An Integrated Framework for Interprovincial Water Conflicts (IFIWC): A Case of Punjab and Sindh Water Conflicts in Pakistan

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Abstract: Existing frameworks for analyzing water conflicts often fail to capture the dynamic feedback among climate variability, power asymmetries, and diverse stakeholder behaviours, especially within intrastate contexts. This study proposes an Integrated Framework for Interprovincial Water Conflicts (IFIWC) in Pakistan to address the longstanding dispute between Punjab and Sindh provinces under escalating climate change pressures. Building on key insights from hydro-hegemony, political ecology, and environmental security approaches, the framework interlinks conflict profiling, causal drivers, actor analysis, and conflict dynamics. Notably, it incorporates an Agent-Based Modeling (ABM) approach to simulate emergent negotiation patterns and collective decision-making processes among competing provincial and societal actors. Furthermore, the framework embeds climate feedback loops, recognizing that climate change both amplifies and is influenced by conflict dynamics. Together, these elements provide a robust conceptual and practical basis for modelling water allocation scenarios and evaluating adaptive governance strategies for the Indus Basin. This approach offers new insights for policymakers and researchers seeking to manage interprovincial water disputes in an era of increasing climate stress.

Key Words: Agent-Based Modeling (ABM), Hydro Hegemony, Socio-Hydrology, Conflict Analysis Framework, Punjab Sindh Water Conflict, Interprovincial Water Conflict

Introduction

The Indus River is the lifeline of the agricultural sector of Pakistan, which contributes 21% of its total Gross Domestic Product (GDP) (Khan, 2016). The location of Punjab and Sindh province along the Indus River is a typical case of an upper and lower riparian tussle over water allocation. The conflict is further complicated by climate change and population rise in Punjab and Sindh provinces. Therefore, an integrative framework for understanding the is needed. The water dispute between the two federating units within Pakistan has the potential to turn into real conflict, which can be a challenge to national integration, where the political actors are already politicizing the issue for their political gains. There is ample scientific literature on transboundary water conflict studies, but intrastate conflict studies are scarce. Conflict analysis is a multidisciplinary approach that draws subject matters from multiple disciplines like political science, economics, sociology, and computational mathematics (Xu et al., 2009). Multiple types of conflict analysis frameworks about environmental problems were presented during the last decade (Almeida et al., 2017; Hipel & Walker, 2011; Tayia, 2019; Zeitoun et al., 2019). There are more factors other than climate change that need to be incorporated into

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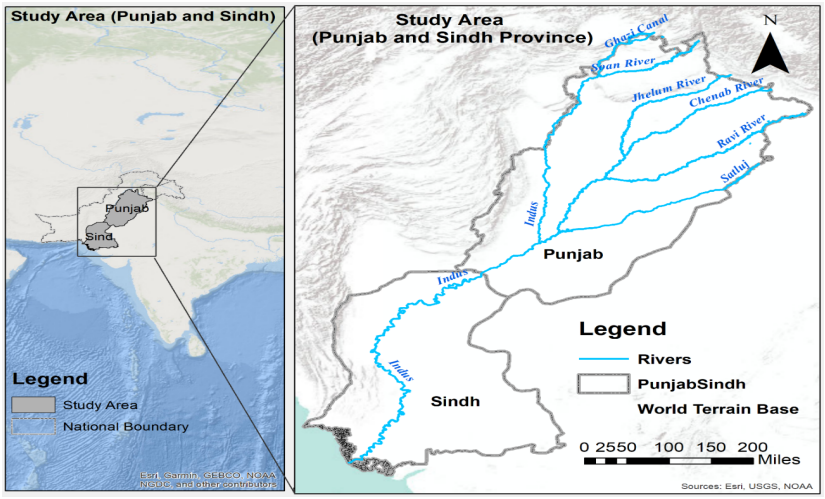
the analysis framework as a global comparative analysis of water security was presented (Link et al., 2016). Most of the frameworks related to river water are about the transboundary aspect of the river basin. Studies are absent when two different provincial units share the river basin within a country. The research literature on transboundary river conflicts is abundant, but the interprovincial and water conflict studies within the political divisions are comparatively scarce. The Indus water-sharing conflict between Sindh and Punjab is more relevant to the politics of water distribution, access, and allocation than the question of demand and supply in the context of climate change and population rise (Bandyopadhyay, 2015; Link et al., 2016b; Mustafa, 2007; Mustafa et al., 2013; Mustafa & Qazi, 2007). The water issue in Pakistan, coupled with institutional weaknesses and bad governance, is accentuating the internal discord in the country (Bandyopadhyay, 2015; Link et al., 2016b; Mustafa, 2007; Mustafa et al., 2013; Mustafa & Qazi, 2007).

Conflict is a dynamic process that occurs between interdependent parties as they experience negative emotional reactions to perceived disagreements and interference with the attainment of their goals (Barki & Hartwick, 2004). Water, food, and land scarcities affect billions around the world, raising concerns about violence, mass migrations, and prolonged regional and international disputes (Maxwell & Reuveny, 2005). The complexity of the Indus River water conflict necessitates applying models to unlock the complexity. This model ranges from simple mental maps to complex stochastic computer simulations of conflict dynamics. But, no single model can perfectly evaluate and make decisions (Shmueli et al., 2008). This covers the mechanism of social planning, water market, game theory, static and dynamic systems engineering models, and negotiation analyses. The development of a framework for models is the foundation for modelling and simulations.

Engineering research has primarily aimed to design methods that optimize how water is distributed among various users sharing a common resource base (Lee & Dinar, 1996). From an economic perspective, scholars have explored multiple strategies to determine the most efficient ways to divide water among competing stakeholders (Priscoli & Wolf, 2009). Additionally, approaches such as social planning and the establishment of water markets have been investigated as mechanisms to achieve optimal resource distribution (Becker, 1996). Over the past twenty years, game theory has emerged as a more integrated economic tool, linking negotiation processes with expected outcomes in the context of cross-border water disputes (Madani, 2010). Political science research has shed light on how political barriers shape both the progression and resolution of international water conflicts (Priscoli & Wolf, 2009). In parallel, management studies have concentrated on methods to streamline and support the process of resolving disputes over shared water. Nevertheless, many of these theoretical solutions have struggled to translate into practical, long-term resolution of transboundary water disputes in reality (Allan & Mirumachi, 2013). The present study aims to prepare an analytical framework for a better understanding of the interprovincial water conflict in the context of climate change. It further summarizes the previously presented analytical framework of environmental and water conflicts that enhances the overall analytical strength and enables a more thorough examination of the various components involved in resolving transboundary water disputes (Tayia, 2019). We have figured out the actors, drivers, and factors as an element of the conflict and their dynamic interaction under the changing climate.

Figure 1

Study Area



Study Area

The Indus Plains, which cut across the Pakistani provinces of Punjab and Sindh, is very water-stressed and agriculturally productive (Mobeen et al., 2023, 2025). Interprovincial water sharing has been a point of conflict in this area for many years. Indus Basin Irrigation System (IBIS) comprises a command area of 16.85 million hectares (Mha) (Hasan et al., 2021). Punjab, the upper riparian, has the leverage of some of the main headworks and canal diversions and Sindh, the lower riparian, relies on controlled flows for its agriculture and livelihoods. The world's largest irrigation system in the area, about 80% of the cultivated land is irrigated (Muhammad et al., 2016) and contributes 90% of the national harvest (Zhu et al., 2013). Historical disputes over fair distribution resulted in the Water Apportionment Accord 1991 between provinces, but disputes survived because of the sense of unfairness, political conflicts and climate-induced air flow variation.

Review of Existing Frameworks for Water Conflict Analysis

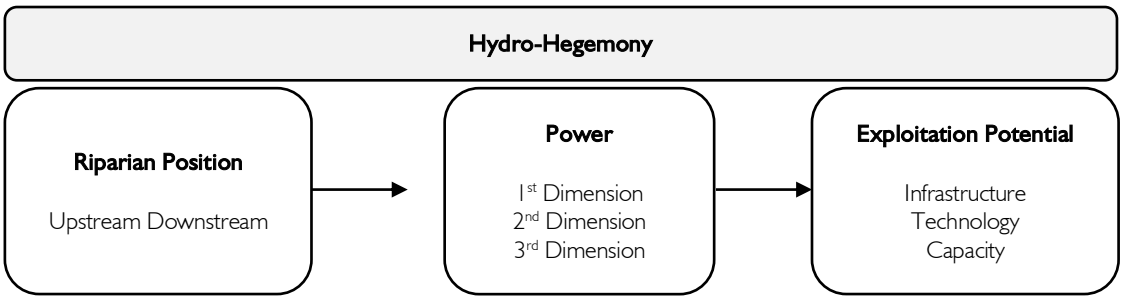
Several conceptual frameworks have been developed to understand transboundary and interprovincial water conflicts across different contexts. Notable among these are the Hydro-Hegemony Framework, the Political Ecology Approach, and frameworks emphasizing Environmental Security and Water Governance Regimes. These frameworks provide valuable theoretical foundations that inform the design of the present study's integrated conflict analysis model for Punjab and Sindh.

Hydro-Hegemony

The concept of "hydro-hegemony" has been explored previously, for instance (Warner, 1992; Williams, 2002), but has not been extensively conceptualized or systematically theorized to date. (Naff & Matson, 1984) and (Medzini, 2001) explained that the "power ratio" between competing riparians is based on each actor's overall economic, political, and military power. The degree of hydro-hegemony achieved by riparians is best evaluated through a review of their power position and resource exploitation potential. These are represented graphically below.

Figure 2

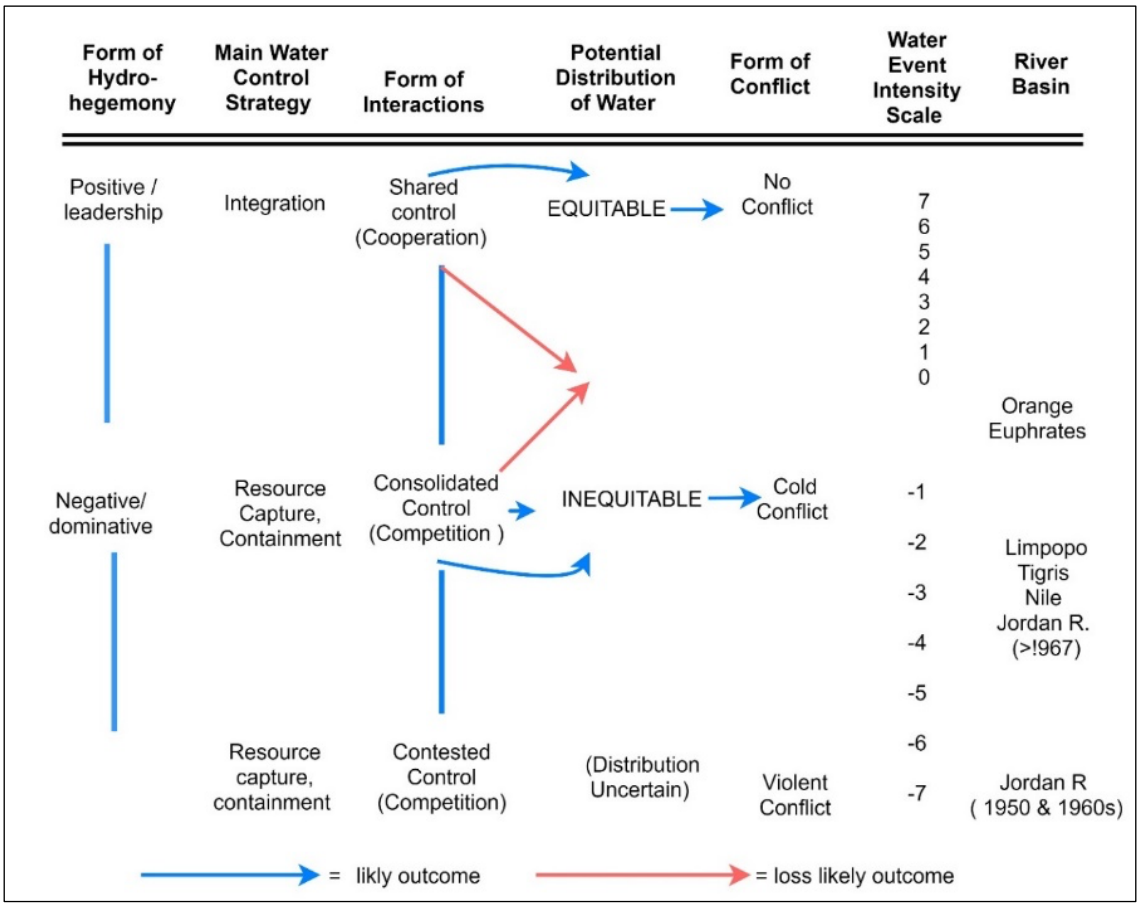
The Pillars of Hydro-hegemony (Medzini, 2001; Naff & Matson, 1984)



In 2006, Zeitoun and Warner applied a Hydro-hegemony framework to the river basins, where existing hydro-hegemonic frameworks appear toward the dominant type. They established that the conventional analysis tends to underplay the position that power imbalance plays in establishing and sustaining water dispute circumstances that stop short of the aggressive mode of battle and are regarded as unobjectionable conditions of asymmetrical cooperation. Hydro-Hegemony's conceptual framework outlined aims to assign these two characteristics and differing dispute levels of intensity. Their issues emerge in the persistent and strategic question of who gets how much space, how, and why. At the river basin level, hydro-hegemony is accomplished by water resources management techniques such as resource recovery, integration, and conservation. Political mechanisms beyond the water field structure basin-wide hydro-political partnerships in a manner varying from the advantages of political and economic leadership collaboration to the unequal aspects of supremacy. It is suggested that the framework offers an empirical model useful to analyze the choices of absolute dominant or hegemonized riparian and how they could shift away from dominance to cooperation (Zeitoun & Warner, 2006).

Figure 3

The Framework of Hydro-Hegemony: Combining the Form of Hydro-Hegemony, a Form of Interaction, the Outcome of the Interaction, and the Intensity of the Conflict



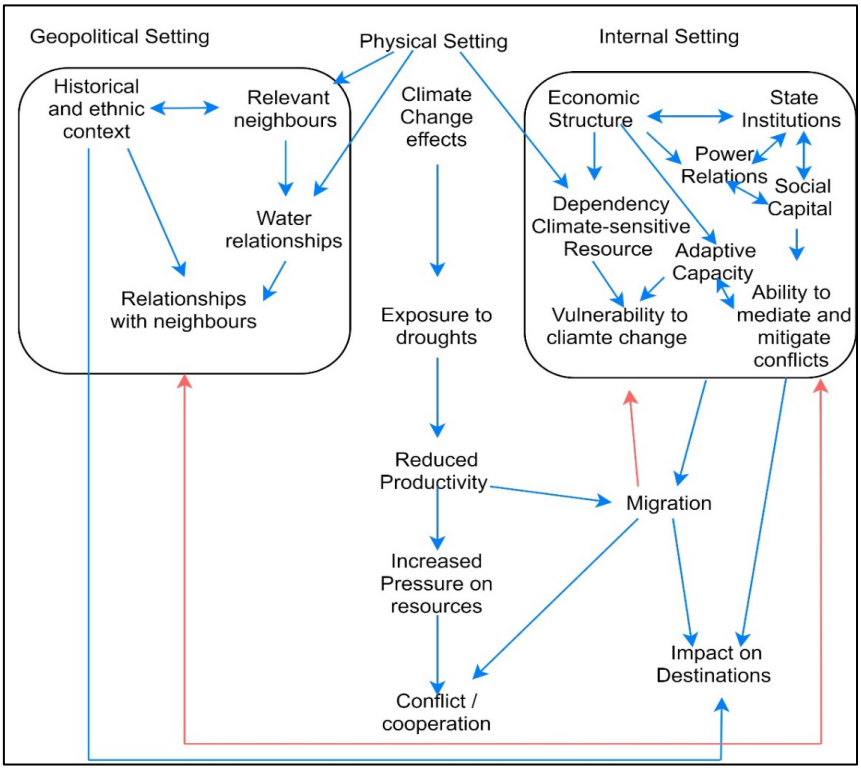
Relationships among riparian states sharing transboundary water resources often fall along a spectrum ranging from true cooperation to intense rivalry. Analytical perspectives generally assume that each riparian actor will pursue strategies to optimize its own benefits. In contexts where water availability is low, competition typically intensifies as parties vie for greater control over limited flows. Conversely, when water is plentiful, one country may focus on harnessing hydropower potential while another prioritizes flood management. At times, control over water resources may even be leveraged to achieve unrelated political or strategic goals. Such dynamics frequently lead to imbalanced water allocations and sustained disputes between neighbouring states. During this time of dysfunctional relationships, brief military battles over previously mentioned water supplies took place. Israel's conquest of the Syrian Golan and the West Bank in 1967 effectively consolidated its dominance over the region and marked the beginning of the Israeli hegemony (Feitelson, 2000), a time of "controlled chaos" that continues to this day (Zeitoun & Warner, 2006).

Effects of Droughts on Conflict or Cooperation in the Middle East

In the Middle East, Feitelson and Tubi (2017) analyzed climate change's influence on the conflict by using a conceptual framework. They studied climate change-induced droughts leading to the armed conflict in the Euphrates and lower Jordan River basins. They developed a framework linking climate change, droughts, and conflict. The key factors that influenced the responses to the drought in the two basins are described and evaluated comparatively using multiple sources. Results demonstrate that the behaviour of the political and economic systems of the upper riparian countries and states are crucial factors influencing the risk of war. Most notably, conflicts only emerge when fundamental factors, especially the capacity for adaptation, are minimized. They found that climate change is an intermediate aspect, which should be evaluated as such rather than as the main conflict catalyst.

Figure 4

Effects of Droughts on the Conflict or Cooperation (Feitelson & Tubi, 2017)

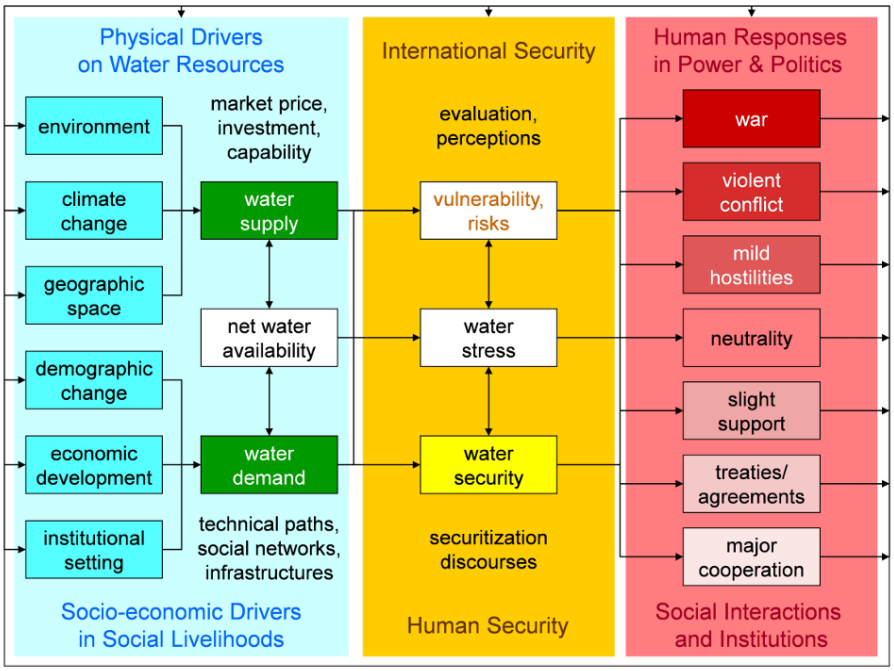


A Framework of the Water-Security-Conflict Nexus

An analytical framework of the water-security nexus is developed that integrates the physical and socioeconomic pathways connecting water availability with conflict or cooperation. Link et al. (2016a) developed a framework to identify the linkage and pathways between coupled human and natural systems of water use. The interplay of these linkages can play a role in conflict and cooperation at multiple scales. This integrative framework deconstructs the environmental and human settings into multiple actors engaged in conflict.

Figure 5

Integrative Conceptual Framework of the Water-Security-Conflict Nexus (Link et al., 2016a)



The pathways chain effect is represented in three compartments, which are connected through causal connections and feedback loops. The framework can be best understood by dividing it into four parts: Systemic drivers and pathways, evaluation of water stress and water security, Human response and social interactions between conflict and cooperation, and linkage in the water security conflict nexus.

Methodology

For developing an effective foundation for analyzing the Punjab and Sindh water conflict in the context of climate change, this study starts with an extensive review of relevant theoretical frameworks in water conflict scientific literature. Key perspectives include the Hydro-Hegemony Framework (Zeitoun & Warner, 2006), which conceptualizes how power asymmetries shape transboundary water interactions, and the Political Ecology Approach, which situates water disputes within broader socio-political and environmental processes. Additionally, the framework by Mason and Zeitoun (2013) emphasizes multi-level hydropolitics and the role of formal and informal institutions in managing competing demands. By synthesizing insights from these frameworks, the study identifies critical elements of power relations, institutional trust, and climate vulnerability that must be addressed in a regionally grounded conflict analysis.

Building upon this review, the research develops a context-specific conflict analysis framework tailored to the Indus Basin, with a particular focus on the Punjab and Sindh provinces. The proposed framework decomposes the conflict into four interconnected components: conflict profile, causes, actors, and dynamics. This structure draws methodologically from Fisher (2000), who advocate for multi-dimensional conflict mapping, and Mason and Richard (2005), who outline pathways for integrating environmental variables into conflict assessments. The study visualizes these interactions through a series of conceptual diagrams, progressively expanding from basic elements to a comprehensive interaction map that reflects climate impacts, governance processes, and stakeholder hierarchies. Notably, we adapted and extended from Link et al. (2016a) the Integrative Conceptual Framework of the Water-Security-Conflict Nexus to align with the Punjab Sindh context by incorporating sub-national actors, hydrological governance institutions, and climate-driven variability in water availability.

Proposed Framework for Climate-Induced Water Conflict Analysis in the Indus Basin

The water availability in the Indus Basin has varied due to climate change during the recent past. The water in the Indus is allocated according to the water apportionment accord (1991) signed among the provincial units. However, the fluctuating demand and supply pose a challenge to the existing setup of decision-making. The competing need for water is not only creating a conflict among the major federating actors (provinces), but the situation at the end-user level is also complicated. The water-related protests reported in the press by the common public, like household users, farmers, and industrialists, are also of grave concern.

Figure 6

Theoretical Framework Illustrating Climate-Induced Water Sharing Dynamics Between Punjab and Sindh (Adapted from (Fisher et al., 2000).

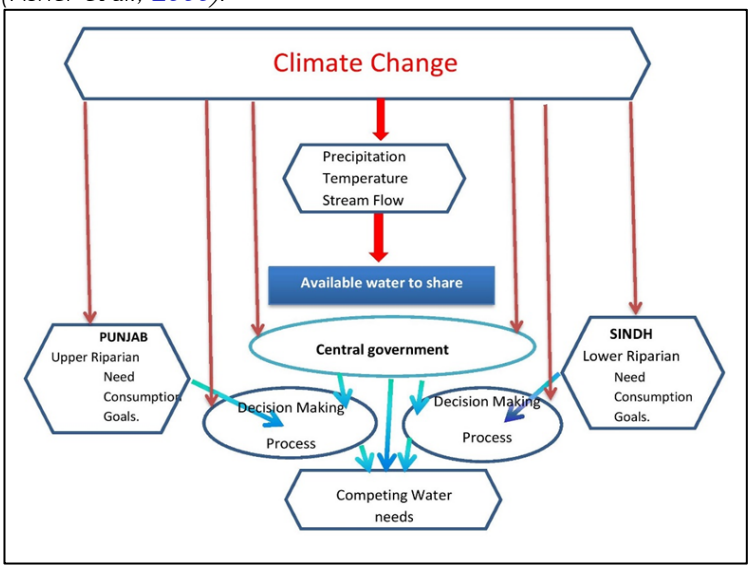


Figure 6 illustrates how climate change affects key hydrological variables such as precipitation, temperature, and streamflow, which determine the total water available for allocation. The central government acts as the primary decision-making body, mediating the competing demands of Punjab (upper riparian) and Sindh (lower riparian) based on their consumption needs and development goals. Red arrows show the direct influence of climate factors, while blue arrows depict the governance processes and negotiation pathways. Overall, the framework visualizes the complex interplay between climate variability, institutional decisions, and provincial competition for scarce water resources.

We apply climate change as an overarching independent variable in the conflict analysis framework used by different researchers and practitioners for analyzing various conflicts. The major components of the analysis are the profile, causes, actors, and dynamics of water conflict. The suggested mechanism is meant to provide a forum for the analysis of water conflict under climate change. It takes climate change as an independent variable governing water scarcity in the Indus River and the stakeholders' demand and dynamics of supply. In the context of our framework, we see the Punjab and Sindh water conflict with the following four lenses.

Figure 7

Conflict Analysis Framework Integrating Climate Change with Water Allocation Disputes

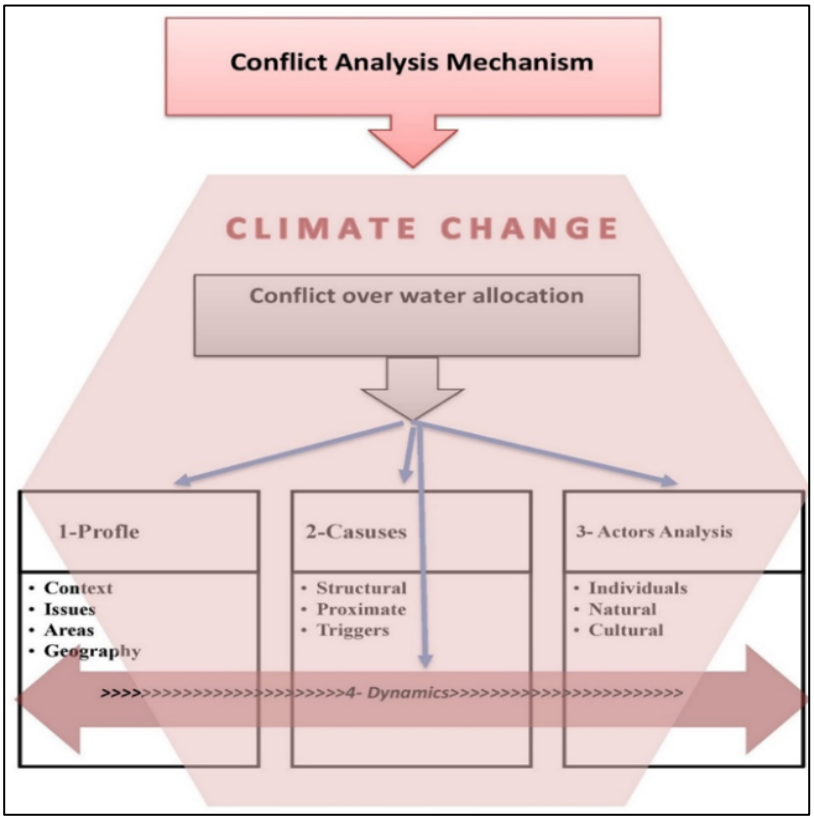


Figure 7 breaks down the mechanism of conflict analysis into four sequential elements within the broader impact of climate change. It identifies the conflict profile (context, issues, areas, geography), causes (structural, proximate, triggers), and actors' analysis (individual, natural, cultural factors). The arrows show how these elements interact to shape the conflict over water allocation in a changing climate. A directional flow illustrates how these factors collectively drive the evolving conflict dynamics in the Punjab and Sindh water dispute.

Profile / Understanding of Conflict

The first component of the analysis describes the situational analysis of the geophysical settings of the basin and its climatic characteristics. Understanding the historical evolution of irrigation practices and interprovincial agreements helps explain present-day grievances and recurring disputes in the Indus Basin.

It also examines the political, economic, social, and environmental institutions and structures that shaped the conflict. In 1951, the per capita water availability in Pakistan was 5210 cubic meters, which declined to 1100 cubic meters in 2006, which further reduced to 1038 cubic meters in 2010. This value was 877 cubic meters in 2020 (Ranjan, 2012). The study shows that the inter-provincial water conflicts date to before the creation of Pakistan. The first conflict between Punjab and Sindh was raised in 1901 when the Indian Irrigation Commission restricted Punjab from taking water from the Indus River after approval of Sindh (Khalid & Begum, 2013). This conflict between Punjab and Sindh was settled by the Cotton Committee of India in 1919 (Palijo, 2003). Pakistan became a downstream riparian with India after its creation in 1947 (Palijo, 2003). The Rau Commission pointed out the implications to Sindh due to the Dam construction in Punjab. At the time of scarcity of water, regional leaders became more vocal, especially those in the lower riparian area (Sayal, 2015). On the other hand, Punjab demands the construction of the Bhakra dam on the River Sutlej. The province of Sindh was against this construction. At that moment, the British brought both provinces to the table, and an agreement was signed between Sindh and Punjab. This agreement was known as the Sindh-Punjab Water Agreement, and the contract ended on 31 March 1948.

The water apportionment accord was issued in 1991 with 55.94 MAF shares for Punjab and 48.76 MAF for Sindh (Farooq, 2014). Many experts contend that the official method for calculating Indus system flows relies on relatively recent data from 1977 onward, which tends to favour upstream provinces and places downstream Sindh at a disadvantage (Mustafa et al., 2013).

Figure 8

Integrated Framework for Interprovincial Water Conflicts (IFIWC)

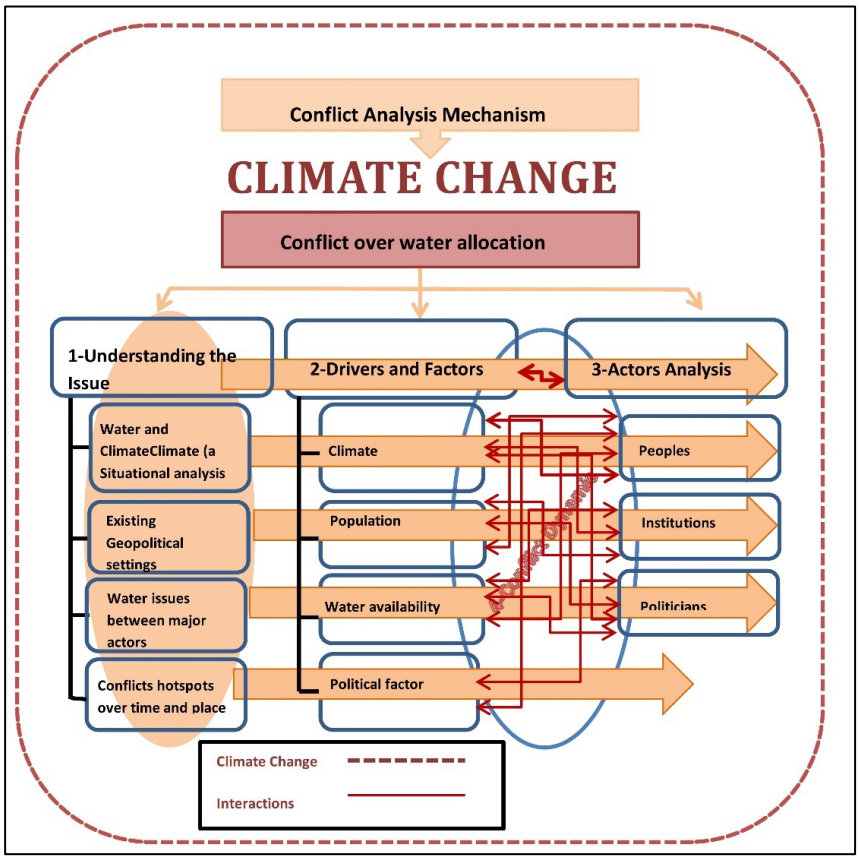


Figure 8 presents a holistic conflict analysis framework showing how climate change intensifies water allocation disputes through multiple interacting pathways. The left block (Understanding the Issue) captures situational elements: water-climate context, geopolitical settings, specific water issues, and conflict hotspots over time and space. The central block (Drivers and Factors) details the major conflict drivers, climate variability, population pressures, water availability, and political factors, which link back and forth with the situational context and various actors.

The right block (Actors Analysis) specifies key stakeholders' peoples, institutions, and politicians whose interactions, decisions, and rivalries shape the emergent conflict patterns. Red and orange arrows visualize complex feedback loops and climate–society interactions, laying the foundation for agent-based simulations of Punjab–Sindh water conflict dynamics under changing climate conditions.

Factors and Drivers' Analysis

This identifies the reason behind the conflict. This component opens with the facts about population, water, and political process. The conflict causes are the structural reasons for conflict? e.g. unequal land distribution, political exclusion, poor governance, impunity, and lack of state authority (Herbert, 2017). The proximate causes, e.g. arms proliferation, illicit criminal networks, and natural resource discoveries. Over time, with the increase in world population and the number of nation-states, the intensity and quantity of conflicts for natural resources have risen at an alarming rate (Kasymov, 2011). However, certain actors may actually benefit from prolonging social unrest and conflict, using it to consolidate political power, limit open debate, or strengthen the ruling regime (Ovink, 2016). Water resources are neither evenly nor fairly distributed across regions, and the widening gap between supply and rising demand has intensified both interprovincial and transboundary disputes in Pakistan (Magsi & Atif, 2012). As competition for water grows, decision-makers must manage not only the resource itself but also the complex social interactions among stakeholders (Magsi & Atif, 2012). In Sindh, weak governance and ageing irrigation infrastructure exacerbate these challenges. Consequently, Sindh has found itself at the centre of persistent disputes over water distribution. High demand coupled with inadequate water supply fuels interprovincial conflicts, while political, environmental, and distributional factors further aggravate the situation (Khan, 2014). Punjab is experiencing significant challenges in its agricultural sector and related social impacts, which have increasingly become politicized. Various political factions within the province have staged protests, alleging that their water entitlement is being unfairly diverted by other regions. This tension has also fueled resistance to constructing new reservoirs and storage structures upstream, which are perceived as tools to manipulate flow control. Meanwhile, Sindh, located at the downstream end of the Indus River system, fears that ongoing disagreements will further reduce its already constrained water supply.

Actors' Analysis

These are the primary stakeholders who are further explained by examining their interests, concerns, goals, hopes, fears, strategies, positions, preferences, worldviews, expectations, and motivations (Herbert, 2017). The federating units Sindh and Punjab are the major stakeholders of the discussion. Starting from the Sindh perspective, they claimed that Punjab stole 16000 cusecs water of Sindh at Taunsa and Guddu in one week (Khalid & Begum, 2013). Sindh always says that they get less water than the Accord 1991 decided for them. The situation increased the salination of lower Sindh, which is not suitable for agriculture. Insufficient water does not meet the requirements of the province, which affects the ecosystem. Another effect is the mangroves, which are shrinking due to the water shortage. Sindh suffers from a lower riparian development of canals, and a dam on the upper head of the River reduces the supply for lower rivers only in the flooding season water gives to them (Khalid & Begum, 2013). The water issue may become a source of dissatisfaction because the lower Indus basin is moving towards famine situations and ecological disasters (Magsi, 2012). Pashtun nationalist groups like the ruling Awami National Party in KPK are also opposed to this barrage, claiming that the reservoir would flood the province's fertile agricultural lands. Given the deep sentiments of Sindh against Kalabagh, any initiative by a freely elected yet controlled Punjab government and a military-led nationalist government in Sindh to create the dam could precipitate extreme animosity (Mustafa et al., 2013). On the other hand, Punjab said that the irrigation system is the lifeline of the agriculture of the province, which is 80 per cent of the total agricultural production of Pakistan. A large portion of Punjab agriculture comes from the canal water of the Indus Basin, almost 90 percent of the output. There are a million big and small industrial units in Punjab that generate the second-highest employment in the country and consume nearly 2.2 MAF of water per year (Khalid & Begum, 2013).

Figure 8

Pyramid of Key Actors Influencing Interprovincial Water Allocation Dynamics

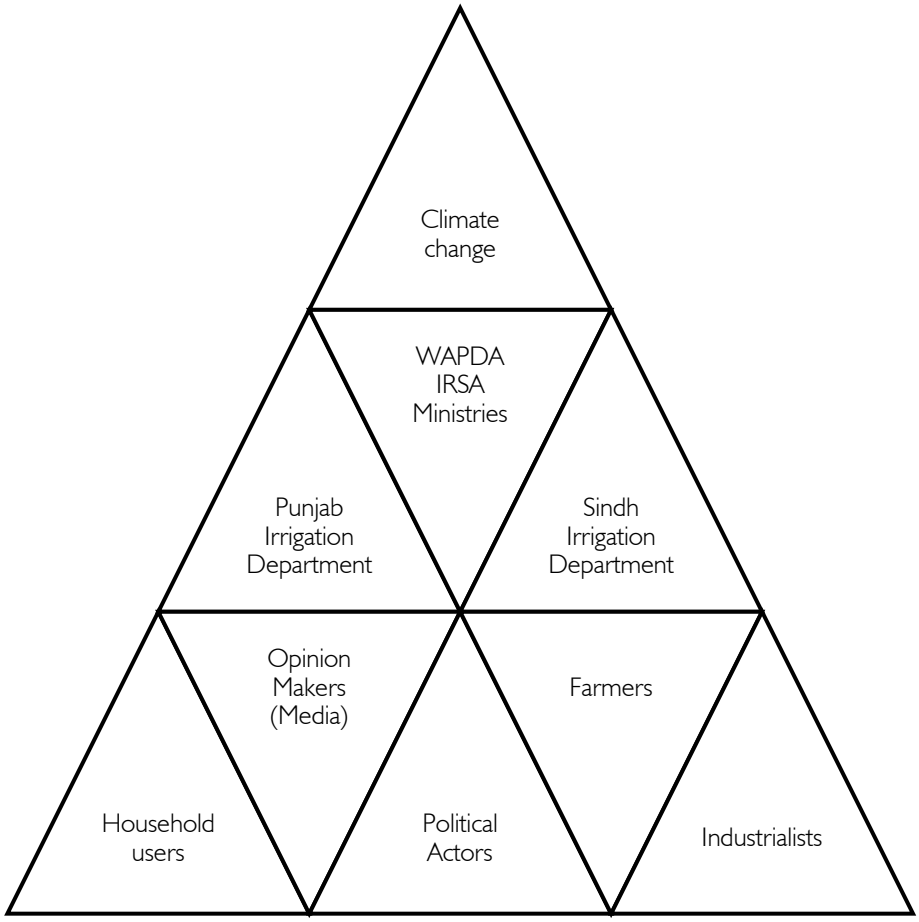


Figure 8 illustrates the hierarchical structure of key stakeholders influencing water allocation between Punjab and Sindh under climate change pressures. At the apex, climate change represents the overarching environmental driver impacting water availability. Central governance bodies (WAPDA, IRSA, Ministries) mediate between provincial irrigation departments and a diverse base of societal actors, including farmers, households, industry, media, and political actors. The pyramid emphasizes the layered interactions among policy institutions, user groups, and external climate forces shaping conflict dynamics.

Conflict Dynamics

This component in the framework is the dynamic part of the framework. This studies the interactions among the first three elements of the framework. The sub-components of the dynamic element are interconnected with many variables, processes, actors, and institutions with feedback loops. The conflict dynamics in the framework can be modelled as an agent-based model. In the future, I want to model these conflict dynamics among the farmers of both Sindh and Punjab province, Pakistan.

The stakeholders who shape the conflict play crucial roles and demonstrate specific behaviors within the conflict setting. These key actors can be better understood by analyzing their interests, priorities, ambitions, fears, strategies, stances, preferences, perspectives, expectations, and motivations (Herbert, 2017). An actor analysis seeks to answer questions such as: Which parties have the power to influence or disrupt the conflict context? What social or political divisions exist? Who holds authority, and how is leadership exercised? In today's context of increased environmental awareness and broader recognition of downstream riparian rights, the situation in Sindh is often viewed as breaching international standards, given the perceived marginalization by the central government. This persistent inequity in water distribution could fuel further discontent, especially as the lower Indus region faces increasing risks of severe water

scarcity and ecological degradation. The strength of anti-dam emotions in Sindh does not compare to any other province. Given the deep sentiments of Sindh against Kalabagh, any initiative by a freely elected yet controlled Punjabi government and a military-led nationalist government in Sindh to create the dam could precipitate extreme animosity (Mustafa et al., 2013). On the other hand, Punjab said that the irrigation system is the lifeline of the agriculture of the province, which is 80 percent of the total agricultural production of Pakistan. A large portion of Punjab agriculture comes from the canal water of the Indus Basin, almost 90 per cent of the output. Agriculture sector workers more than 50% of the workforce and accounts for 70% of export revenues. The salinity or over-abstraction of groundwater, or reallocations for environmental remediation of the Indus Delta or to satisfy domestic demands, would limit water supply for irrigation (Archer et al., 2010).

Discussion

Traditional Models of Water Conflict

Existing conceptual models for water conflict have predominantly approached the issue from singular disciplinary angles, often lacking integration of dynamic human-environment interactions. For instance, political economy frameworks in hydropolitics emphasize power asymmetries (Wei et al., 2022). Such hydro-political models argue that stronger riparian actors secure more favourable water allocations. Wolf et al. (2003), for example, identified institutional "incapacity" as the failure of agreements like water accords to absorb shocks such as droughts or unilateral projects as a root cause of many water disputes (Wei et al., 2022).

Economic and game-theoretic models have also been applied to water conflicts, aiming to simulate the rational behaviour of actors in resource allocation scenarios. Hydroeconomic models integrate hydrological data with economic optimization, assuming actors are utility-maximizers with perfect information (Harou et al., 2009). These models have been used to estimate the gains from cooperation or the costs of conflict under various water-sharing arrangements. In some cases, they have been extended with behavioural economics and rudimentary agent-based elements to relax assumptions of unbounded rationality (Espey & Towfique, 2004; Schill et al., 2019). Several studies have incorporated bounded rationality and learning to reflect that riparian states' decisions depend on past outcomes, relative gains, or intangible values (Espey & Towfique, 2004). These early socio-hydrological models marked a theoretical shift towards viewing water conflicts as complex adaptive systems. Scholars note persistent difficulty in representing social variables beyond economic payoff, and such models often minimise the cultural or cognitive dimensions of cooperation (Ding et al., 2016; Khan et al., 2017; Yu et al., 2019).

Threats of "classic" theories (e.g., Homer-Dixon, 1991) would be that there will translate reduced water availability into increased between-group tensions and inter-group conflict. Modern scholarship further hones this view, understanding climate change to be a "threat multiplier" rather than an immediate trigger for water wars. That is, climate stresses magnify underlying political and economic fissures that can lead to violence (Ide, 2018; Ide et al., 2020; Ide et al., 2021; Scheffran & Battaglini, 2011). Yet, conventional environmental security models typically stop at stating that increased water stress raises conflict risk; they do not model the iterative feedback loop wherein conflict, in turn, undermines adaptive capacity. Recent assessments stress that water conflicts are multi-causal influenced by governance, development, and social context intervenes by exacerbating these factors (Ide et al., 2021; Xia et al., 2021). Notably, a scoping review by Kåresdotter et al. (2025) found that climate-driven water scarcity is heightening disputes in vulnerable regions while simultaneously conflicts themselves reduce communities' ability to cope with climate impacts (vicious feedback) (Xia et al., 2021).

Integrating Agent-Based Modeling in Water Conflict Frameworks

A defining theoretical innovation of the IFIWC is its integration of the Agent-Based Modeling perspective. At a conceptual level, employing an ABM approach means that provinces are modelled as autonomous "agents" with individual objectives, decision rules, and interactions. This allows the framework to capture heterogeneous behaviours. For example, an upstream province might behave in a self-maximizing way, whereas a downstream province might adopt a more risk-averse or cooperative strategy and observe how these micro-level behaviours collectively produce macro-

level conflict or cooperation outcomes. In essence, the ABM approach enables the study of emergent phenomena: the complex, system-level pattern that arises from many localized decisions and feedbacks (Gain et al., 2021; Lillo-Saavedra et al., 2024).

In contrast, the IFIWC's ABM component aligns with the socio-hydrological principle that human–water systems evolve jointly and often non-linearly (Sivapalan et al., 2014; Sivapalan et al., 2012). It provides a bottom-up simulation of interprovincial interactions grounded in rules that reflect real-world decision processes rather than relying on a top-down equilibrium solution.

The theoretical benefits of this ABM approach are illustrated by recent applications in the water conflict literature. For example, Lillo-Saavedra et al. (2024) developed a socio-hydrological ABM approach to examine irrigation conflicts among farmer organizations in Chile, which offers a microcosm of the kind of dynamics IFIWC seeks to address. Their model assigned different "personality" types to agents (selfish, neutral, cooperative) and tested scenarios of water scarcity and governance oversight (Lillo-Saavedra et al., 2024). Notably, the simulation revealed emergent conflict patterns: under drought conditions with low institutional oversight, selfish agents frequently violated water-sharing rules, leading to intensified conflicts, whereas strong oversight markedly reduced these conflicts even during scarcity (Lillo-Saavedra et al., 2024).

The literature on transboundary and regional water conflicts further validates the inclusion of the ABM perspective. Researchers have begun to treat administrative or regional units as agents in basin-scale models. For instance, Khan et al. (2017), cited in Huber et al. (2019), developed an ABM where watershed administrative units were defined as agents making water management decisions for agriculture, hydropower, and ecological needs. Huber et al. (2019) mentioned that many previous water management models have low explanation and prediction power due to neglecting two-way dynamic feedback between humans and water systems.

Incorporating Climate Feedback Loops in Conflict Models

Equally innovative is the IFIWC's incorporation of climate-driven feedback loops, embedding the water conflict within a changing environmental context. The novelty lies in recognizing that water conflicts and climate change impacts are mutually reinforcing and modelling this two-way coupling. Recent theoretical work on the climate and water conflict nexus supports this integrated view. (Ide et al., 2021; Unfried et al., 2022; Xia et al., 2021). The IFIWC framework's design acknowledges this cycle. For example, a prolonged drought may trigger more aggressive water extraction behaviors by provinces, which in turn could undermine collective arrangements and reduce system resilience to the next drought. It aligns with the emerging socio-hydrological theory that emphasizes the co-development of human and environmental trajectories, including feedback between climate events and societal responses (Rajah et al., 2024).

Empirically, the importance of integrating climate loops is evident in recent case studies. A global review by (Kåresdotter et al.) in Ambio (2025) highlighted that climate change is already intensifying water stress in many regions, which "increases the risks of water conflicts," especially in arid and semi-arid areas. The IFIWC's novelty is making this feedback an integral part of its framework. It conceptually allows for scenario analyses where, say, repeated cycles of low rainfall and contentious water allocations can lead to progressively worsening relations or, conversely, where recognition of climate threats spurs cooperative adaptation measures that feedback positively by reducing conflict risk. Lastly, this framework bridging the gap between existing models and the complex reality of interprovincial water conflicts under climate change, the IFIWC stands as a novel conceptual model. It extends the frontier of water conflict theory by providing a platform where the social, technical, and climatic dimensions of water disputes are analyzed together, reflecting the true complexity of water conflicts in Pakistan and beyond.

Conclusion

This study proposes an Integrated Framework for Interprovincial Water Conflicts (IFIWC) that systematically explains the complex Punjab and Sindh water dispute within a coupled human-environment context. Unlike traditional approaches that isolate economic, political, or hydrological factors, the IFIWC combines conflict profiling, causal drivers,

actor analysis, and dynamic feedback to reflect the multifaceted nature of water allocation under climate stress. A central innovation is the integration of an Agent-Based Modeling (ABM) approach to incorporate dynamic and diverse stakeholders to adapt as climate conditions evolve. The explicit inclusion of climate feedback loops further enhances realism, showing how environmental variability and institutional effectiveness interact to shape conflict dynamics. Overall, the IFIWC reveals that the Indus Basin conflict arises not just from physical scarcity but from the intricate effects of historical legacies, power asymmetries, and climate-induced risks. The effective resolution demands policies and modelling tools that embrace this complexity. By providing an adaptable, interdisciplinary framework, this study offers a robust basis for future simulations, scenario testing, and policy design to promote equitable and resilient water sharing between Punjab and Sindh amid growing climate challenges.

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