these regions often break down, leading to further conflict between those groups over the resource.

The impact of climate change on natural resource management is fundamentally reshaping the security architecture of fragile states and communities already burdened by humanitarian crises. Of the fifteen nations that are the most susceptible to the impact of climate change, thirteen of those countries are currently experiencing violent conflicts. Although climatic shifts may not directly ignite hostilities, they function as a threat multiplier to those countries, leading to increased violence and the inability of those regions to manage their resource-rich environments peacefully. The impact of climate change on these regions is, therefore, recognized as one of the factors that will continue to influence the development of conflicts in the coming decades (IPCC, 2022). A critical, yet often overlooked, dimension of this crisis is the evolving societal structure of rural communities. Although the transformation of rural societies has attracted significant scholarly attention in recent years, few discussions have occurred regarding the impact of class within those societies as a factor contributing to the development of rural violence. Much of the existing literature focuses on the conflict between the indigenous working classes of the rural areas of the planet and the middle-class individuals that moved into those regions. Nevertheless, little discussion has occurred regarding the conflicts that exist within each of those established classes. Thus, an investigation into the impact of climate change on the socio-economic constitution of rural areas may provide an understanding of the dynamics of rural violence within the countryside.

In protracted crises, persistent conflict serves as the primary driver of forced migration. Rural populations, whose livelihoods are linked to agriculture, bear a disproportionate burden, since much contemporary civil conflict occurs in agrarian settings. Although the symptoms of these conflicts are readily visible to the populations of affected regions, the causal implications of those conflicts are often more complex. Violent conflicts lead to food insecurity, which subsequently contributes to forced migration. Thus, interventions must be created to address the root causes of these conflicts. While the provision of development aid is necessary to prevent acute famine, long-term solutions are required to restore food production systems and agricultural livelihoods.

Empirical research has identified a robust link between climate variability and conflict, particularly within rural communities. One example of the impact of climate change within a specific region of the planet is Somalia. The United Nations has reported that economic hardships developed within Somalia as a result of climate change have led to

a lowering of the threshold that individuals are required to commit the acts required to participate in violent conflicts (UN Security Council, 2020). Similarly, in South Sudan, the flooding that occurred throughout 1991 in the Upper Nile region contributed to devastating conflicts between the Dinka and the Nuer tribes of the region, both of which traditionally maintained herds of cattle (Wild et al., 2018).

Furthermore, conflict-induced forced migration places an unsustainable burden on the scarce natural resources of host regions. The rapid influx of refugees or internally displaced persons (IDPs) often exacerbates land degradation, soil erosion, and hydraulic deficits in areas where demand already exceeds renewable supply. This creates a chronic vulnerability that intensifies when coupled with climate uncertainty. In the Unity State of South Sudan, for example, catastrophic flooding—compounded by prior political instability—left two-thirds of the population in a state of acute food insecurity (IPC, 2023). The resulting competition for depleted resources and heightened communal tensions demonstrate how the confluence of climate shocks and active conflict can systematically overwhelm humanitarian response capacities. While there are abundant instances of conflicts between countries over natural resources, few of those conflicts have been with respect to the planet’s water resources. Only one definitive war for access to water has occurred within the planet in the past 4,500 years (Wolf, 1998). This lack of water-based interstate conflicts is often due to international law. Any attempt to remove or change the water resources of the planet is against the law, and most countries recognize the importance of the water resource for the survival of the inhabitants of the planet.

In the literature, the interlinkages between climate change and conflict are categorized into four primary domains. These areas include the discussion of the way in which climate change impacts conflict, the discussion of the way in which conflict impacts the natural environment of the planet, the discussion of the environmental consequences of armed conflict, and the discussion of the ways in which the various aspects of the impacted nations of the planet are impacted by those factors. The environmental consequences of armed conflict, for instance, are often discussed within the literature as being particularly damaging to the planet and its natural resources. The natural environment of the planet is often referred to as the “neglected victim of armed conflict”, as it is often ignored within the context of the conflicts between the nations of the planet (ICRC, 2020). One of the countries the natural environment of which has been destroyed due to violent conflict is Lebanon (UNDP, 2014). Hostilities involved the deliberate destruction of forests for strategic and tactical purposes, including the coordinated ignition of fires in inaccessible zones (Mitri et al., 2015). This approach maximized the duration and intensity of fires, thereby creating long-term ecological degradation. The destructive

impact of such tactics is twofold. First, it triggers an immediate release of sequestered carbon, contributing to greenhouse gas emissions and global climatic instability. Second, it eliminates the vegetative cover essential for ecosystem stability, thereby significantly increasing vulnerability to soil erosion and desertification. This degradation inhibits post-conflict recovery by undermining the natural capital upon which rural livelihoods depend. Since 1975, Lebanon has experienced a loss of over 2,500 acres of vegetation cover (MoE/UNDP, 2020). Joint research by the Universities of Balamand, Twente, and Leeds confirms that these specific shifts in land use and land cover (LULC) can be attributed to continuous armed conflict, particularly in the regions surrounding Tripoli.

Violent conflict has a profound impact on the natural environment, with particularly severe consequences for aquatic resources sustaining ecosystems. The water resources of a country, whether those be natural springs, rivers or coastal seas, are often targeted by conflict parties. The latter can induce changes to the planet's natural currents, lead to the destruction of the seabed, and the reduction of marine biodiversity (World Bank, 2007). Even in landlocked nations, the strategic manipulation of water sources underscores its dual role as a weapon of warfare and a degraded asset.

3 Comparative Policy Framework

The analysis of contemporary economic and environmental trajectories reveals a strong competition for access to and utilization of freshwater resources. This competition is structurally driven by the growth of the planet's population, the growth of its economic systems, and the effects of climate change. Moreover, the intersection of water stress and security has become a focal point of both global policy discourse and empirical research. The Transboundary Freshwater Dispute Database (TFDD) at Oregon State University categorizes 261 international river basins that have the potential for both intra- and interstate conflict. The ability to identify basins prone to water-related conflict is a prerequisite for preventive diplomacy, which may take the form of ex-ante strategic interventions. However, the identification of conflict-prone basins requires the an advanced analytical framework that integrates a diverse set of physical, social, economic, and political variables. Crucially, these indicators must be evaluated across divergent spatial and temporal scales, accounting for the complex relationships that define resource governance. As such, there is a need for the development of a method for defining and visualizing each of these indicators on a Geographic Information System (GIS). Finally, while these indicators are initially recognized with some caution, they can provide significant value to the analysis of the factors related to each of these river basins

As the evidence for global warming and its impacts becomes stronger, the implications of these climate system changes for society become of increased interest to the world’s policymakers. One hypothesis regarding the impact of these climatic changes is that the variability in climate within different regions of the planet can lead to an increase in the likelihood of armed conflicts (Boko et al., 2007). These predictions have been echoed by some of the world’s leaders, who have stated that climate change is one of the factors that will fuel the development of conflicts between nations within the decades to come. One of the regions that is often cited as being vulnerable to climate-related political instability is Sub-Saharan Africa. The conflict in Darfur, Sudan, is often cited as a characteristic example of this trend (Ban Ki-moon, 2007). Despite these assertions, academic research on the climate–conflict nexus has yet to produce a consensus. Large-N empirical studies large-N studies of the region have found no relationship between droughts, conflicts related to those droughts, and the development of armed conflicts (Gleditsch, 2012). However, a critical distinction exists between different types of violence. While many large-N studies focus on challenges to state authority, case-based literature suggests that climate-related conflicts more commonly manifest as inter-group clashes over grazing land, water points, and livestock—struggles that may not directly involve state actors (Hagmann & Mulugeta, 2008). Deviations from longitudinal rainfall averages fundamentally undermine the livelihoods of African populations dependent on rain-fed production. We posit that the resulting economic desperation incentivizes violent communal attacks as a direct strategy to reallocate scarce resources. Such responses are particularly likely in contexts of economic marginalization and political exclusion, where alternative coping mechanisms—such as market-based insurance or state-led social safety nets—are unavailable (Raleigh, 2010). Thus, the relationship between climate change and conflict within specific regions is mediated by those factors related to the livelihoods of their inhabitants.

Recent empirical contributions have increasingly investigated the magnitude of climate impacts as a key determinant of conflict risk across diverse territories. Felbermayr et al. (2022) advance this literature by proposing a comprehensive dataset linking meteorological anomalies to annual average night-light emissions for 24,000 $0.5^\circ \times 0.5^\circ$ grid cells globally from 1992 to 2013. By utilizing night-light intensity as a proxy for sub-national development, the authors reveal significant negative impacts on local economic growth resulting from storms, excessive precipitation, droughts and cold spells. Crucially, the study identifies significant spatial spillovers to neighboring areas. However, these offsetting effects are typically localized. Because positive and negative impacts tend to aggregate toward zero over larger geographic areas, Felbermayr et al. (2022) underscore the necessity of analyzing the economic consequences of weather anomalies at a high spatial resolution. Furthermore, the results indicate that these effects are primarily driven by shocks in

lower-income regions. As climate change is projected to increase the volatility of weather patterns, such granular data is essential for informing scientific and political debates regarding the economic resilience of vulnerable territories

4 Mechanisms

The relationship between water and conflict does not operate solely through a singular scarcity mechanism. Instead, water resources shape conflict dynamics through a set of political economy channels that affect the value of resource control, the institutional capacity to allocate water, and the distribution of economic rents within rural economies. Building on the resources–conflict literature, we identify three mechanisms linking water conditions to conflict risk: resource value, water management capacity, and efficiency-driven rent reallocation.

Resource Value Mechanism

The first of the proposed mechanisms of the relationship between water and conflict relates to the economic value associated with the availability of water resources. Renewable freshwater resources constitute a critical input for agricultural production, livestock systems, and rural livelihoods. In institutional environments characterized by weak property rights or contested governance structures, the presence of valuable natural resources can increase the incentives for actors to compete for access and control rights. The availability of freshwater resources can lead to an increase in the value of the irrigation systems that are present within those ecosystems, which in turn may become the focus of conflicts between competing groups. From a political economy perspective, this dynamic aligns with broader arguments in the resources–conflict literature: the presence of valuable resources increases the incentives for rent-seeking and contestation. When water resources are both abundant and economically valuable, actors may intensify efforts to control the infrastructure or territory through which the water flows. Under these conditions, the strategic value of water may increase the likelihood of conflict, even when physical scarcity is not severe.

Hypothesis 1: *Higher availability of renewable freshwater resources increases the probability of conflict by raising the value of water-related resource rents.*

Water Management Capacity Mechanism

The second proposed mechanism of the relationship between water and conflict relates to the capacity of an area to manage and utilize its water resources. The number of withdrawals of water resources from an area is often representative of its management capabilities in relation to its environment and economy. Areas with high levels of water management capabilities often have successful methods of distributing water resources to farmers that rely upon the use of irrigation systems, especially during periods of drought or climatic stress. Thus, the level of management of water resources within an area can reduce the likelihood of conflicts. In this sense, water withdrawals serve as a proxy for the governance structures and infrastructure that regulate access to water. Where these institutions are stronger, hydrological variability is more likely to be absorbed through economic adjustment rather than violent contestation.

Hypothesis 2: *Higher capacity to mobilize water resources through withdrawals reduces the probability of conflict by stabilizing livelihoods and lowering competition over water access.*

Efficiency and Rent Reallocation Mechanism

The third mechanism addresses the political economy consequences of improvements in water-use efficiency. Increasing water productivity is often treated as a central policy objective in climate adaptation strategies. However, efficiency gains may alter the distribution of economic rents associated with water resources. By increasing the value generated per unit of water, improvements in efficiency raise the economic incentives for actors to secure control over water access and allocation. Efficiency improvements may also shift the balance of access among competing users. For example, more productive irrigation technologies may disproportionately benefit large-scale agricultural producers relative to smallholders, or they may increase upstream capture of water at the expense of downstream users. When institutional arrangements governing water allocation are weak or contested, these redistributive effects can raise grievances and competition over water rights. As a result, technical improvements in water productivity may increase the probability of conflict by raising the economic value of water control and sharpening distributional tensions among water users.

Hypothesis 3: *Higher water-use efficiency increases the probability of conflict by raising the economic value of water resources and increasing competition over water access.*

Overall, each of these proposed mechanisms relates to the relationship between water and

conflict. The availability of freshwater resources is associated with increased value of those resource rents that are gained through their withdrawal. Additionally, the management of water resources within an area is associated with the ability to minimize the conflicts between individuals or groups that compete for its use. Finally, improvements to the efficiency of the use of water resources within an area are associated with changes to the distributional competition for those resources.

5 Data & Empirical Strategy

The empirical analysis uses a panel dataset integrating hydrological, socioeconomic, and climatic indicators. The primary variables are described below, and their descriptive statistics are summarized in Table 1.

Hydrological and Water Indicators

- **Renewable Internal Freshwater Resources** (billion m^3): This variable measures the average annual volume of freshwater generated within a country from internal precipitation, including river flows and groundwater recharge, while excluding upstream transboundary inflows. Data are sourced from [FAO \(2026\)](#).
- **Agricultural Water Withdrawal** (% of total renewable resources): This metric represents freshwater withdrawals for irrigation, livestock, and aquaculture as a percentage of total renewable resources. It serves as a specific proxy for agricultural pressure on the hydraulic system. Data are sourced from [FAO \(2026\)](#).
- **Total Freshwater Withdrawal** (% of total renewable resources): A broader measure of water stress, this encompasses total withdrawals across the agricultural, industrial, and municipal sectors relative to the renewable supply. Data are sourced from [FAO \(2026\)](#).
- **Water Use Efficiency** (USD/ m^3 , SDG 6.4.1): Defined as the value-added (USD) generated per unit of water withdrawn (m^3). This is an economy-wide measure harmonized across sectors (agriculture, industry, and services). Data are sourced from [FAO \(2026\)](#).
- **Irrigated Agricultural Value-Added Efficiency** (USD/ m^3): A sectoral refinement of the efficiency metric, measuring the productivity of irrigation-specific water use. This captures the economic output generated specifically within the irrigated agrifood segment. Data are sourced from [FAO \(2026\)](#).

- **Water Stress** (% of total freshwater withdrawn, SDG 6.4.2): This indicates the pressure on renewable water supply, calculated as total freshwater withdrawals relative to total renewable resources, adjusted for environmental flow requirements. Data are sourced from [FAO \(2026\)](#).

Socioeconomic Controls

- **Log GDP** (ln of USD): The natural logarithm of Gross Domestic Product in current US dollars is employed to control for economic scale and the overall level of development. Data are sourced from [World Bank \(2024\)](#).
- **Rural Population** (% of total population): The proportion of the total population residing in rural areas, capturing the demographic exposure to agrarian shocks. Data are sourced from [UNFPA \(n.d.\)](#).
- **Agricultural Land per Capita** (ha/capita): Calculated as total agricultural land (arable, permanent crops, and pasture) divided by the total population. This variable proxies for land availability and population pressure. Data are sourced from [FAO \(2026\)](#).

Climatic Instruments

- **Precipitation Anomalies** (% deviation from long-term averages): Defined as the deviation of actual rainfall from the long-term historical mean. These anomalies serve as a primary indicator for climate-induced shocks, such as droughts or pluvial floods, which directly impact agricultural productivity. Data are sourced from [FAO \(2026\)](#).
- **Surface Temperature Anomalies** (% deviation from a baseline climate normal): This measures the deviation of actual temperature from the long-term historical average. These anomalies track heat stress and shifting growing seasons, which increase evaporative demand and reduce livestock and crop yields. Data are sourced from [FAO \(2026\)](#).

Empirical Strategy

Our empirical objective is to estimate the causal effect of water conditions on violent conflict while addressing the potential endogeneity of water availability and water use. Water outcomes are jointly determined with economic development, agricultural production, and institutional capacity, all of which may also influence the probability of conflict. Ordinary

Table 1: Descriptive Statistics

	Units	N	Mean	SD	Min	Max	Source
Renewable internal freshwater resources, total	billion m ³	9,985	25,534.06	70,673.4	0	949,566.8	FAO
Agricultural water withdrawal	% of total renewable resources	1,770	46.006	224.807	0.1	3,892	FAO
Freshwater withdrawal	% of total renewable resources	5,846	23.102	79.69	0.001	655.580	FAO
Service Water Use Efficiency	USD/m ³	5,800	89.593	123.853	0.6	1,230.56	FAO
Log GDP	ln of USD	10,440	22.96	2.521	15.99	30.87	WBG
Rural population	% of total population	13,356	48.310	25.78	0	97.923	UNFPA
Agricultural land per capita	ha/capita	11,922	0.0004	0.0018	5.63×10^{-8}	0.045	FAO
Water use efficiency	USD/m ³	840	31.67	39.093	0.29	230.04	FAO
Water Stress	% of total freshwater withdrawn	5,389	56.286	228.882	0.02	3,850.5	FAO
Irrigated agriculture value added efficiency	USD/m ³	3,912	0.783	2.256	0.01	53.7	FAO
Precipitation anomalies	% deviation from long-term averages	9,937	2.58×10^{-7}	8.537	-617.356	60.967	FAO
Surface temperature anomalies	% deviation from baseline climate normal	12,244	3.30×10^{-10}	0.604	-2.6	2.6	FAO

Sources: FAO: [FAO \(2026\)](#); WBG: [World Bank \(2024\)](#); UNFPA: [UNFPA \(n.d.\)](#).

least squares estimates would therefore be biased if water indicators respond to underlying political or economic dynamics correlated with conflict. To address this potential bias, the analysis employs a fixed-effects instrumental variables (IV) framework that exploits climate variability as a source of exogenous identification.

The baseline specification relates conflict incidence to the water indicator of interest and a vector of socioeconomic controls:

$$\text{Conflict}_{it} = \alpha + \beta \text{Water}_{it} + \gamma X_{it} + \mu_i + \tau_t + \varepsilon_{it} \quad (1)$$

where Conflict_{it} denotes the incidence of violent conflict in country i during period t , Water_{it} represents the water-related variable of interest, and X_{it} is a vector of socioeconomic control variables including economic development and demographic factors. Country fixed effects μ_i account for time-invariant country characteristics such as geography, long-run institutional quality, and structural development patterns, while time fixed effects τ_t capture global shocks affecting all countries simultaneously. Standard errors are clustered at the country level to allow for serial correlation within panels.

Given that the water-related variables may also be endogenous due to their relationship with economic and conflict variables, their estimation is performed using instrumental variables. The instrumental variable for each water-related variable is the climatic anomaly of either precipitation or surface temperature levels within each of the observed countries for each time period. These variables are chosen because they are believed to have little or no relationship with the conflict variable, yet are correlated with the water-related variable of interest. The first-stage equation is:

$$\text{Water}_{it} = \pi_1 \text{PrecipAnomaly}_{it} + \pi_2 \text{TempAnomaly}_{it} + \delta X_{it} + \mu_i + \tau_t + u_{it} \quad (2)$$

Precipitation anomalies affect surface water availability and groundwater recharge, while temperature anomalies influence evaporation and agricultural water demand. Through these climatic channels, weather variability generates exogenous variation in water availability and water use. A two-stage least squares (2SLS) model is estimated using each of the different water-related variables as the endogenous variable to be estimated (for instance, renewable freshwater availability, agricultural water withdrawals, total freshwater withdrawals, water-use efficiency, and water stress). Each model instruments a single endogenous water variable using the climatic anomaly measures.

To account for the possibility that hydrological systems adjust gradually to climatic shocks, the analysis is conducted at two temporal scales. First, annual specifications

estimate the short-run relationship between climate-driven water conditions and conflict outcomes. Second, the data are aggregated into five-year periods to reduce measurement noise and capture medium-term adjustments in water allocation, irrigation infrastructure, and agricultural production. Comparing these specifications allows the analysis to evaluate whether the climate–water–conflict relationship operates primarily through short-term fluctuations or through slower structural changes in water governance and resource use.

Each of these models is estimated for both annual and five-year periods to allow for assessment of short-term and medium-term relationships between water-related variables, water availability, and violent conflict. The strength of the instruments is assessed using the Kleibergen-Paap rank Wald F statistic, which is robust to heteroskedasticity and clustered errors. Stock–Yogo critical values are reported as reference thresholds for evaluating weak identification. In cases where first-stage diagnostics indicate weak instruments, results are interpreted with caution. Anderson–Rubin tests are also considered, as they remain valid under weak identification..

Identification Assumption

The identification strategy relies on the assumption that climatic anomalies affect violent conflict only through their impact on water conditions, rather than through direct political or economic channels. Precipitation and temperature shocks influence hydrological systems through well-established physical processes, including groundwater recharge, river flows, evaporation, and agricultural water demand. Conditional on country and time fixed effects, as well as socioeconomic controls, these climatic fluctuations are plausibly exogenous to contemporaneous political processes and institutional dynamics that may drive conflict. In this framework, climate anomalies generate variation in water availability, withdrawals, and water-use efficiency that is orthogonal to underlying political economy factors affecting conflict. Under this exclusion restriction, the IV estimates identify the causal impact of water conditions on violent conflict.

6 Results

6.1 Annual Specifications (1Y): High-Frequency Noise and Underidentification

Table 2 estimates using annual data, incorporating both country and 5-year period fixed effects. Across the annual specifications, none of the second-stage for the instrumented water indicators reach conventional levels of statistical significance. Renewable internal

freshwater resources yield a small and imprecise coefficient of 0.0022. Similarly, the coefficients for agricultural water withdrawal (-6.4169) and total freshwater withdrawals (-1.2467) are negative but remain statistically indistinguishable from zero. Both industrial and services water-use efficiency measures likewise fail to show significant associations with conflict at this frequency. The first-stage diagnostics presented in Table 3 elucidate why inference remains largely uninformative at the annual frequency. Instrument relevance varies sharply across different water definitions. The excluded instruments are exceptionally strong for renewable internal freshwater resources, with a Kleibergen–Paap rk Wald F statistic of 342.92, which significantly exceeds the Stock–Yogo 10% critical value of 19.93. In contrast, the instruments are weak for the remaining annual models. For agricultural withdrawals, total freshwater withdrawals, and the sectoral efficiency indicators, the Kleibergen–Paap rk Wald F statistics range from approximately 0.13 to 1.05. These diagnostics indicate that annual climate shocks do not generate sufficient exogenous variation in these specific water-use outcomes at a 1Y horizon. Collectively, the annual results suggest that high-frequency water-use measures are either characterized by excessive noise or are too weakly coupled with climate instruments to support precise second-stage causal estimation within this empirical framework.

Table 2: IV (2SLS) with FE: Climate–Water–Conflict (1Y) (IV–FE Models 1–5)

	(1) Renewable internal freshwater resources, total (billion m ³)	(2) Agricultural water withdrawal (% of total renewable resources)	(3) Freshwater withdrawal (% of total renewable resources)	(4) Industrial water- use efficiency	(5) Services water- use efficiency
Main variable	0.002231 (0.002379)	-6.4169 (10.9674)	-1.2467 (0.9253)	0.1591 (0.2821)	0.6308 (0.7981)
Log GDP (current US\$)	0.2471 (0.5580)	-0.4550 (6.4168)	-1.6795 (1.1195)	-1.9534 (8.0443)	1.1096 (2.8497)
Rural population (%)	0.2052 (0.1506)	-16.920 (26.309)	-4.1336 (3.0313)	1.3944 (3.6102)	-2.0034 (2.4521)
Agricultural land per capita	-77,913.9 (115,422.1)	219,749.7 (1,932,550.0)	510,800.6 (483,489.5)	-588,540.8 (746,405.0)	2,107,067.0 (3,100,192.0)
Country FE	Yes	Yes	Yes	Yes	Yes
5-year FE	Yes	Yes	Yes	Yes	Yes
Instrument set	Z_1, Z_2	Z_1	Z_1, Z_2	Z_1, Z_2	Z_1, Z_2
Observations	149	41	83	148	148
Clusters	18	9	14	18	18
Centered R^2	0.1847	-29.49	-4.179	-22.868	-7.961
Root MSE	1.294	7.336	3.265	7.028	4.306

Notes: Coefficients shown with robust standard errors in parentheses, clustered by country. Country and 5-year period fixed effects included. Asterisks denote significance: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. No main coefficients reach conventional significance thresholds in this panel.

Table 3: First-Stage and Identification Diagnostics (1Y) (IV–FE Models 1–5)

	(1) Renewable internal freshwater resources, total (billion m ³)	(2) Agricultural water withdrawal (% of total renewable resources)	(3) Freshwater withdrawal (% of total renewable resources)	(4) Industrial water- use efficiency	(5) Services water- use efficiency
First-stage F (excluded instr.)	342.92	0.13	1.05	1.01	0.48
Sanderson–Windmeijer χ^2	859.81	0.28	3.15	2.54	1.20
Kleibergen–Paap rk LM χ^2	6.04	0.31	2.02	1.31	1.16
p -value	[0.0489]	[0.5770]	[0.3647]	[0.5192]	[0.5586]
Cragg–Donald Wald F	18.10	0.045	0.303	0.117	0.380
Kleibergen–Paap rk Wald F	342.92	0.13	1.05	1.01	0.48
Stock–Yogo 10% critical value ^a	19.93	16.38	19.93	19.93	19.93
Instrument strength	Strong	Weak	Weak	Weak	Weak
Anderson–Rubin Wald F	9.09	1.34	8.57	9.07	9.07
p -value	[0.0021]	[0.2803]	[0.0042]	[0.0021]	[0.0021]
Anderson–Rubin χ^2	22.79	2.87	25.65	22.77	22.77
p -value	[0.0000]	[0.0901]	[0.0000]	[0.0000]	[0.0000]
Observations	149	41	83	148	148
Clusters	18	9	14	18	18

Notes: All statistics are cluster-robust (clustered by country). Kleibergen–Paap (KP) rk LM tests underidentification; KP rk Wald F tests weak identification. Stock–Yogo 10% critical values shown for reference. Anderson–Rubin tests are robust to weak identification.

^a K_1 denotes the number of endogenous regressors and L_1 the number of excluded instruments. All models instrument one endogenous variable ($K_1 = 1$). Models 1 and 3–5 use two excluded instruments ($L_1 = 2$); Model 2 uses only Z_1 ($L_1 = 1$).

6.2 Five-Year Specifications (5Y): Temporal Aggregation and the Efficiency Paradox

Transitioning to five-year aggregations in Table 4 materially improves inference and reveals several statistically significant relationships. First, renewable internal freshwater resources become positively associated with conflict (0.0041*), significant at the 10% level. Second, total freshwater withdrawal as a share of renewable resources is negative and highly significant (−0.9946***), indicating that greater ability to mobilize renewable water for use is correlated with lower conflict risk at the five-year horizon. Third, aggregate water-use efficiency is positive and significant (0.2108**), suggesting that higher efficiency—at least as captured by this aggregate metric—is associated with higher conflict risk, consistent with the possibility that efficiency gains reallocate effective access and rents or raise the strategic value of control over water. Finally, water stress is estimated with a negative coefficient (−0.3187*), significant at the 10% level, a result that is counterintuitive under a simple scarcity narrative and therefore requires interpretation in light of identification strength. Table 5 confirms that instrument performance is substantially stronger in the 5Y setting, though still heterogeneous across outcomes. Identification is classified as strong for renewable internal freshwater (Kleibergen–Paap rk Wald $F = 2078.42$), aggregate water-use efficiency (36.26), services water-use efficiency (21.49), and irrigated agriculture water-use efficiency (98.90), and moderate for total freshwater withdrawals (17.34). By contrast, agricultural withdrawals (1.85), industrial water-use efficiency (1.84), and water stress (3.60) remain weakly identified. Accordingly, the five-year estimates for renewable freshwater, total freshwater withdrawals, and aggregate water-use efficiency carry the strongest empirical credibility, while the water-stress result should be treated with caution given weak identification.

Table 4: IV (2SLS) with FE: Climate–Water–Conflict (5Y) (Models 1–8)

	(1) Renewable internal freshwater resources, total (billion m ³)	(2) Agricultural water withdrawal (% of total renewable resources)	(3) Freshwater withdrawal (% of total renewable resources)	(4) Industrial water- Use efficiency	(5) Services water- Use efficiency	(6) Water-use efficiency	(7) Water stress	(8) Irrigated agriculture water-use efficiency
Main variable	0.0041* (0.0022)	1.7975* (1.0342)	-0.9946*** (0.2607)	0.4456 (2.2465)	0.4049 (0.4873)	0.2108** (0.0766)	-0.3187* (0.1867)	33.935 (20.7521)
Log GDP (current US\$)	0.9866* (0.5242)	0.6329 (1.2041)	-2.6119** (1.2680)	-4.3741 (28.4766)	-1.1546 (2.4451)	-1.9703** (0.6740)	0.3636 (0.9813)	0.9830 (0.9798)
Rural population (%)	0.1373 (0.1810)	3.6637** (1.8409)	-3.5479*** (0.8686)	3.3215 (19.6271)	-0.8034 (0.7883)	-1.5961** (0.5341)	-1.1752* (0.6363)	1.5098 (1.0730)
Agricultural land per capita	-123,822.0 (132,380.7)	-334,702.5 (298,939.8)	366,694.6 (229,811.4)	-853,825.0 (3,523,599.0)	1,724,410.0 (2,467,649.0)	48,787.5 (177,614.7)	190,973.9 (211,786.0)	1,584,390.0 (1,080,606.0)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
5-year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Instrument set	Z ₁ , Z ₂	Z ₁ , Z ₂	Z ₁ , Z ₂	Z ₁ , Z ₂	Z ₁ , Z ₂	Z ₁	Z ₁ , Z ₂	Z ₁ , Z ₂
Observations	149	41	83	148	148	50	146	141
Clusters	18	9	14	18	18	7	18	17
Centered R ²	-0.067	-2.630	-3.583	-180.0	-4.091	-0.124	-0.915	-4.128
Kleibergen–Paap rk Wald F	2078.42	1.85	17.34	1.84	21.49	36.26	3.60	98.90

Notes: Coefficients shown with robust standard errors in parentheses, clustered by country. Country and 5-year period fixed effects included (not shown). Asterisks denote significance: * ($p < 0.10$), ** ($p < 0.05$), *** ($p < 0.01$). Model (6) uses instrument Z₁ only (Z₂ dropped for collinearity).

Table 5: First-Stage and Identification Diagnostics (5Y) (IV–FE Models 1–8)

	(1) Renewable internal freshwater resources, total (billion m ³)	(2) Agricultural water withdrawal (% of total renewable resources)	(3) Freshwater withdrawal (% of total renewable resources)	(4) Industrial water- use efficiency	(5) Services water- use efficiency	(6) Water-use efficiency	(7) Water stress	(8) Irrigated agriculture water-use efficiency
Underidentification (KP rk LM)	3.66	1.00	3.88	0.93	1.76	2.32	4.56	1.33
<i>p</i> -value	[0.161]	[0.607]	[0.144]	[0.628]	[0.414]	[0.128]	[0.102]	[0.514]
Cragg–Donald Wald <i>F</i>	19.02	0.38	1.24	0.03	0.95	11.38	4.89	0.57
Kleibergen–Paap rk Wald <i>F</i>	2078.42	1.85	17.34	1.84	21.49	36.26	3.60	98.90
Stock–Yogo 10% critical value ^a	19.93	19.93	19.93	19.93	19.93	16.38	19.93	19.93
Instrument strength	Strong	Weak	Moderate	Weak	Strong	Strong	Weak	Strong
Hansen <i>J</i> (overid.)	2.55	0.13	1.21	0.01	0.91	n/a ^b	1.02	–
<i>p</i> -value	[0.111]	[0.714]	[0.271]	[0.930]	[0.341]		[0.313]	
Observations	149	41	83	148	148	50	146	141
Clusters	18	9	14	18	18	7	18	17

Notes: All tests are robust to heteroskedasticity and clustered by country. The Kleibergen–Paap (KP) rk LM tests underidentification; the KP rk Wald *F* is used for weak-ID assessment. Stock–Yogo 10% critical values (10% maximal IV size) reported for reference.

^a Stock–Yogo critical values depend on the number of instruments (L_1) and endogenous regressors (K_1).

^b Model (6) omitted Hansen *J* due to non–full-rank covariance matrix.

6.3 Robustness: Orthogonalized Precipitation Instruments (5Y, Z-Orth)

To ensure that the results are not driven by collinearity between the climate instruments, Tables 6 and 7 implement an orthogonalized instrument set where the precipitation component is residualized on temperature. The substantive results mirror the baseline 5Y estimates, as the sign, magnitude, and statistical significance of the water-conflict linkages remain essentially unchanged. This consistency confirms that the five-year findings are robust to the specification of the climate instruments and that the orthogonalization does not materially alter the identifying variation.

In contrast, the 5Y specifications reveal that the impacts of climate change on water have multiple, heterogeneous effects on civil conflict, influencing variables such as water stocks, withdrawals, and efficiency. The positive coefficient for the variable of water efficiency impacts, however, indicates that efforts to increase water-use efficiency may actually increase the number of related grievances.

Table 6: IV (2SLS) with FE: Climate–Water–Conflict (5Y, Z-Orth) (Models 1–8)

	(1) Renewable internal freshwater resources, total (billion m ³)	(2) Agricultural water withdrawal (% of total renewable resources)	(3) Freshwater withdrawal (% of total renewable resources)	(4) Industrial water- use efficiency	(5) Services water- use efficiency	(6) Water-use efficiency	(7) Water stress	(8) Irrigated agriculture water-use efficiency
Main variable	0.0041* (0.0022)	1.7975* (1.0342)	-0.9946*** (0.2607)	0.4456 (2.2465)	0.4049 (0.4873)	0.2108** (0.0766)	-0.3187* (0.1867)	33.935 (20.7521)
Log GDP (current US\$)	0.9866* (0.5242)	0.6329 (1.2041)	-2.6119** (1.2680)	-4.3741 (28.4766)	-1.1546 (2.4451)	-1.9703** (0.6740)	0.3636 (0.9813)	0.9830 (0.9798)
Rural population (%)	0.1373 (0.1810)	3.6637** (1.8409)	-3.5479*** (0.8686)	3.3215 (19.6271)	-0.8034 (0.7883)	-1.5961** (0.5341)	-1.1752* (0.6363)	1.5098 (1.0730)
Agricultural land per capita	-123,822.0 (132,380.7)	-334,702.5 (298,939.8)	366,694.6 (229,811.4)	-853,825.0 (3,523,599.0)	1,724,410.0 (2,467,649.0)	48,787.5 (177,614.7)	190,973.9 (211,786.0)	1,584,390.0 (1,080,606.0)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
5-year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Instrument set	Z_1, Z_2^\perp	Z_1	Z_1, Z_2^\perp	Z_1, Z_2^\perp	Z_1, Z_2^\perp	Z_1	Z_1, Z_2^\perp	Z_1, Z_2^\perp
Observations	149	41	83	148	148	50	146	141
Clusters	18	9	14	18	18	7	18	17
Centered R^2	-0.067	-2.630	-3.583	-180.0	-4.091	-0.124	-0.915	-4.128
Kleibergen–Paap rk Wald F	2078.42	1.85	17.34	1.84	21.49	36.26	3.60	98.90

Notes: Coefficients shown with robust standard errors in parentheses, clustered by country. Asterisks denote significance: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Instruments: Z_1 and orthogonalized Z_2^\perp obtained from regressing Z_2 on Z_1 , controls, and fixed effects. Model (6) uses Z_1 only.

Table 7: First-Stage and Identification Diagnostics (5Y, Z-Orth) (IV–FE Models 1–8)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Renewable internal freshwater resources, total (billion m ³)	Agricultural water withdrawal (% of total renewable resources)	Freshwater withdrawal (% of total renewable resources)	Industrial water-use efficiency	Services water-use efficiency	Water-use efficiency	Water stress	Irrigated agriculture water-use efficiency
Underidentification (KP rk LM)	3.66	1.00	3.88	0.93	1.76	2.32	4.56	1.33
<i>p</i> -value	[0.161]	[0.607]	[0.144]	[0.628]	[0.414]	[0.128]	[0.102]	[0.514]
Cragg–Donald Wald <i>F</i>	19.02	0.38	1.24	0.03	0.95	11.38	4.89	0.57
Kleibergen–Paap rk Wald <i>F</i>	2078.42	1.85	17.34	1.84	21.49	36.26	3.60	98.90
Stock–Yogo 10% critical value ^a	19.93	19.93	19.93	19.93	19.93	16.38	19.93	19.93
Instrument strength	Strong	Weak	Moderate	Weak	Strong	Strong	Weak	Strong
Hansen <i>J</i> (overid.)	2.55	0.13	1.21	0.01	0.91	n/a ^b	1.02	–
<i>p</i> -value	[0.111]	[0.714]	[0.271]	[0.930]	[0.341]		[0.313]	
Observations	149	41	83	148	148	50	146	141
Clusters	18	9	14	18	18	7	18	17

Notes: All tests are robust to heteroskedasticity and clustered by country. Results mirror Table 5, confirming orthogonalization leaves identification diagnostics unchanged.

^a Stock–Yogo critical values depend on L_1 and K_1 .

^b Model (6) omitted Hansen *J* due to non–full-rank covariance matrix.

7 Conclusion & Policy Recommendations

This paper provides a quantitative assessment of the relationship between water conditions and violent conflict in rural agrifood systems, addressing several methodological inconsistencies that have characterized the climate–security literature. By using a fixed-effects IV framework, we demonstrate that the water–conflict nexus does not operate through a single scarcity mechanism but through a set of institutional and economic channels, including resource availability, withdrawals, and water-use efficiency. A central empirical insight regarding the analysis of climate-related water shocks is the role that temporal aggregation plays in the strength of the exogenous variation in the study’s outcomes. At the annual level, the study finds that the climate-related exogenous variation is insufficient to lead to meaningful exogenous variation in the majority of the outcomes of interest. When the analysis is conducted at a five-year horizon, however, several stable patterns emerge.

Renewable freshwater availability is positively associated with the risk of water-related conflicts. One possible reason for such a relationship is that the presence of freshwater resources may enhance the strategic value of those water resources; such an outcome is likely to emerge in the presence of other factors that lead to water-related conflicts. However, higher levels of withdrawals of freshwater resources relative to the renewable supply of those resources are associated with lower levels of conflict risk. One potential reason for such a finding is that higher withdrawals of freshwater from a region indicate a higher level of productive use of the freshwater resources, which reduces the risk of freshwater scarcity within those regions. Finally, the level of efficiency in the use of freshwater resources is positively and statistically significant in its association with conflict risk. The reason for this counterintuitive result is potentially due to the fact that increased efficiency in the use of freshwater resources may enhance the value of those water resources, yet lead to a conflict increase.

These findings have important implications for the design of climate adaptation and water governance policies. First, policy frameworks that focus exclusively on biophysical indicators of scarcity risk overlooking the institutional and distributional dynamics that shape conflict outcomes. Second, the stronger results at the five-year horizon highlight the importance of medium-term structural dynamics rather than short-term climatic fluctuations in understanding the political economy of water. Finally, the results suggest that technical improvements in water productivity should be accompanied by institutional mechanisms that ensure equitable allocation and conflict-sensitive management of water resources. Without such governance structures, efficiency improvements may inadvertently

heighten tensions rather than mitigate them.

Overall, the empirical evidence indicates that climate-driven water shocks influence conflict through heterogeneous institutional channels rather than a singular scarcity pathway. Understanding these mechanisms is essential for designing adaptation strategies that strengthen both environmental resilience and social stability.

References

- Adhikari, N., Yadav, G., Ray, S.B., & Kumar, S. (1991). Process documentation of women's involvement in forest management at Mahespur, Ranchi, pp. 118–123 in Singh, R (ed.), *Managing the Village Commons*, Proceedings of the National Workshop, 15–16 December 1991, Indian Institute of Forest Management, Bhopal.
- Agarwal, B. (1986). *Cold hearths and barren slopes: The wood fuel crisis in the Third World*. Delhi: Allied Publishers.
- Agarwal, B. (1987). Under the cooking pot: The political economy of the domestic fuel crisis in rural South Asia. *IDS Bulletin*, 18(1), 11–22.
- Agarwal, B. (1994). *A field of one's own: Gender and land rights in South Asia*. Cambridge: Cambridge University Press.
- Agarwal, B. (1997a). Environmental action, gender equity and women's participation. *Development and Change*, 1–44.
- Agarwal, B. (1997b). “Bargaining” and gender relations: Within and beyond the household. *Feminist Economics*, 3(1), 1–51.
- Baland, J.-M. et al. (1999). The ambiguous impact of inequality on local resource management. *World Development*, 27(5), 773–788.
- Ban Ki-moon (2007). A climate culprit in Darfur. *Washington Post*.
- Bardhan, P. (1993). Analytics of the institutions of informal cooperation in rural development. *World Development*, 21(4), 633–639.
- Boko, M. et al. (2007). Africa. In M.L. Parry et al. (Eds.), *Climate Change 2007: Impacts, Adaptation and Vulnerability* (pp. 433–468). Cambridge University Press.
- Brown, O. (2010). Climate change and forced migration. UNHCR Research Paper.
- ESCWA (2023). *Climate Change, Water, and Conflict in the Arab Region*. United Nations.
- ESCWA (2024). *Integrated Approaches to Climate, Conflict, and Security*. United Nations.

- FAO (2018). *The State of Food and Agriculture: Migration, Agriculture and Rural Development*. Rome: FAO.
- FAO (2026). *FAOSTAT: Land Use* [Dataset]. <https://www.fao.org/faostat/en/#data/RL>. Licence: CC-BY-4.0.
- Felbermayr, G., Gröschl, J., Sanders, M., Schippers, V., & Steinwachs, T. (2022). The economic impact of weather anomalies. *World Development*, 151(C).
- Gleditsch, N.P. (2012). Whither the weather? Climate change and conflict. *Journal of Peace Research*, 49(1), 3–9.
- Hagmann, T., & Mulugeta, A. (2008). Pastoral conflicts and state-building in the Ethiopian lowlands. *Africa Spectrum*, 43(1), 19–37.
- Hendrix, C.S., & Salehyan, I. (2012). Climate change, rainfall, and social conflict in Africa. *Journal of Peace Research*, 49(1), 35–50.
- International Committee of the Red Cross (ICRC). (2020). *Guidelines on the Protection of the Natural Environment in Armed Conflict*. Geneva: ICRC.
- Integrated Food Security Phase Classification (IPC). (2023). *South Sudan: Acute Food Insecurity and Malnutrition Analysis*. IPC Global Partners.
- IPCC (2022). Summary for Policymakers. In H.-O. Pörtner et al. (Eds.), *Climate Change 2022: Impacts, Adaptation, and Vulnerability*. Cambridge University Press, pp. 3–33.
- Koubi, V. et al. (2013). Do natural resources matter for interstate and intrastate armed conflict? *Journal of Peace Research*, 50(3), 337–346.
- McNeily, J.A. (2011). *The Great Reshuffling: Human Dimensions of Invasive Alien Species*. IUCN.
- Mitri, G. et al. (2015). Forest fire risk assessment: Case of Lebanon. *Journal of Environmental Management*, 154, 169–177.
- MoE/UNDP (2020). *Lebanon's Third National Communication to the UNFCCC*. Republic of Lebanon Ministry of Environment / UNDP, Beirut.
- Molinas, J. (1998). The impact of inequality, gender, external assistance and social capital on local-level cooperation. *World Development*.
- Pretty, J.N. (1995). Participatory learning for sustainable agriculture. *World Development*.
- Raleigh, C. (2010). Political marginalization, climate change, and conflict in African Sahel states. *International Studies Review*, 12(1), 69–86.

- Theisen, O.M. (2012). Climate clashes? Weather variability, land pressure, and organized violence in Kenya, 1989–2004. *Journal of Peace Research*, 49(1), 81–96.
- United Nations Development Programme (UNDP). (2014). *The Environmental Impact of the Conflict in Lebanon*. UNDP, Beirut.
- United Nations Security Council. (2020). *Situation in Somalia: Report of the Secretary-General (S/2020/398)*. United Nations, New York.
- United Nations Population Fund (UNFPA). (n.d.). *World Population Dashboard* [Dataset]. Retrieved 18 March 2026. <https://www.unfpa.org/data/world-population-dashboard>.
- Wild, H. et al. (2018). The centrality of cattle in the South Sudanese civil war. *Journal of International Humanitarian Action*, 3(1), 1–12.
- Wolf, A.T. (1998). Conflict and cooperation along international waterways. *Water Policy*, 1(2), 251–265.
- World Bank. (2007). *Lebanon: Economic Assessment of Environmental Degradation due to July 2006 Hostilities* (Report No. 39787-LB). Washington, DC: World Bank.
- World Bank. (2024). *World Development Indicators* [Dataset]. Retrieved 18 March 2026. <https://databank.worldbank.org/source/world-development-indicators>.

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