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ARAL SEA GOVERNANCE IN CENTRAL ASIA: PROBLEMS AND DIRECTIONS

The Aral Sea crisis remains a defining transboundary environmental challenge in Central Asia, with persistent implications for environmental security, regional stability, and sustainable development. This study synthesizes the literature on Aral Sea governance to consolidate the main constraints identified by scholars and to distill actionable directions for improving regional coordination and policy implementation. Drawing on a multilingual publication dataset published between 1991 and 2024, we first conduct a CiteSpace-based bibliometric analysis of the English-language subset to map the international research landscape, and then apply boundary analysis to the full multilingual dataset to identify and categorize the key governance problems discussed for the Aral Sea basin.

Across the reviewed literature, 27 governance problems are identified. Based on mention frequency, regional-level barriers account for the largest share (65%), followed by national (24%), individual (8%), and international-system factors (3%). Governance responses discussed in the literature largely fall under mitigation and adaptation, yet implementation is repeatedly constrained by weak institutional coordination, limited governance capacity, and related constraints. By showing how these barriers are distributed across governance levels, the study offers practical directions for regional cooperation and future research on Aral Sea governance.

Keywords: Aral Sea governance, Central Asia, ecological crisis, boundary analysis.

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Орталық Азиядағы Арал теңізін басқару: мәселелер мен бағыттар

Арал теңізі дағдарысы Орталық Азиядағы ең өзекті трансшекаралық экологиялық сын-қатерлердің бірі болып қалып отыр және экологиялық қауіпсіздікке, өңірлік тұрақтылыққа әрі орнықты дамуға ұзақ мерзімді ықпалын тигізуде. Бұл зерттеу Арал теңізін басқаруға қатысты ғылыми әдебиеттерді жинақтап, ғалымдар атап көрсеткен негізгі шектеулерді жүйелейді және өңірлік үйлестіру мен саясатты іске асыруды жақсартуға бағытталған қолданбалы ұсыныстарды айқындайды. 1991–2024 жылдары жарияланған көптілді жарияланымдар деректеріне сүйене отырып, алдымен CiteSpace негізіндегі библиометриялық талдау арқылы ағылшын тіліндегі деректердің ішкі жиынтығы бойынша халықаралық зерттеулердің жалпы көрінісі карталанады, кейін толық көптілді деректер жиынтығына шекаралық талдау әдісі қолданылып, Арал теңізі алабында талқыланатын басқарудың негізгі проблемалары анықталып, жіктеледі.

Қарастырылған әдебиеттер бойынша басқаруға қатысты 27 мәселе айқындалды. Аталу жиілігіне қарай кедергілердің ең үлкен үлесі өңірлік деңгейге тиесілі (65%), одан кейін ұлттық (24%), жеке (8%) және халықаралық жүйелік факторлар (3%) келеді. Әдебиетте талқыланатын басқару шаралары негізінен салдарын жұмсарту және бейімделу бағыттарына топтастырылғанымен, оларды іске асыру көбіне институционалдық үйлестірудің әлсіздігі, басқарушылық әлеуеттің шектеулілігі және соған байланысты өзге де шектеулер салдарынан қайта-қайта тежеледі. Осы кедергілердің басқару деңгейлері бойынша қалай бөлінетінін көрсету арқылы зерттеу өңірлік ынтымақтастықты күшейту және Арал теңізін басқару жөніндегі болашақ зерттеулер үшін практикалық бағыт-бағдар ұсынады.

Түйін сөздер: Арал теңізін басқару, Орталық Азия, экологиялық дағдарыс, шекаралық талдау.

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Управление Аральским морем в Центральной Азии: проблемы и направления

Кризис Аральского моря остаётся одним из ключевых трансграничных экологических вызовов в Центральной Азии и продолжает оказывать устойчивое влияние на экологическую безопасность, региональную стабильность и устойчивое развитие. В настоящем исследовании обобщается научная литература по вопросам управления Аральским морем с целью систематизировать основные ограничения, выделяемые исследователями, и сформулировать практические направления для улучшения региональной координации и реализации политики. Опираясь на многоязычный массив публикаций за 1991–2024 гг., мы сначала проводим библиометрический анализ на основе CiteSpace по англоязычной подвыборке, чтобы картировать международный исследовательский ландшафт, а затем применяем метод пограничного анализа ко всему многоязычному массиву для выявления и классификации ключевых проблем управления, обсуждаемых применительно к бассейну Аральского моря.

По итогам обзора литературы выявлено 27 проблем управления. Согласно частоте упоминаний, наибольшая доля барьеров относится к региональному уровню (65%), далее следуют национальный (24%), индивидуальный (8%) и уровень факторов международной системы (3%). Обсуждаемые в литературе меры реагирования в целом группируются вокруг смягчения последствий и адаптации, однако их реализация неоднократно сдерживается слабой институциональной координацией, ограниченной управленческой ёмкостью и сопутствующими ограничениями. Показывая, как эти барьеры распределены по уровням управления, исследование предлагает практические ориентиры для развития регионального сотрудничества и дальнейших исследований по управлению Аральским морем.

Ключевые слова: управление Аральским морем, Центральная Азия, экологический кризис, пограничный анализ.

Introduction

The Aral Sea, located between Kazakhstan and Uzbekistan in the interior of the Eurasian continent, is characterized by extremely low annual precipitation (100-130 mm) and high evaporation rates (1250–1450 mm), resulting in a structurally fragile hydrological system (Central Asia Climate Portal, 2024). The basin's surface water resources (approximately 116 km³ per year) are primarily supplied by the Amu Darya and Syr Darya rivers, while groundwater reserves provide only limited additional support (Table 1). This natural imbalance, compounded by large-scale Soviet irrigation policies, initiated the severe shrinkage of the Aral Sea beginning in the 1960s (Figures 1 and 2). By the early 2000s, the lake had lost nearly 80% of its volume, salinity had increased by 6–12 times, and extensive coastal retreat and desertification had occurred (Wu, 2010: 200). Hydrological modeling further confirms that 86% of the shrinkage is attributable to unsustainable anthropogenic water use, rather than climate variation alone (Der Beek, 2011: 684).

The scale of ecological degradation – exemplified by the emergence of the Aralkum Desert, a major source of toxic dust storms – underscores the urgent need for effective governance solutions. Although regional cooperation was institutionalized after independence through the establishment of the Interstate Commission for Water Coordination (ICWC) in 1992 and the International Fund for Saving the Aral Sea (IFAS) in 1993, the literature continues to document fragmented institutional mandates, limited coordination capacity, divergent national priorities, and uneven implementation. Meanwhile, growing involvement from external partners has made it more urgent to reassess governance approaches.

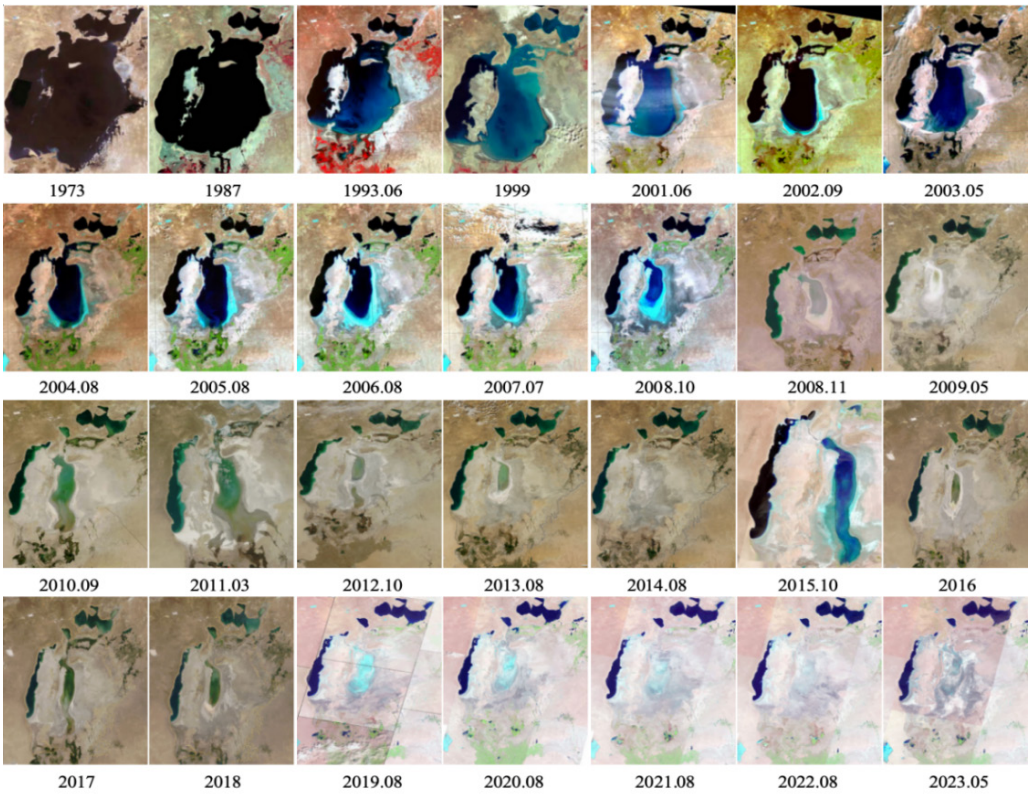
Although the hydrological decline of the Aral Sea and its socio-ecological impacts have been widely studied, we still lack a systematic, multi-level assessment of the governance constraints and the policy pathways discussed in the literature. This study therefore focuses on the Aral Sea governance system, examining the structural problems identified by scholars and the directions they propose for future action. Our aim is to synthesize this body of research to clarify the main barriers to effective governance and to highlight priority areas for strengthening regional cooperation.

Table 1. Surface water resources in the Aral Sea Basin (average annual runoff, km³/a)

Country	River Basin		Total	
	Amu Darya Basin	Syr Darya Basin	Average Annual Total Runoff	Percentage of Total Basin Volume
Kazakhstan	—	2.516	2.516	2.2
Kyrgyzstan	1.654	27.542	29.196	25.2
Tajikistan	58.732	1.005	59.737	51.5
Turkmenistan	1.405	—	1.405	1.2
Uzbekistan	6.791	5.562	12.353	10.6
Afghanistan and Iran	10.814	—	10.814	9.3
Total	79.396	36.625	116.021	100

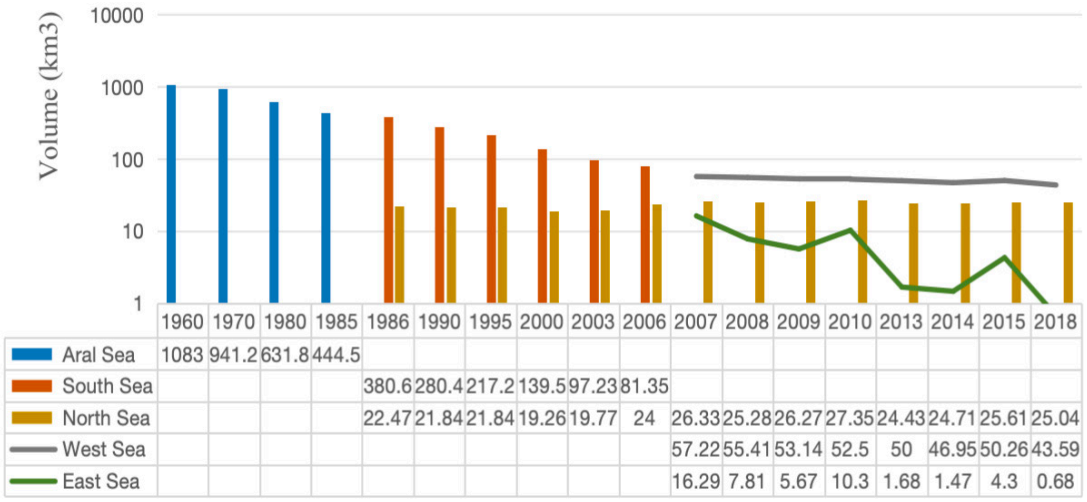
Source: *The table compiled by the authors*

Figure 1. Satellite imagery of the Aral Sea changes from 1973 to 2023



Source: *The figure compiled by the authors*

Figure 2. Changes in the volume of the Aral Sea from 1960 to 2018



	1960	1970	1980	1985	1986	1990	1995	2000	2003	2006	2007	2008	2009	2010	2013	2014	2015	2018
Aral Sea	1083	941.2	631.8	444.5														
South Sea					380.6	280.4	217.2	139.5	97.23	81.35								
North Sea					22.47	21.84	21.84	19.26	19.77	24	26.33	25.28	26.27	27.35	24.43	24.71	25.61	25.04
West Sea											57.22	55.41	53.14	52.5	50	46.95	50.26	43.59
East Sea											16.29	7.81	5.67	10.3	1.68	1.47	4.3	0.68

Source: *The figure compiled by the authors.*

To meet these objectives, the study pursues three tasks: (1) mapping the field's knowledge structure and thematic evolution through bibliometric visualization; (2) identifying governance obstacles across national, regional, and international levels using boundary and hierarchical analysis; and (3) synthesizing the governance strategies proposed in the literature and assessing their implications for future policy design.

Methodology

Using a multilingual set of publications from 1991 to 2024, this study first maps the research landscape of Aral Sea governance through CiteSpace-based bibliometric visualization and then identifies and structures governance problems using boundary analysis.

Data collection

We compiled a multilingual publication dataset on the Aral Sea crisis and its governance through systematic searches across multiple databases. All records were screened at the full-text level, and irrelevant items were excluded. The final dataset consists of 407 publications: 63 in Chinese, 247 in English, 88 in Russian, and 9 in Kazakh and Uzbek.

Chinese-language retrieval (CNKI; CQVIP). The search strategy targeted Chinese-language equivalents of "Aral Sea crisis" OR "Aral Sea governance", within the time window 1991-12-26 to 2024-12-31. Document types were limited to journal articles, theses/dissertations, and conference papers. After screening, 63 records were retained.

English-language retrieval (Web of Science; PQDT; JSTOR; EBSCO). The search query was: Topic/All fields = ("The Aral Sea Crisis" OR "Management of the Aral Sea" OR "Governance of the Aral Sea") AND Time = (1991–2024), with document types restricted to Article, Review Article, and Proceeding Paper. After screening, 247 records were retained. Because CiteSpace uses a Web of Science–compatible input standard and only the Web of Science Core Collection supports exporting full records in plain-text format, the Core Collection served as the primary source for bibliometric mapping. Records retrieved from PQDT, JSTOR, and EBSCO were treated as supplementary materials and manually imported into the CiteSpace input directory. After processing, CiteSpace successfully parsed 240 English-language records for visualization.

Russian-language retrieval (Google Scholar). The search query was: Content = ("Аральский кризис или управление Аральским морем") AND Time = (1991–2024). After screening, 88 records were retained.

Kazakh- and Uzbek-language retrieval (Google Scholar). Searches were conducted sequentially in Kazakh and Uzbek using the terms for "Aral Sea crisis" and "Aral Sea governance" (Kazakh: "Арал теңізі дағдарысы", "Арал теңізін басқару"; Uzbek: "Orol dengizi inqirozi", "Orol dengizini boshqarish"). After screening, 9 records were retained.

Bibliometric mapping (English-language subset)

Bibliometric visualization was conducted on the English-language subset (see Appendix A) using CiteSpace 6.3.R1. Parameter settings were: Time Slicing = 1991–2024, Years Per Slice = 1, g-index (k = 25), Top N = 50, with network pruning via Pathfinder and Pruning sliced networks. Visual outputs were generated for institutions, countries, and keywords, producing an institutional collaboration network, a keyword co-occurrence map, and a burst-term table (burst detection parameter γ = 0.6). To improve readability, single-occurrence nodes (frequency = 1) were suppressed in the institutional and keyword maps.

Problem synthesis

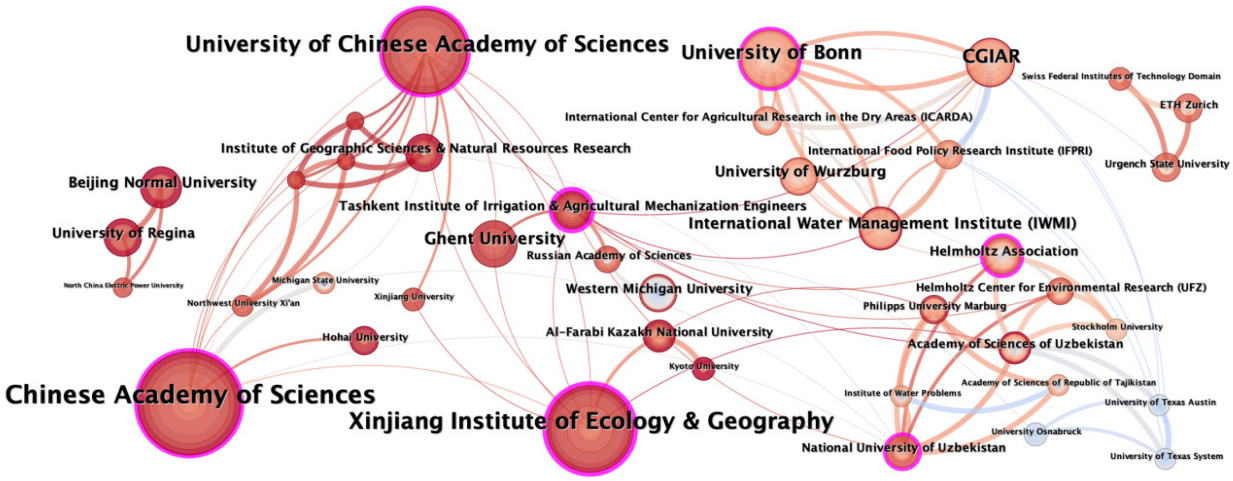
To synthesize governance constraints systematically, all 407 publications were reviewed individually. Governance-related issues were extracted and consolidated into 27 distinct problems. A problem saturation curve was then constructed by relating the cumulative number of problems identified to the number of studies reviewed. The 27 problems were subsequently coded and grouped hierarchically into individual, national, regional, and international-system levels. Finally, we calculated and ranked how often each problem was mentioned across the dataset, showing where constraints concentrate and how these concentrations contribute to governance fragmentation.

Visual Analysis of Research Status

The visual analysis based on CiteSpace illustrates the structural characteristics of global scholarship on Aral Sea governance and highlights evolving research patterns across institutions, countries, and thematic domains.

As shown in Figure 3, three major collaboration clusters can be observed: one anchored by the University of the Chinese Academy of Sciences and the Xinjiang Institute of Ecology and Geography; a second cluster linking the University of Bonn, CGIAR, and the International Water Management Institute; and a third cluster connecting the Helmholtz Association with Uzbek scientific institutions, pointing to sustained European engagement in Central Asian ecological and water-related research.

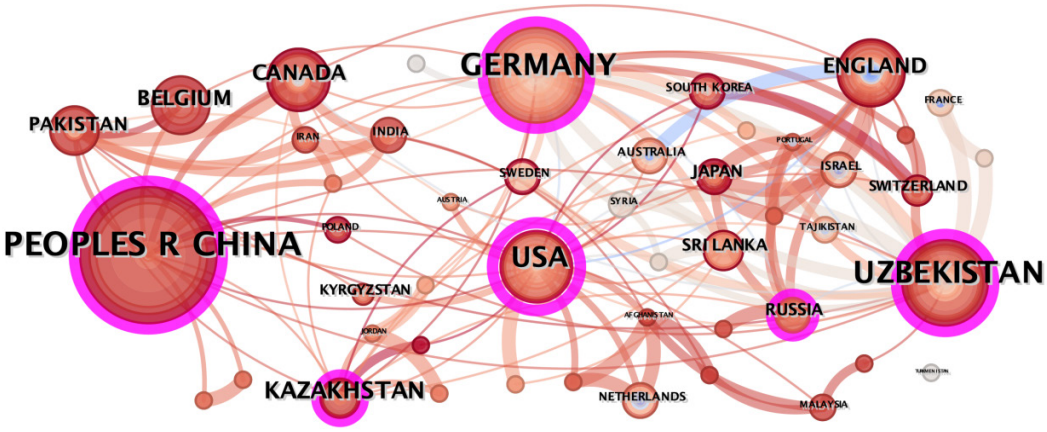
Figure 3. Cooperation network of international research institutions



Source: *The figure compiled by the authors*

As shown in Figure 4, China, Uzbekistan, Germany, the United States, and Kazakhstan stand out as the principal hubs in the English-language literature on the Aral Sea. Uzbekistan, Germany, the United States, and China exhibit relatively high centrality and are linked to partners in Kazakhstan, Russia, the United Kingdom, India, Japan, etc., pointing to a broadly cross-border pattern of collaboration. By comparison, China–Russia co-authorship ties appear thinner, which may reflect both database language coverage and differing research traditions, with Russian scholarship more strongly oriented toward multidisciplinary hydrological and ecological monitoring.

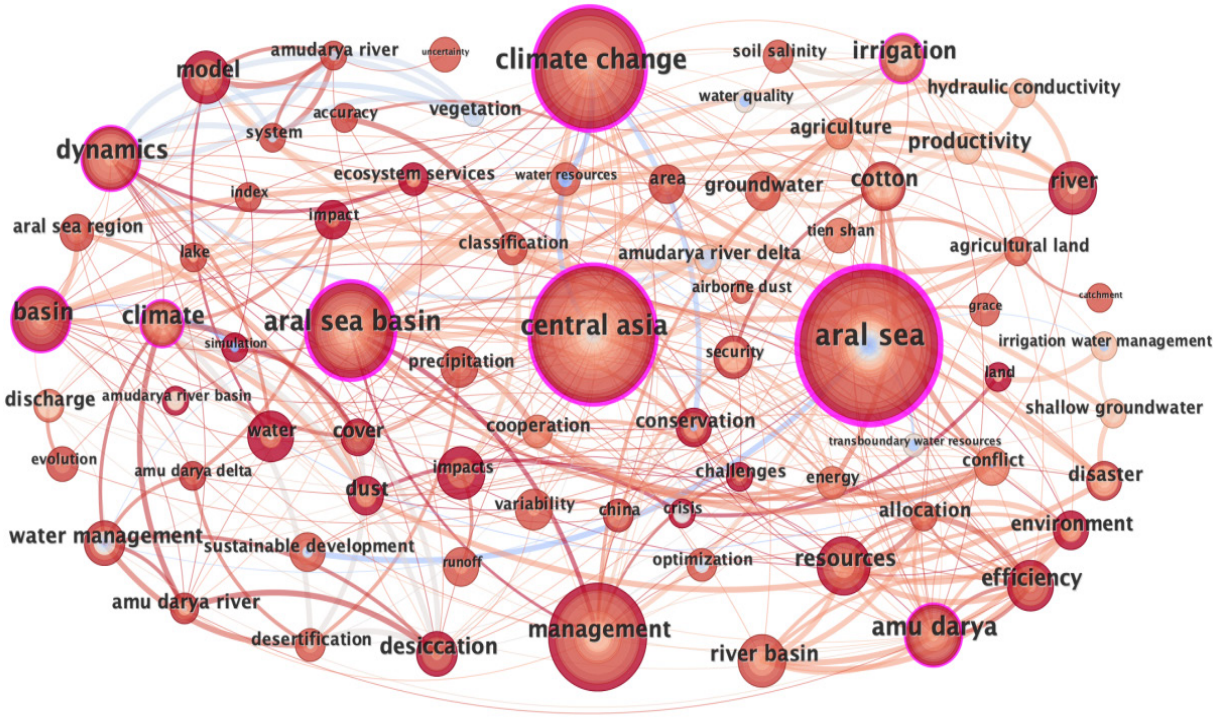
Figure 4. Distribution of countries publishing in international journals



Source: *The figure compiled by the authors*

As shown in Figure 5, international keyword clustering suggests that climate change and ecological management serve as prominent organizing themes. Within this thematic structure, the literature pays close attention to the combined impacts of climate change and human activities on the Aral Sea, hydrological dynamics and evaluations of water-use efficiency, water-management approaches across the five Central Asian states, and ecological restoration strategies.

Figure 5. Co-occurrence map of keywords internationally



Source: *The figure compiled by the authors*

As shown in Table 2, burst-term analysis captures shifts in scholarly attention over time. Newly emerging terms (including "dynamics," "precipitation," and "impacts") are consistent with growing interest in integrated climate–hydrology assessments and a stronger tendency to discuss the broader security implications of water scarcity. Meanwhile, longer-lasting bursts (e.g., "cotton" and "water management") indicate sustained attention to the irrigation legacy and the governance challenges associated with it.

Table 2. Top 9 keywords with the strongest citation bursts internationally

Keywords	Strength	Duration	1991-2024
water management	2.71	2003-2007	
cotton	3.09	2011-2016	
security	2.93	2014-2015	
conflict	2.59	2017-2019	
cooperation	2.19	2017-2019	
tien shan	2.35	2018-2019	
dynamics	2.48	2019-2020	
precipitation	2.23	2019-2022	
impacts	2.69	2021-2024	

Source: *The table compiled by the authors*

The visualizations indicate that research on Aral Sea governance has broadened institutionally and become more internationally networked. They also show a growing tendency to treat the crisis through an integrated lens that connects ecological degradation, climatic stressors, and fragmented governance. While these patterns do not in themselves prescribe solutions, they delineate the field's contours and provide a clearer starting point for identifying where structural constraints cluster and how regional cooperation might be assessed and strengthened.

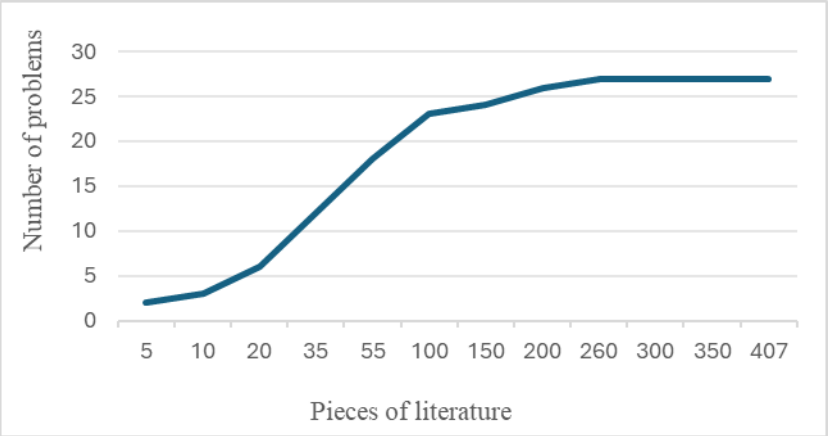
Problems in Aral Sea Governance Under Boundary Analysis

Through reviewing 407 pieces of literature individually, this study compiled 27 specific problems. Based on the number of problems discovered and the literature reviewed, we drew a problem saturation curve for the problems existing in the process of Central Asian countries' governance of the Aral Sea crisis (Figure 6). Based on this, these specific problems were further classified hierarchically (Figure 7), and the frequency of problems mentioned in the literature was ranked (Table A.1). The results show that approximately 65% belong to regional-level problems, 24% to national-level problems, 8% to individual-level problems, and 3% to international system-level problems.

Regional-Level Problems

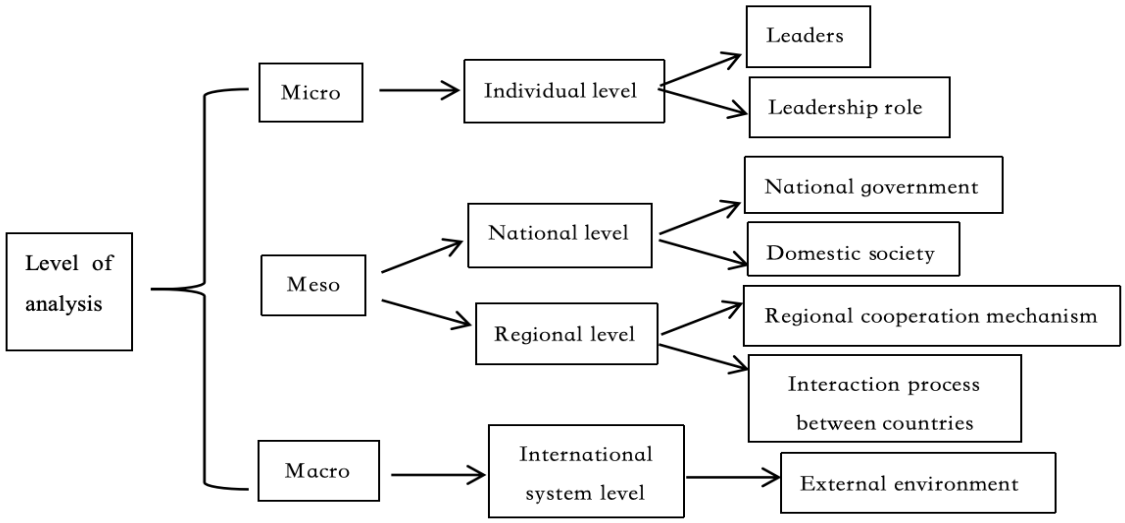
In Aral Sea governance, regional-level problems are recognized as the central bottleneck, which can be divided into four dimensions: First, water rights problems are often identified as a foundational constraint on governance, severely affecting the rational allocation and utilization of water resources; Second, current cooperation mechanisms have obvious deficiencies or operate inefficiently, making it difficult to meet actual governance needs; Third, significant differences and contradictions exist among the five countries, increasing coordination difficulties; Fourth, most agreements and laws have failed to be effectively implemented, making it difficult for governance to achieve practical results.

Figure 6. Problem saturation curve of Aral Sea governance



Source: *The figure compiled by the authors*

Figure 7. Levels of analysis of the Aral Sea governance problems



Source: *The figure compiled by the authors*

Uneven Water Allocation and Unsettled Water Rights

A persistent distributional imbalance across the basin sits at the center of the Aral Sea crisis (Turner, 2003: 55). In the Soviet era, seasonal water releases were effectively coordinated through a centrally managed water-energy bargain between upstream and downstream republics. After the Soviet Union dissolved, the basin-wide coordination embedded in the water–energy exchange largely unraveled. Although the 1992 Almaty Agreement formally preserved Soviet-era water allocation quotas (often described as a continuation of the principle that water-rich upstream states used proportionally less water) these arrangements failed to establish clearly defined and mutually accepted water rights (Min, 2022: 64). As a result, regional actors entered a condition of nominal consensus combined with persistent practical confrontation (Guo et al., 2022: 18). At the same time, national economic priorities diverged: downstream countries continued to prioritize irrigation-based agricultural production, while upstream countries increasingly sought to utilize water resources for hydropower development. The breakdown of the former energy compensation mechanism intensified water–energy imbalances,

bringing supply–demand contradictions to the forefront and triggering recurrent disputes across the basin.

Mismatch Between Governance Needs and Regional Cooperation Mechanisms

A substantial gap exists between the complexity of Aral Sea governance challenges and the institutional capacity of existing regional cooperation mechanisms. First, many agreements concluded among Central Asian states rely heavily on broad and principle-oriented provisions regarding cooperation obligations and implementation pathways, limiting their operational effectiveness (Wang et al., 2022: 70). As a result, these agreements often lack problem orientation and fail to generate substantive governance outcomes.

Second, basin-wide management institutions remain weak, with unclear functional mandates and fragmented divisions of responsibility, leading to low operational efficiency. In particular, the International Fund for Saving the Aral Sea (IFAS) has been widely criticized for its largely formal authority and insufficient institutional reform (Janusz-Pawletta, 2015: 895). Third, key supporting mechanisms are underdeveloped, including transparent information-sharing systems (Li et al., 2018: 99), effective monitoring and sanction mechanisms (Weinthal, 2000: 295–311), incentive structures to promote compliance, credible dispute resolution procedures (Vinogradov et al., 2001: 353), and sustained coordination platforms (Severskiy, 2004: 353). Finally, key legal areas – most notably groundwater governance, rules for transboundary allocation, and agreed limits on water use – remain underdeveloped, leaving the basin without a coherent legal architecture for collective action on the Aral Sea crisis (Rakhmatullaev et al., 2012: 67–80).

Divergent Interests and Uneven Governance Capacity

Cross-state differences among the five Central Asian countries add another layer of difficulty to regional governance. First, low levels of political trust and enduring suspicions make it hard to sustain stable coalitions for cooperation (Kamalov, 2009: 367–369). Second, priorities around water use, energy security, and development diverge sharply, so states often pursue different policy objectives rather than a shared basin-wide agenda (Yu et al., 2019: 10). Third, willingness to participate and administrative capacity vary substantially across countries, which translates into uneven implementation and inconsistent outcomes on the ground (Hao, 2021: 65).

Within the existing literature, Kazakhstan is frequently identified as the most proactive actor in Aral Sea governance. Due to its geographical position in the northern Aral Sea and its relatively stronger fiscal capacity, Kazakhstan faces more immediate ecological impacts and possesses greater resources to support governance initiatives. Consequently, it has emerged as a central participant and an important driver of water resource management reforms in the basin. In contrast, other Central Asian states have undertaken more limited actions and contributed comparatively fewer resources to addressing the crisis (Yang et al., 2024: 181–184).

Weak Implementation of Agreements and International Water Law

The limited effectiveness of regional governance is further reflected in the persistent gap between treaty commitments and practical implementation. Many agreements signed since independence lack enforceability and binding force, resulting in weak compliance and continued disputes over water allocation (Isaynov et al., 2013: 95). Moreover, international water law has not been uniformly adopted or effectively applied across the region.

Although Kazakhstan, Uzbekistan, and Turkmenistan have acceded to the Convention on the Protection and Use of Transboundary Watercourses and International Lakes, and Kazakhstan and Uzbekistan have joined the Convention on the Law of the Non-Navigational Uses of International Watercourses, other Central Asian states remain outside these frameworks. Divergent interpretations of international water law and differing national positions have prevented the establishment of a shared normative foundation for transboundary river governance. As a result, the region continues to lack universally recognized guiding principles capable of structuring stable, predictable, and effective cooperation.

National-Level Problems

At the national level, governance constraints primarily stem from political–institutional structures and socio-economic limitations within Central Asian states. In terms of state governance, most Central Asian countries exhibit highly centralized and authoritarian political systems. The excessive concentration of political power increases the risk of unequal resource allocation and rent-seeking behavior, which undermines effective environmental

governance (Borishpolets, 2010: 32). In the context of Aral Sea governance, public funds and resources intended for ecological restoration are often diverted to satisfy specific interest groups rather than addressing the core environmental challenges. Empirical studies indicate that corruption and misappropriation of project funds (such as the redirection of resources to non-affected regions or affiliated enterprises through fictitious contracts) have significantly reduced the effectiveness of governance initiatives (Glanz et al., 2014: 153). In addition, the economic structures of Central Asian countries have remained heavily dependent on cotton cultivation and other irrigation-intensive agricultural activities since the dissolution of the Soviet Union. This path-dependent development model has weakened economic resilience and constrained fiscal capacity. Even Kazakhstan and Uzbekistan, which possess relatively stronger economic foundations among the five states, face substantial financial limitations that restrict their ability to implement large-scale and sustained interventions to mitigate the ongoing shrinkage of the Aral Sea (Ablekim et al., 2019: 16).

From the perspective of domestic society, public engagement in Aral Sea governance remains limited. Existing research suggests a general lack of sustained attention and participation by local communities and social organizations (Hirsch et al., 2010). While public awareness of the severity of the Aral Sea crisis has increased at a superficial level, this awareness has not translated into active participation or collective action. This disjunction between cognition and practice reflects a broader pattern of participation inertia, in which individuals fail to perceive their own responsibilities and agency in addressing environmental problems. As a result, the Aral Sea crisis has struggled to evolve into a socially mobilizing public issue. Furthermore, the widespread deterioration and aging of hydrological infrastructure significantly constrain governance capacity (Migranyan, 2024: 104–124). Inadequate monitoring facilities and outdated technical equipment impede accurate assessment of ecological conditions and delay policy adjustments. Shortages of professional expertise, insufficient technical training, and weak administrative execution capabilities further exacerbate national-level governance challenges.

Individual-Level Problems

At the individual level, governance outcomes are strongly shaped by how political leaders set priorities and weigh competing goals. Since independence, most Central Asian states have consolidated presidential systems in which agenda-setting and key policy powers are concentrated in the executive. Where checks on executive authority are weak, policy practice tends to reflect leaders' preferences rather than stable, rule-based constraints – so institutions are more often molded by power than used to constrain it (Liang, 2022: 36).

This governance structure has two recurring consequences. First, nationalist narratives among political elites can harden bargaining positions (Shi, 2009: 29), pushing decision-makers to prioritize narrowly defined national or ethnic interests over basin-wide ecological needs and the legitimate claims of neighboring states. Second, short-term economic considerations can displace long-horizon ecological strategies that require sustained commitment and yield benefits only gradually, encouraging a reactive approach to the Aral Sea crisis. Some officials have even questioned whether preserving the Sea is worthwhile, arguing that allocating water to irrigated agriculture delivers quicker economic returns (Glanz et al., 2014: 153).

International System-Level Problems

At the international system level, governance of the Aral Sea is shaped and often constrained by Central Asia's broader geopolitical and security environment. Since the dissolution f the Soviet Union, major powers, including the United States and Russia, have sought to expand their regional influence through diplomatic engagement, economic and technical assistance, and strategic communication. Such competitive dynamics have contributed to the securitization of transboundary water issues, recasting water allocation and basin management as questions of national and regional security rather than shared environmental governance. As a result, basin-wide integration and multi-level cooperation have been weakened (Li et al., 2018: 103). In addition, a volatile regional security context can further crowd out sustained attention and resources for long-term environmental cooperation, increasing uncertainty and transaction costs for coordinated action on the Aral Sea crisis.

Constraints and Pathways

Aral Sea governance faces a set of persistent constraints as well as a growing, but still contested, range of governance pathways.

Problem Synthesis

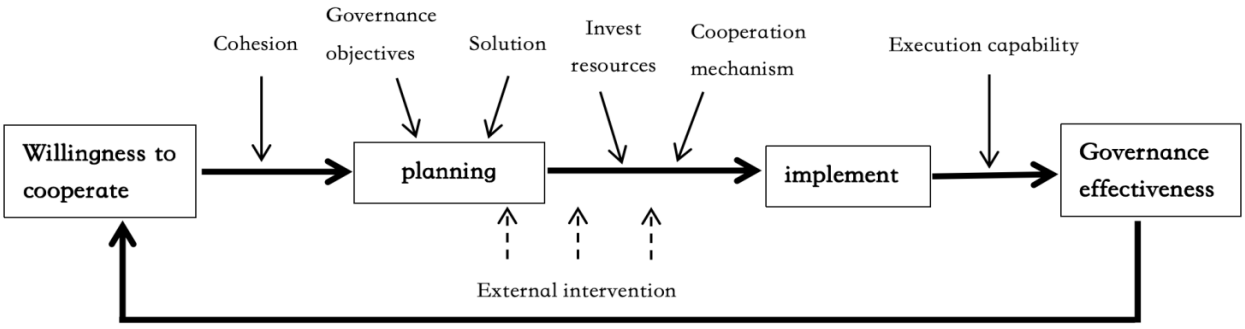
Aral Sea governance is not something any single state can address on its own. As a transboundary environmental challenge, it is hindered by persistent

coordination gaps and uneven cooperation among the five Central Asian countries.

First, effective governance requires a shared diagnosis of regional environmental risks and sustained political commitment to cooperation. Enhancing mutual understanding and political trust is a prerequisite for building collective action capacity. Second, countries need to articulate common governance objectives and establish coherent policy pathways, supported by adequate resource inputs (including finance, technology, expertise, and infrastructure) and functional cooperation mechanisms such as information-sharing, coordination, incentives, and compliance frameworks. Third, effective implementation depends on an integrated governance structure combining top-down state coordination with bottom-up participation by local communities, enterprises, civil society, and international organizations. Governance outcomes should, in turn, feed back into policy learning and strategic adjustment. Throughout this process, external actors continue to exert significant influence on regional governance dynamics (Figure 8).

In sum, weak regional cooperation remains the primary constraint on effective Aral Sea governance. Existing work attributes governance shortfalls to four interrelated factors: limited political commitment and cohesion; fragmented planning and competing objectives; gaps in institutional arrangements and resource support; and weak implementation and enforcement of existing agreements. Taken together, these dynamics generate a vicious circle that continues to constrain governance effectiveness.

Figure 8. Path map of factors affecting regional environmental governance effectiveness



Source: *The figure compiled by the authors*

Governance pathways

Current governance strategies generally follow two complementary pathways: mitigation and adaptation.

Mitigation

Mitigation strategies primarily emphasize ecological restoration and the deceleration of the Aral Sea's shrinkage. The literature identifies two mutually reinforcing approaches: top-down coordinated governance and bottom-up polycentric collaboration.

From a top-down perspective, differences in resource endowments and vulnerability levels necessitate differentiated responsibilities. Kazakhstan and Uzbekistan, given their relatively stronger capacities and higher exposure, are expected to assume greater responsibility for supplying regional environmental public goods, while other states contribute through coordinated support. Priority actions include basin-wide assessments of existing policies and ecological risks (particularly climate change) to identify governance gaps and coordination bottlenecks (Prniyazova et al., 2024: 44). On this basis, comprehensive and context-specific restoration programs should be developed, guided by principles of ecological suitability, water balance, and integrated land–water management (He et al., 2021: 136). Strengthening institutional capacity is essential, including enhancing the authority and effectiveness of ICWC and IFAS, clarifying institutional mandates through supplementary legal instruments, and deploying modern hydrological monitoring and data systems in key river basins.

Complementing this approach, bottom-up and outside-in polycentric governance seeks to address

the fundamentally human-induced nature of the Aral Sea crisis. This requires activating local ecological awareness and participation through environmental education and community engagement (Berdimuratova, 1999: 128-139), while decentralizing governance authority to empower local governments. Local actors are better positioned to design and implement context-sensitive measures aligned with on-the-ground realities. At the same time, international organizations and external partners should be encouraged to participate through embedded and equal cooperation, rather than hierarchical intervention, thereby enhancing resource mobilization and policy innovation.

Adaptation

Adaptation strategies focus on mitigating the socio-economic, political, and human security impacts of the Aral Sea crisis. Politically, ecological degradation has intensified tensions over transboundary water allocation and increased the risk of regional instability. Economically, declining water availability undermines agriculture, fisheries, and livelihoods, exacerbating poverty and inequality. Socially, environmental degradation has generated population displacement and health risks, giving rise to new challenges associated with environmental migration.

In response, two priority adaptation pathways have emerged. The first centers on resolving focal water-related conflicts, particularly disputes over water allocation, energy compensation, and hydropower development. Effective resolution requires shared recognition of the public-good nature of transboundary water resources and basin ecosystems, alongside the dual attributes of water as both a livelihood necessity and an economic commodity. Establishing unified regional water governance frameworks that integrate scientifically grounded allocation rules with market-based water-energy exchange mechanisms can help mitigate persistent coordination dilemmas. These arrangements should be accompanied by broader institutional reforms and supported by international organizations and external partners capable of providing financial, technical, and policy assistance.

The second pathway prioritizes safeguarding livelihoods and promoting sustainable development. Immediate efforts should focus on improving public health systems, livelihood protection, and disaster preparedness in affected areas (Wu et al., 2023: 925), with particular attention to vulnerable groups such as women and children. In the longer term, adaptation requires transforming regional development models by improving water-use efficiency, modernizing irrigation infrastructure, promoting crop diversification, and fostering emerging industries. Reducing excessive dependence on irrigation-intensive agriculture and resource-based sectors is essential for enhancing economic resilience and long-term adaptive capacity.

Results and discussion

This section situates the study's main findings within broader debates on environmental governance and clarifies their implications for future research and policy.

Based on a systematic review and bibliometric analysis, this study finds that existing scholarship has developed a solid understanding of Aral Sea governance at the national and regional levels, with particular attention to governance motivations, institutional arrangements, policy instruments, and implementation constraints across the five Central Asian states. However, the dominance of national and regional lenses also means that the field remains largely state-centric and regionally bounded, which limits its ability to capture the crisis's multi-layered governance complexity. Consequently, the absence of an integrated multi-level analytical framework has constrained more systematic accounts of how global norms, international actors, and transboundary environmental regimes interact with regional institutions and domestic policies.

At the same time, the frequent conflation of Aral Sea governance with broader Central Asian water management highlights the need for more problem-specific analysis. Regional water governance is an essential backdrop, but overly general framings can blur what is distinctive about the Aral Sea case – its acute ecological sensitivity, the legacy of Soviet-era irrigation, and the particular configuration of cross-border governance constraints. Relatedly, the crisis is not well captured by political or institutional accounts alone. It is produced through the interaction of ecological change, climatic variability, socio-economic restructuring, and historical path dependence, which points to the value of more systematic interdisciplinary integration.

Debates over future governance pathways place institutional design and political feasibility at the center of the discussion. Calls for supranational arrangements reflect awareness of deep-seated constraints – unequal allocation patterns, contested

rights and responsibilities, and weak coordination, but their prospects are often limited by sovereignty sensitivities and domestic incentive structures. In this regard, more flexible arrangements (such as regional water-energy alliances) may offer a pragmatic alternative, balancing coordination needs with political realities. Overall, advancing research on Aral Sea governance requires a shift toward multi-level, interdisciplinary, and problem-specific approaches, alongside renewed attention to institutional innovation, to enhance both analytical rigor and policy relevance.

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