Intergovernmental Cooperation Networks in Arid Region Watershed Governance (Postprint)

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Abstract

As the frequent emergence of cross-domain public affairs poses new challenges to government governance structures and their governance capacity, constructing cross-domain intergovernmental cooperation has gradually become an inevitable choice for addressing public issues such as watershed governance. Existing research primarily focuses on intergovernmental cooperation in watersheds of humid regions, with relatively scarce studies on watershed governance in arid regions. This study takes the intergovernmental cooperation network in the governance of the Kashi River Basin in southern Xinjiang as its research object, employs social network analysis methods, and examines both the phase networks and the overall network of the basin during the 5-year period from 2018 to 2022, aiming to clarify the evolutionary logic, holistic characteristics, and underlying logic of the intergovernmental cooperation network structure in the Kashi River Basin. The results indicate: (1) The governance of the Kashi River Basin has formed a relatively stable multi-actor intergovernmental cooperation network. Watershed governance is gradually exhibiting a trend of pluralistic coordination, with cooperation among water-related departments continuously deepening and departments such as the Ecology and Environment Bureau gradually being incorporated into the intergovernmental cooperation framework. (2) The governance of the Kashi River Basin exhibits a "core-periphery" intergovernmental cooperation network structure. Watershed governance remains centered on watershed management agencies and water resources departments as core actors, which drive multi-departmental collaborative actions through horizontal radiation. (3) Vertical authority shapes the intergovernmental cooperation structure of the Kashi River Basin. It promotes local governments in the basin to overcome institutional inertia and departmental fragmentation, thereby facilitating the effective implementation of cross-departmental cooperation.

Full Text

Preamble

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Intergovernmental Cooperation Networks in Watershed Management of Arid Regions

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Abstract: The increasing prevalence of cross-domain public affairs presents new challenges to government structures and governance capacity, making cross-domain intergovernmental cooperation an essential strategy for addressing public issues such as watershed management. While existing research has primarily focused on intergovernmental cooperation in humid region watersheds, studies on watershed governance in arid regions remain scarce. This study examines the intergovernmental cooperation network in the Kashgar River Basin of southern Xinjiang, employing social network analysis to investigate both the phased and overall network structures of the basin from 2018 to 2022. The analysis clarifies the evolutionary logic, overall characteristics, and underlying structural dynamics of the Kashgar River Basin' s intergovernmental cooperation network. The findings reveal three key patterns: (1) A stable multi-agent intergovernmental cooperation network has formed in the Kashgar River Basin, characterized by deepening cooperation among local governments and an emerging trend toward multi-actor, multi-channel coordination. (2) The governance structure exhibits a "core-periphery" configuration, with watershed management institutions and water conservancy departments occupying central positions that drive multisectoral coordinated actions through horizontal collaboration, while other actors maintain a degree of dependency within this framework. (3) Vertical power dynamics fundamentally shape the intergovernmental cooperation structure, as political authority from higher-level governments helps overcome institutional inertia and departmental fragmentation, thereby facilitating effective cross-sectoral and cross-regional cooperation.

Keywords: arid regions; watershed management; intergovernmental cooperation network; social network approach

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Introduction

As urbanization and informatization accelerate the flow of resources and intensify cross-boundary environmental problems, traditional territorial management models struggle to meet the demands of modern environmental governance systems due to factors such as pollution externalities. How to break down departmental silos under hierarchical bureaucratic structures, strengthen inter-agency collaboration, and improve cross-sectoral governance performance has become

a critical issue in contemporary public administration reform worldwide. Intergovernmental cooperation is widely recognized as an important strategy for overcoming administrative fragmentation and addressing cross-boundary environmental challenges [**?**, **?**].

Xinjiang, located in China' s arid region, faces fundamental water scarcity as a defining geographic characteristic. With population growth and socioeconomic development, water demand continues to rise, leading to frequent problems including water resource shortages, water ecological degradation [**?**], and supply-demand contradictions [**?**]. These challenges necessitate establishing an intergovernmental cooperation governance model to address environmental public issues. Watershed governance essentially represents an organized collective action in which relevant governance entities cooperate organically across different levels to achieve watershed protection and sustainable development. Consequently, watershed governance must prioritize cooperation among local governments in organizational structure, mechanism establishment, and institutional design [**?**].

From a structural analysis perspective, watershed intergovernmental cooperation is viewed as an organized collective governance action. However, during the collective action process, factors such as interest expression mechanisms [**?**], vertical intervention [**?**], and policy incentives influence cooperation establishment. To effectively resolve fragmentation in watershed governance, governments attempt to integrate instrumental rationality and value rationality through vertical authority intervention and horizontal coordination mechanisms, employing project-based and campaign-style governance approaches to construct watershed governance structures [**?**]. Horizontal collaboration mechanisms in watershed governance are primarily studied through transaction cost theory, which identifies reduced transaction costs, risk avoidance, and cooperative benefits as key motivations for forming horizontal collaborative relationships [**?**]. Meanwhile, political authority, economic disparities, and environmental policies also constitute driving forces for cross-domain cooperation mechanisms, thereby building intergovernmental horizontal collaboration networks and forming synergistic governance pathways that enhance overall watershed management [**?**].

In addition to horizontal collaboration mechanisms, vertical intervention is equally indispensable in watershed governance. Central and higher-level governments primarily promote intergovernmental horizontal collaboration through two intervention mechanisms—vertical authority and horizontal radiation—thereby facilitating the formation and development of watershed intergovernmental cooperation [**?**]. From a meta-governance perspective, central and higher-level governments guide the self-organizing nature of local government cooperation in watershed management through three types of vertical intervention: authority-based, incentive-based, and information-based approaches [**?**].

Extensive research demonstrates that collaborative governance institutions show strong advantages in overcoming collective action dilemmas in common-pool resources. Scholars have noted that unidirectional or bidirectional connections

among actors constitute dyadic relationships, and multiple actors with such relationships form social networks comprising a series of participants, thereby creating cooperative governance structures [**?**]. Intergovernmental cooperation networks represent dependency-based cooperative relationship structures formed among local governments or between local governments and other participants to reduce potential risks. Interdependence constitutes the core essence and conceptual foundation of intergovernmental cooperation networks, with intergovernmental cooperation entities serving as actors within these networks. Network structure depicts the dynamic structural relationships among participants and their characteristics as resources, information, and knowledge flow through the network [**?**]. The positions and relationships of intergovernmental cooperation actors within the network determine its structural features, which in turn significantly influence actor behaviors and produce different governance outcomes. Therefore, given the increasingly interconnected nature of public affairs, multi-dimensional in-depth examination of intergovernmental cooperation from a governance practice perspective is necessary to investigate current network structures, formation processes, and outcomes of regional environmental governance cooperation.

1.1 Research Area Overview

The Kashgar River Basin is located in southern Xinjiang, characterized by complex terrain and water systems that span across Kashgar Prefecture, Kizilsu Kirghiz Autonomous Prefecture (referred to as Kezhou), and the Third Division of the Xinjiang Production and Construction Corps (XPCC). It represents a typical cross-boundary river basin. The basin region primarily comprises counties and cities focused on agriculture, including the border reclamation and defense units of the XPCC. Due to its location in an arid region, the Kashgar River Basin exhibits insufficient water resource endowment and scarcity.

1.2 Research Methods

Social network analysis originated from French sociologist Émile Durkheim' s structural-functional theoretical framework [**?**]. Unlike conventional quantitative or qualitative methods, social network analysis can visually present cooperation network structures and inter-actor relationships through graphical representations, clearly depicting structural characteristics and providing valuable insights for understanding intergovernmental relationships in cross-domain watershed governance and how these relationships influence management outcomes.

This study employs UCINET social network analysis software to examine the evolutionary process and logic of intergovernmental cooperation governance structures in the Kashgar River Basin over the past five years (2018–2022), analyzing the structural features of the overall cooperation network and collaborative relationships among actors. The research aims to achieve two objectives:

First, to visualize the phased and overall networks of intergovernmental cooperation in the Kashgar River Basin; Second, to empirically investigate the dynamic evolution and overall structural characteristics of the cooperation network, and further analyze how actors within the network influence governance resources, information, and decision-making.

1.3 Data Sources and Processing

Existing academic literature lacks comprehensive social network analysis of watershed intergovernmental cooperation governance, with insufficient detailed analysis of network structural characteristics and inter-actor collaborative relationships, particularly regarding watershed intergovernmental cooperation in arid regions. To address this gap, this study employs social network analysis to examine the intergovernmental cooperation network formed by the Xinjiang Uygur Autonomous Region government and Kashgar River Basin local governments, analyzing the network's evolutionary logic, overall structure, and internal characteristics.

For data collection, this study focuses on intergovernmental relationships in Kashgar River Basin governance, identifying the Xinjiang Uygur Autonomous Region government, Kashgar Prefecture government, Kezhou government, XPCC Third Division, and relevant county-level governments as network actors. Intergovernmental cooperation relationships measure the relational attributes of specific cooperative actions among basin governments, with data collection and screening based on cooperative behaviors among actors. The data collection period spans 2018–2022, drawing primarily from regulations, policies, and news updates regarding Kashgar River Basin governance published on official websites of the Xinjiang Uygur Autonomous Region Water Resources Department and local basin governments, with particular focus on intergovernmental cooperation documents. To ensure data reliability and validity, this study utilizes two data sources: First, official laws, regulations, policies, and news updates on watershed governance published on relevant government websites; Second, manually collected government documents related to watershed governance interactions. Due to the limited and incomplete content of policies published on government websites, manual collection constitutes the primary data source, mainly comprising meeting minutes compiled during field research. Collected documents were then consolidated and filtered to obtain final data suitable for measurement. Since cooperation is bidirectional, directionality was not considered in coding, yielding a relational matrix for intergovernmental cooperation in the Kashgar River Basin.

2 Results and Analysis

This study examines structural characteristics of intergovernmental cooperation governance in the Kashgar River Basin, analyzing both phased networks and the overall network to clarify the evolutionary logic, overall features, and underlying

structural dynamics of the basin' s intergovernmental cooperation network.

2.1 Dynamic Evolution of Intergovernmental Cooperation Network

Data were divided into five phases by year (2018–2022) to generate visual network maps of intergovernmental cooperation governance in the Kashgar River Basin. In these maps, nodes represent participating governments and functional departments at various levels, while connecting lines represent cooperative relationships among actors. Since China comprehensively implemented the River Chief System under central leadership, the Kashgar River Basin River Chief System Working Group has formulated comprehensive basin-wide remediation plans to further improve governance performance, with local governments at all levels forming multilateral, complex, interactive network structures that gradually establish stable intergovernmental cooperation governance frameworks.

Building upon visual network analysis, structural indicators were measured for each time period, yielding the results shown in Table . Network size represents the number of actors participating in the cooperation network in each phase, while network density indicates the closeness of cooperative relationships among actors. Network centralization reflects the centralization trend of the overall network, revealing its concentration degree. Specifically, network density is positively correlated with the closeness of actor relationships—higher density values indicate more sufficient cooperative relationships among actors, greater mutual influence, and stronger functions in transmitting, absorbing, and processing governance resources. Generally, closer relationships facilitate smoother information flow, greater resource support, and enhanced mutual collaboration [**?**].

Regarding network centralization, higher values reflect more concentrated network structures and indicate the presence of highly influential nodes, whereas lower values suggest more decentralized network structures. As shown in the network evolution diagrams and structural characteristic analysis tables, the network density of intergovernmental cooperation in the Kashgar River Basin has generally increased year by year from 2018 to 2022, reflecting increasingly frequent cooperative interactions among governance actors and indicating that intergovernmental cooperative governance relationships are developing toward greater stability. The evolution diagrams reveal that cooperative relationships in the Kashgar River Basin had already formed by 2018 and were further consolidated in 2019, with expanded network scale and more frequent cooperation. The Kashgar River Basin Administration played a leading and coordinating role, with prefecture-level water resources departments actively cooperating in governance efforts. During this period, the cooperation structure primarily featured "water resources departments as main actors, relevant departments as supplementary actors."

In 2020, intergovernmental cooperative relationships weakened noticeably compared to 2019, as local governments in the basin shifted attention toward public

health security. Consequently, network scale, density, and centralization indicators all fell below previous levels. However, in 2021, all indicators improved significantly, with the cooperation network restoring stable relationships and maturing continuously. Beyond water resources departments, cooperative relationships with other relevant departments gradually became more prominent. By 2022, the network exhibited the closest connections among actors, with watershed governance no longer dominated solely by water resources departments and cooperation among more functional departments being strengthened. The cooperation structure during this period featured "water resources department leadership with enhanced local cooperation."

Overall, the network centralization of Kashgar River Basin intergovernmental cooperation showed a declining trend, indicating that influence among network nodes began moving toward a more balanced state and the network' s centralization tendency moderated.

2.2 Overall Network Structure Characteristics

2.2.1 Overall Network Structure Overall network analysis provides a macro perspective for grasping watershed intergovernmental cooperation network characteristics. The 2018–2022 cooperative relationship network for Kashgar River Basin governance is shown in [Figure 1: see original paper]. Further calculation of overall network structural indicators provides more specific information, as presented in Table .

The overall intergovernmental cooperation network in the Kashgar River Basin comprises 35 governance actors with abundant connections. Frequent cooperative interactions have laid a foundation for building trust and reciprocity among local governments and facilitating smooth collective action in watershed governance. The overall network density value of 0.287 indicates good and stable cooperative relationships among governance actors. The network characteristic path length is 2.154, meaning that any two nodes can connect through an average of 2.154 intermediate nodes. Characteristic path length reflects the transmission distance of various resources within the network—shorter paths indicate smoother communication among nodes. The Kashgar River Basin intergovernmental cooperation network maintains a moderate characteristic path length, suggesting that governance actors face no significant difficulties in information exchange and resource sharing.

2.2.2 Centrality Analysis Centrality analysis constitutes a core component of social network analysis, reflecting actors' central positions within cooperation networks. From a social network theory perspective, centrally positioned nodes possess more governance resources and social capital, exerting greater influence that can directly or indirectly affect other actors' behaviors. To comprehensively analyze the Kashgar River Basin intergovernmental cooperation network characteristics, this study measures three centrality indicators: degree centrality, betweenness centrality, and closeness centrality.

Degree Centrality measures the closeness of connections between a node and other nodes. Higher degree centrality indicates a more central network position and more apparent influence and power attributes. Calculations reveal specific degree centrality values for each actor in the cooperation network from 2018 to 2022, as shown in [Figure 2: see original paper]a. Vertically, degree centrality indicators for most nodes show an upward trend year by year, indicating increasingly frequent cooperative interactions among governance actors. Horizontally, the Kashgar River Basin Administration, local governments in the basin, and their water resources departments exhibit significantly higher degree centrality than other watershed governance actors, demonstrating their central roles in intergovernmental cooperation governance. In 2018, degree centrality for functional departments other than water resources departments was markedly lower, presenting a water-resources-dominated pattern. By 2022, degree centrality for prefecture-level ecology and environment bureaus, natural resources bureaus, and agriculture and rural affairs bureaus increased noticeably, indicating their rising central positions and the formation of a multi-department collaborative network structure led by water resources departments.

Betweenness Centrality measures the intermediary role of network nodes. Nodes with high betweenness centrality can control and influence the flow of information resources by serving as intermediaries. Analysis results for betweenness centrality in the Kashgar River Basin intergovernmental cooperation network from 2018 to 2022 are presented in [Figure 2: see original paper]b. In 2018, the Kashgar River Basin Administration exhibited the strongest influence on other governance actors, followed by the Xinjiang Uygur Autonomous Region Water Resources Department. From 2019 onward, the betweenness centrality value of the Kashgar River Basin Administration gradually decreased, reflecting a declining centralization trend in the network. This indicates that highly influential nodes' control over information and resources gradually weakened, allowing all nodes to engage in more autonomous and equal cooperative governance, with Kashgar River Basin governance gradually aligning with its essential governance nature.

Closeness Centrality measures the proximity among network nodes and reflects actors' resource-sharing capabilities. Lower closeness centrality values indicate higher centrality, meaning the node is closer to other nodes with tighter connections and greater influence in information and power distribution. Based on closeness centrality analysis results for the Kashgar River Basin intergovernmental cooperation network from 2018 to 2022 ([Figure 2: see original paper]c), nodes with the lowest closeness centrality values (highest centrality) were consistently watershed management institutions and prefecture-level water resources departments, followed by prefecture-level governments and their functional departments. Notably, closeness centrality values for relevant functional departments in 2020 decreased compared to 2019, indicating that departmental influences gradually converged during Kashgar River Basin governance and a multi-centered governance network structure gradually formed.

By calculating centrality indicators for all actors in the Kashgar River Basin' s overall network from 2018 to 2022 and ranking them, the top 10 actors with high degree centrality, high betweenness centrality, and low closeness centrality were identified (Table). The results show that the Kashgar River Basin Administration and various water resources departments consistently occupy central positions in the cooperation network. These 10 government departments maintain the most cooperative relationships with other watershed governance actors, holding relatively central positions in the network and demonstrating strong initiative in cooperative actions. The Kashgar River Basin Administration plays an "intermediary" role in the cooperation network, serving as a bridge for most relationships and a crucial node for information transmission, coordinating interests and promoting cooperation.

2.2.3 Cohesive Subgroup Analysis Cohesive subgroups represent subsets of different nodes within cooperation networks. Cohesive subgroup analysis helps identify the number of substructures within cooperation networks and the relationship characteristics among subgroup members. Analyzing cohesive subgroups in the Kashgar River Basin cooperation network can visually reveal subgroup quantities and better understand subgroup structural states, quantitatively examining the network' s internal characteristics.

After conducting binary symmetric processing on collected sample data for Kashgar River Basin intergovernmental cooperation, UCINET software' s faction analysis was employed for cluster research (Table). The results indicate that in the 2018 network, the Kashgar River Basin Administration belonged to 4 subgroups as an important shared member, maintaining joint action relationships with different actors within subgroups. Xinjiang Uygur Autonomous Region government departments, Kashgar Prefecture Administrative Office, Kashgar Prefecture Forestry and Grassland Bureau, Kashgar Prefecture Agriculture and Rural Affairs Bureau, Kezhou government departments, and XPCC Third Division government departments (excluding water resources departments) did not belong to any faction in this network, remaining isolated nodes. In 2019, the network structure showed no significant changes, still reflecting a state dominated by watershed management institutions and water resources departments.

In the 2022 intergovernmental cooperation network, watershed management institutions and water resources departments occupied prominent core positions, while other governance actors remained at peripheral positions, with tight cooperative relationships yet to form among all watershed governance actors. Prefecture-level ecology and environment bureaus, agriculture and rural affairs bureaus, forestry and grassland bureaus, and other departments began appearing in some subgroups. In 2021, various ecology and environment bureaus and natural resources bureaus appeared in 2 subgroups, and by 2022, they appeared in 3 subgroups. Cohesive subgroup analysis results show that subgroup members gradually expanded from water resources departments to other relevant departments, with main cooperative forces gradually increasing and a multi-agent

watershed intergovernmental cooperation network taking shape.

Further analysis of the overall network's cohesive subgroups reveals that the network contains 11 subgroups, with [Figure 3: see original paper] illustrating the subgroup situation. In the diagram, square nodes represent formed subgroups, circular nodes represent actors participating in intergovernmental cooperation, and each actor points to its affiliated subgroup. Cohesive Subgroup 1 contains the most members (16 governance actors) and constitutes the core subgroup of the Kashgar River Basin intergovernmental cooperation governance network, including the Xinjiang Uygur Autonomous Region Water Resources Department, Kashgar River Basin Administration, Kashgar and Kezhou governments and their water resources and hydrology departments, as well as the XPCC Third Division. These are key members of watershed cooperative governance, leading and responsible for water resource protection, water ecological restoration, water pollution prevention, and other watershed management tasks, while conducting joint river patrols and inspections.

3 Conclusions

This study reveals three fundamental characteristics of intergovernmental cooperation in the Kashgar River Basin:

First, a stable multi-agent intergovernmental cooperation network has formed in the Kashgar River Basin governance. The dynamic evolution of this network demonstrates deepening cooperation among local governments, gradually forming a diversified, multi-channel collaborative network structure. The increasing network density reflects a trend toward greater stability, indicating that intergovernmental cooperation in the Kashgar River Basin has entered a more robust stage. Simultaneously, actors that previously held strong influence and control in the cooperation network have gradually equalized with other actors, enabling more equitable consultation and dialogue among governance entities and allowing the essence of governance to gradually re-emerge.

Second, the Kashgar River Basin governance exhibits a "core-periphery" intergovernmental cooperation network structure. In recent years, through the joint efforts of multiple departments, the governance framework has gradually incorporated ecology and environment bureaus and other relevant departments. Throughout its governance structure, watershed management institutions and water resources departments remain the core actors, driving coordinated actions among multiple departments through horizontal collaboration that creates ripple effects across peer regions and departments. Although other actors have entered the cooperative governance framework, they maintain a certain degree of "dependency" in cooperative relationships, resulting in an overall "core-periphery" distribution pattern under the integration of watershed management institutions.

Third, vertical power fundamentally shapes the intergovernmental cooperation structure in the Kashgar River Basin. Vertical authority serves as a key factor

in stimulating intergovernmental cooperation willingness, promoting implementation, and enhancing cooperation capacity, forming a dynamic logic 主线 (main thread) together with intergovernmental cooperation actors. Higher-level governments' vertical power primarily manifests as the transmission of political authority, which exerts significant promotional effects on public policy implementation and institutional advancement through hierarchical structures and top-down power operation [**?**]. This vertical power enables executive actors at all levels to overcome institutional inertia and departmental fragmentation, promoting effective concentration of cross-sectoral, cross-regional resources and successful intergovernmental cooperative governance.

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Note: Figure translations are in progress. See original paper for figures.