

Digital Technology Enabling Urban Agglomerations in the Yellow River Basin: Logic, Efficiency and Approach

Xuhan Chang

*Law School, Ocean University of China, Qingdao, China
chx23017@163.com*

Abstract. Digital technology has provided a new path for the ecological governance of the Yellow River Basin, which has achieved initial results, but there are still some problems, such as the fragmentation of governance basis caused by the lack of high-level laws, the coexistence of inconsistent horizontal data standards and vertical digital divide, and the lack of coordinated urban development, which seriously affect the effectiveness of the ecological governance of the Yellow River Basin enabled by digital technology. Therefore, it is necessary to build a legal system of "unified draft + difference appendix", establish a unified data collection and analysis platform, and strengthen urban digital collaboration, so as to strengthen the deep coupling between digital technology and Yellow River management, and provide support for ecological protection and high-quality development of the basin.

Keywords: digital technology, the Yellow River Basin, Ecological environment management

1. Introduction

In recent years, as an important issue of global sustainable development, the coordinated development of digitalization and greening has provided a new path and paradigm for ecological environment governance. The Yellow River is the mother river of the Chinese nation. Promoting the ecological environment protection and high-quality development of the Yellow River Basin is a major strategic plan for national development. The digital management of the ecological environment of the Yellow River Basin is also an important part of the digital management of beautiful China and green China. In this context, some regions try to introduce digital technology, reflecting the effectiveness and spatial spillover effect of artificial intelligence enabling ecological environment governance, for example, in the case of ecological restoration of the river beach in Zhongwei section of Ningxia, the procuratorial organ obtains topographic change data through laser radar scanning, and the joint water conservancy department estimates the loss rate of flood discharge capacity to 18%. 120000 square meters of hardened ground were demolished, 180000 alkali-resistant plants such as *Tamarix chinensis* and *Elaeagnus angustifolia* were replanted, soil organic matter content was restored from 0.6% to 1.8%, and bird population increased by 23% year on year. For another example, Qinghai has established an integrated monitoring system of "snow mountains, glaciers, rivers, lakes, wetlands and swamps", with 412 ecological sensors deployed, and the amount of carbon sequestration in the source areas of the three rivers will increase by 126,000 tons in 2024. Henan has implemented the system of "river length + chief procurator", with 187 joint river patrols

in 2024, and 43 problems hindering flood discharge have been solved. Shandong piloted "emission right mortgage loan", providing green credit of 1.14 billion yuan for 37 enterprises, and COD emissions decreased by 14.8% year on year [1]. Although many achievements have been made, there are still many urgent problems to be solved. For example, the legal system related to digitalization is imperfect, digital governance is "fragmented", and there is spatial heterogeneity in the level of digitalization in different areas of the basin. This paper focuses on the current situation of digital ecological governance in the Yellow River Basin, analyzes the logic and effectiveness of digital technology enabling ecological governance, and puts forward realistic and feasible countermeasures to realize the coupling development of urban agglomeration and ecological environment in the Yellow River Basin.

2. Realistic logic of digitalization of ecological protection in the Yellow River Basin

In the Digital Twin Yellow River Construction Plan (2022-2025), it is mentioned that we should comprehensively promote the modernization of data, algorithms and computing power, speed up the construction of digital twin Yellow River with the functions of forecasting, early warning, rehearsal and preplan, and provide digital scenarios and intelligent model support for the application of "2 + N" water conservancy intelligent business in the Yellow River Basin. Digitalization plays an important role in the ecological protection of the Yellow River Basin. Supporting the development of the Yellow River Basin with the continuous development and application of digital technology is an important strategic policy of the Yellow River Basin at present, and an important part in promoting the progress of governance mode, urban collaborative governance and the improvement of laws.

2.1. Active and integrated development of governance model driven by digital technology in the Yellow River Basin

The Yellow River Basin spans nine provinces and regions, covering multiple ecological types such as rivers, lakes, wetlands and mountainous areas, and has multi-dimensional data indicators. Because each data indicator is under the responsibility of different departments or institutions, the current basin management presents a pattern of "vertical classification, horizontal decentralization". Vertically, there is a hierarchical division of data management from the central to local administrative units at all levels; horizontally, data indicators belong to different departments and agencies. This decentralized management will directly lead to the fragmentation of data evaluation criteria, and the process of data conversion will significantly increase the cost [2]. In addition, the systematic contradiction between administrative division and natural river basin leads to the decentralization of governance subjects and serious information barriers, which have been passively responding to the changes of the ecological environment of the river basin for a long time. In this context, the application of digital twin technology, through the creation of digital twin Yellow River, reshapes the spatial logic of the Yellow River Basin governance, integrates the data of water conservancy, ecology and other fields, constructs a dynamic closed-loop mechanism of "perception-analysis-decision-feedback", and promotes the transformation of the traditional mode of ecological governance in the Yellow River Basin.

Historically, the Yellow River has become a disaster-prone, complex and difficult river because of its "good siltation, good decision and good migration". In the past, passive response was used as the strategy of harnessing the Yellow River, but passive harnessing obviously has high risks, and the intervention of digital technology has changed the Yellow River harnessing from passive to active. Digital twin system can collect key data such as hydrology, sediment and engineering safety in real

time through two-way real-time mapping of physical and virtual worlds, and its coupling multi-scale model can significantly improve the accuracy of data index prediction of the Yellow River, while 577 million tons of sediment were realized at Huayuankou during the drought and flood turning period of the Yellow River Basin in 2024. It also proves that digital technology can promote the transformation of the management mode of the Yellow River Basin to an active and forward-looking direction.

2.2. The application of digital technology in the Yellow River Basin promotes the coordinated development of cities

When presiding over a symposium on ecological protection and high-quality development of the Yellow River Basin in Zhengzhou, General Secretary pointed out: "The upstream and downstream, the main and tributaries, and the left and right banks should plan as a whole, jointly do a good job of protection, and coordinate the promotion of governance." [3] The emergence and application of digital technology provides an opportunity to solve the problems of administrative barriers, different information and data standards, scattered resources and difficult management among the provinces in the Yellow River Basin, which hinder the development of cities in the Yellow River Basin. The deep penetration of digital technology is providing new momentum for the coordinated development of cities in the basin and promoting the formation of a new pattern of integrated development by creating a unified data platform, optimizing the efficiency of resource allocation and innovating the mode of collaboration.

At the level of data collaboration, digital technology can break the shackles of "data island" and provide a platform for the horizontal free flow of information and data between cities. Through the construction of a unified data center platform, the data of provinces and regions in the basin are integrated, so as to achieve cross-regional joint monitoring and lay an objective foundation for collaborative decision-making. At the level of resource allocation, digital technology intelligently dispatches river basin resources and optimizes the allocation of resources among cities, thus enhancing the complementary effect of functions among cities. At the level of industrial synergy, digital technology accelerates the connectivity of industrial chains in the basin, relying on digital technology to analyze and identify the industrial advantages and shortcomings of cities, so as to build an industrial chain of "upstream R & D-midstream manufacturing-downstream services".

Digital technology promotes the coordination of cities in the Yellow River Basin, breaking the constraints of administrative barriers on resource allocation through the free flow of data elements, and making cities more closely linked. However, at present, the coordinated development of cities in the Yellow River Basin is still in its infancy, and it is still necessary to find a long-term mechanism to better transform the advantages of digital technology into development momentum.

2.3. The application of digital technology in the Yellow River Basin promotes the two-way integration of law and technology

The ecological protection and high-quality development of the Yellow River Basin is a nationwide undertaking, involving a wide range of diverse issues. If the rule of law is used to promote the ecological protection and high-quality development of the Yellow River Basin, it is necessary to implement legislation, justice and other aspects and the whole process [4]. With the development of the times and the maturity of digital technology, when digital technology is applied to environmental protection, it will inevitably have an impact on environment-related laws. Nowadays, the innovative practice of digital technology in river basin management constantly challenges the adjustment

boundary of traditional law and promotes the adaptive adjustment of provinces and regions along the Yellow River. The complexity of ecological protection and high-quality development in the Yellow River Basin not only challenges the adaptability of the legal system, but also provides a scenario for the innovative application of digital technology, which promotes the further integration of law and technology to better support the development of the basin.

3. Practical problems of ecological protection in digitalized enabling Yellow River Basin

The continuous development of digital technology has injected new momentum into the ecological protection of the Yellow River Basin and provided a strong impetus for the transformation of the governance mechanism of the Yellow River Basin, but its effectiveness has not been maximized. The Yellow River Basin is still facing many practical problems, which restrict the further development of the digitalization of the ecological governance of the Yellow River Basin, including the following dimensions:

3.1. Lack of relevant laws and policies to ensure the digitalization of ecological management of the Yellow River

The Law of the People's Republic of China on the Protection of the Yellow River sets out a principled framework for the overall planning and zoning management of the Yellow River Basin, which provides a certain basis for the legal status of digital means in river basin management. The Technical Regulations for Geographic Information Data of Digital Twin Water Conservancy Projects formulated by the Yellow River Water Conservancy Commission (hereinafter referred to as the "Yellow River Commission") unifies the standards of data acquisition and processing, and provides normative guidance for the application of technology [5]. However, the core problem facing the digitalization of ecological management in the Yellow River Basin is not the complete absence of laws, but the lack of high-level and stable macro-guiding laws. In practice, the promotion of digital governance mainly depends on normative documents, administrative regulations and policy documents, but these three have key problems that affect the long-term effectiveness of governance, such as changeability, changeability and low rank. Therefore, it is still necessary to further improve the legal system guarantee system, through the formulation of high-level special laws, to clarify the legal status and security mechanism of digital technology application, so as to provide a stable and unified legal basis for the whole basin management.

3.2. "Fragmentation" of digital governance in the Yellow River Basin

The "fragmentation" of digital governance in the Yellow River Basin is mainly manifested in the lack of cross-regional coordination and the inconsistency of data standards. Digitizing the development of the Yellow River Basin can not rely solely on a province to play a role. However, the application of digital technology itself mainly focuses on data collection and analysis in a certain aspect, which lacks a holistic and comprehensive governance vision, as well as the limitations of cross-basin collaboration. In this case, there are human factors such as inconsistent technology application and data standards, which make the problem of "fragmentation" prominent, and the "fragmentation" refers specifically to the horizontal level. There are some practices on how to solve the dilemma of data "fragmentation". Henan Province has laid out an integrated monitoring and sensing network of "sky, land and water", which has greatly improved the spatial and temporal resolution of the basin monitoring system. The L1-L3 data base constructed by the Yellow River

Design Institute supports the fine management from the macro planning to the specific engineering level, forming an integrated data view of the whole basin. However, the "sky-ground-water" integrated monitoring and sensing network is only widely used in Henan section, which is insufficient in cross-regional area. There are differences in the acquisition standards, formats and accuracy of data backplanes at different levels of L1-L3, which leads to difficulties in cross-level data fusion, and there are still practical problems. At present, the problems mainly focus on three aspects: the different levels of regional development lead to incomplete access to river basin data, the lack of a unified platform leads to the difficulty of information integration, and the existence of protectionism leads to the low level of inter-provincial sharing.

The Yellow River flows through nine provinces and regions in China. Due to the large gap between the eastern and western regions, there are differences in the development of provinces and regions in the basin, and the process and level of research and development, development and application of digital technology are different. In addition, because the construction of digital facilities requires a lot of manpower, material and financial resources, the digital governance in the initial stage makes the provinces and regions face many problems, such as differences in resource endowment and policy orientation, which also makes the development of digital intelligence in different regions of the Yellow River Basin different. According to the time series statistics of the digitalization development level of the upper, middle and lower reaches of the Yellow River Basin from 2016 to 2023, the digitalization level of the Yellow River Basin as a whole shows a trend of "strong at the bottom and weak at the top", and the digitalization development level of the lower reaches is always in the leading position, followed by the middle reaches. From the perspective of difference, with the passage of time, the siphon effect of resource endowment and the polarization effect of regional development make the difference of digital intelligence development level among regions expand. In addition, according to the statistics of Dagum Gini coefficient, there is a big difference in the level of digital intelligence development between the downstream and the middle and upper reaches, showing the trend of upstream-downstream > downstream-midstream > upstream-midstream, which may be affected by the resource endowment of each region. For example, Shandong Province is a coastal province in the east, which makes a great contribution to the digital development of the Yellow River Basin; while most of the provinces in the middle and upper reaches belong to the western region of China, and their digital and intelligent development is relatively backward, so their contribution is relatively small.

In view of the problems of "difficult information integration" and "protectionism", the Yellow River Basin has been showing a "vertical classification, horizontal decentralization" governance pattern, which is essentially due to the contradiction between the complexity of the Yellow River Basin governance and the adaptability of the digital technology used. On the one hand, different departments and regions in the basin have long adopted decentralized and fragmented data collection and storage modes, resulting in different standards of the same data in different regions and reflecting different realities. For example, due to the lack of unified data standards in water dispatching and resource allocation, the Yellow River Commission spends a lot of time and energy in cross-regional data conversion, which directly reduces the efficiency of data utilization. On the other hand, administrative barriers aggravate "fragmentation", because of the low degree of judicial data disclosure of administrative organs, there are barriers to data sharing between judicial organs and administrative organs in environmental cases, which also hinders the free flow of data and information related to river basin management. In addition, the Yellow River Basin spans the eastern and western regions, and the uneven level of development between the East and the West leads to the uneven level of digital infrastructure construction. For example, the coverage of data

infrastructure in western provinces such as Xinjiang and Qinghai is much lower than that in the east, and the low level of digital technology makes it difficult to support the projects that need real-time monitoring data for flood control and waterlogging prevention and water conservation of the Yellow River.

3.3. There is a strong "digital divide" in the development level of digital intelligence in the provinces and regions of the Yellow River Basin

"Digital divide" is the spatial heterogeneity of digital intelligence level, whose essence is the imperfection of urban coordinated development and the lack of clarity of vertical management system. The application of digital technology requires relevant personnel to have certain professional knowledge and technical ability, but due to the different levels of development in different regions, the number of relevant talents required is also different, so it is necessary to strengthen communication and cooperation within the basin, especially the linkage and cooperation from top to bottom. However, it can be seen from the Assessment of China's Local Government Data Openness in 2022 that the degree of data openness of local governments in Shandong and Sichuan provinces is much higher than that of other seven provinces along the Yellow River. If the cities are allowed to develop on their own, the imbalance will be further deepened, and the gap of digital technology development level between provinces and regions will be further widened. In addition, Shandong, Sichuan and other economically developed areas have rapid technological renewal, and their developed economy can support their continuous renewal of digital tools for ecological management, but compared with developed areas, the underdeveloped western region is facing the contradiction of the difficulty of replacing old and new technologies. New technologies and tools are constantly emerging. In the process of Yellow River Basin management, if we do not follow up the application of new technologies in time, it may lead to the lag of technology application in the region, and there are barriers to interconnection between the old and new technologies, which will affect the formation of closed-loop management of the whole basin, thus not conducive to the sustainable development of ecological digital management in the Yellow River Basin.

4. Optimization path of digitalization driving eco-environmental protection in the Yellow River Basin

In view of the practical problems mentioned above, we should focus on the three aspects of legal system protection, "fragmentation" integration and urban cooperation, and seek the optimal path of digital-driven ecological environment protection in the Yellow River Basin.

4.1. Speed up the systematization of digital law to ensure the long-term development of the Yellow River Basin

On December 26, 2020, the Standing Committee of the National People's Congress passed the first river basin legislation in China, the Yangtze River Protection Law, marking the rise of new "geospatial" legislation represented by river basin legislation. Since then, the Black Land Protection Law (June 2022), the Yellow River Protection Law (October 2022) and the Qinghai-Xizang Plateau Ecological Protection Law (April 2023) have been promulgated one after another. The emergence of this special type of legislative group has further impacted the structure of China's traditional environmental law system [6]. In today's digital age, the traditional legal system is being impacted,

and the digital ecological governance of the Yellow River Basin urgently needs to be guaranteed and supported by a sound legal system, but the current development of the law is obviously unable to effectively guide the development of digital technology, which weakens the driving force of digital technology for ecological governance. Therefore, only by speeding up the construction of the legal system related to the digitalization of the Yellow River Basin can long-term development of the ecological management of the basin be better guaranteed.

First, at the legislative level, we should create a "unified draft + differential appendix" model. This model can provide a legislative path with both system integration and flexibility for cross-regional ecological governance. Because the governance of the Yellow River is a cross-regional act, on the one hand, legislation formulates a unified standard, namely the "unified draft", to apply to all relevant administrative regions, to ensure the consistency of the rules in law enforcement and judicial practice in all regions; On the other hand, in order to fully consider the differences in the level of regional digitization and avoid the "one size fits all" or the game of local interests, the "difference appendix" should be added to the legislation to enhance the adaptability of the law.

Secondly, at the judicial level, we should optimize the centralized jurisdiction system and the consultation system of compensation for ecological environment damage [7]. Compared with general environmental cases, river basin ecological environment cases have the characteristics of rapid pollution diffusion, long chain of governance, and many subjects involved, and need to rely on the institutional advantages of centralized trial, such as unified judgment standards and breaking through local protectionism, while the consultation system of ecological environment damage compensation is an important part of the linking mechanism between litigation and non-litigation. It can play an important role in connecting multiple subjects, promoting rapid repair, compressing the game space of governance, and assisting the digital governance of the Yellow River Basin. Legislation and justice complement each other and improve the digital legal system.

4.2. Promote the "fragmentation" integration of data and realize the free horizontal circulation of data

There is a coupling system of "structure-function-utility" in each river basin, which presents a dialectical relationship of "trinity": the water ecology of the basin reflects the dynamic balance and maintains the material circulation system of the biodiversity of the basin; the water environment of the basin represents the static threshold and delimits the spatial boundary of the ecological carrying capacity of the basin; Water resources in river basins constitute the value of resources and are the basic elements to support economic and social development. In order to solve the problem of "fragmentation", we must break through the single element of the separation of traditional environment and resources, and the governance model should move towards a systematic and comprehensive direction.

The process of digital integration in the Yangtze River Basin is faster than that in the Yellow River Basin, so we can learn from the relevant experience of the Yangtze River Basin on how to achieve the effective integration of digital "fragmentation". For example, the Yangtze River Protection Law proposes to establish a river basin coordination mechanism, requiring local governments and relevant departments to coordinate the promotion of ecological environment protection and restoration in the Yangtze River Basin [8]. Similarly, for the Yellow River Basin, the Yellow River Commission or relevant government departments should consult with the provinces and regions in the basin to establish a set of data circulation platform or basin coordination mechanism suitable for the Yellow River Basin, and the authoritative departments should organize

and lead the provinces and regions to develop and apply digital ecological governance technology, so as to solve the dilemma of digital "fragmentation". Lay the foundation for the coordinated development of cities.

4.3. Strengthen urban digital cooperation to achieve vertical synergy of coordinated development

General Secretary presided over a symposium on comprehensively promoting the ecological protection and high-quality development of the Yellow River Basin in Lanzhou, pointing out: "We should give more prominence to the systematicness, integrity and synergy of the Yellow River management, promote the construction of an integrated ecological environment management system between upstream and downstream, carry out in-depth major projects for the protection and restoration of important ecosystems, and enhance the stability of the basin ecosystem." [9] The indivisibility of the ecological environment management of the urban agglomerations in the Yellow River Basin makes it impossible to ignore the key issue of the coordinated development of cities. It is a long-term measure to strengthen the coordination and cooperation within and among the upper, middle and lower regions of the Yellow River Basin, to jointly formulate and implement the digital development plan, and to promote the coordinated development among regions [10].

First of all, we should clarify the overall construction goal of the digitalization of ecological management in the Yellow River Basin. In the Digital Twin Yellow River Construction Plan (2022-2025), it is clearly stated that the key projects of digital twin Yellow River construction are the safety monitoring project of flood control projects in the lower reaches of the Yellow River, the full-coverage water monitoring system in the Yellow River Basin, the joint dispatching system for disaster prevention of water projects in the Yellow River Basin, the hydrological infrastructure construction project in the Yellow River Basin, and the Yellow River Basin. Warping dam safety information management platform, digital twin Yellow River key technology research and platform construction, digital twin application demonstration in the Yellow River Basin, etc. The plan issued by the Yellow River Commission clearly gives the development goal of the digital twin Yellow River, but the author believes that in order to better promote the power of digital cooperation guided by planning, cities still need to further cooperate to discuss and refine the specific measures to implement the plan in various regions.

Secondly, after defining the goal of holistic construction, we should formulate holistic adjustment strategies. In order to establish a more suitable and perfect adjustment strategy, it is necessary to further clarify the responsibilities of river basin management agencies, river basin ecological environment regulatory agencies and provinces and cities along the Yellow River on the basis of mature river basin management framework such as "national coordination + inter-provincial cooperation". In order to significantly enhance the systematicness and integrity of the management of the Yellow River Basin, a new type of river basin coordination mechanism has been established, which includes the overall planning of major issues by the state, the management of key issues by the competent departments, the inter-provincial coordination and cooperation of related issues, and the implementation of specific issues by local governments. For example, Shandong, as the "leading" region along the Yellow River Basin, should consolidate and develop its first-mover advantages, strengthen scientific and technological innovation, actively promote inter-provincial compensation agreements and other mature experiences, and play a leading role in promoting scientific and technological innovation and industrial synergy in the eastern, central and western regions of China.

5. Conclusion

As an important engine to promote a new wave of science and technology and the development of new quality productivity, digital technology is of great significance to promote the coordinated integration of social and economic systems and ecosystems, and to realize the innovative development of key national ecological function areas. In view of the urgent need to improve the existing legal system and targeted policy support in the Yellow River Basin, the "fragmentation" of digital governance, and the strong "digital divide" in the level of digital intelligence development, the specific implementation still needs to be considered comprehensively in the light of various factors, and the Yellow River Commission and other departments still need to be guided by existing data and policies. More effective measures should be taken to better enable the ecological management of the Yellow River Basin. In the future, with the continuous emergence of new digital technologies, digital governance will still face new challenges. It is necessary to continuously optimize the technical adaptability and cross-regional coordination mechanism, bridge the digital divide, improve the legal protection, integrate digital technology into all aspects of river basin management, and promote the high-quality coordinated development of ecology and economy in the Yellow River Basin.

References

- [1] Data sources: statistical bulletins, special action reports and assessment documents on the implementation of the Yellow River Protection Law published by the Supreme People's Procuratorate, the Ministry of Water Resources and the people's governments of nine provinces (regions) along the Yellow River.
- [2] Si Linbo, Xiao Xinru. How Digital Twins Solve the "Fragmentation" Dilemma of Digital Governance in the Yellow River Basin: An Operational Framework Based on Holistic Governance: 59
- [3] Speech at the Symposium on Ecological Protection and High Quality Development of the Yellow River Basin.
- [4] Li Xiaoqiang, Guo Jiajia. Legal Exploration of Ecological Protection and High Quality Development in the Yellow River Basin: 45.
- [5] Dahe Network. Digital Twin Enabling New Model of Ecological Collaborative Governance in the Yellow River Basin .
- [6] Peng Feng. The Impact of the Rise of River Basin Legislation on the Environmental Law System: 61.
- [7] Liu Mingquan, Zhang Qi. The Transformation of Judicial Paradigm of River Basin Environmental Governance: From Collaboration to Synergy: 59, 68-72
- [8] Huang Xisheng, Shang Rui. Theoretical Structure and Institutional Improvement of Environmental Judicial Cooperation in the Yangtze River Basin: 8-9.
- [9] Xinhua News Agency. " chaired a forum on comprehensively promoting ecological protection and high-quality development in the Yellow River Basin, emphasizing that further deepening reform in an all-round way is the driving force to create a new situation of ecological protection and high-quality development in the Yellow River Basin."
- [10] Wang Jiazhen, Han Youpeng, Chang yuan, Wu Zhenshu. Measurement of Digital Intelligence Development Level and Research on Spatio-temporal Evolution Characteristics in the Yellow River Basin: 64-66.