# Study on Water Resource Scheduling and Optimal Allocation in Farmland Water Conservancy Projects

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**Abstract:** In recent years, with the continuous increase of cultivated land area, the shortage of agricultural irrigation water in China has been intensifying, becoming a significant factor restricting the sustainable development of agriculture. As an important infrastructure for agricultural production, farmland water conservancy projects play a key role in the efficient scheduling and optimal allocation of water resources. Based on this, this paper focuses on the study of water resource scheduling and optimal allocation in farmland water conservancy projects. It first introduces the connotation, significance, and main technical methods of water resource scheduling and optimal allocation; secondly, it analyzes the existing problems and challenges faced in current water resource scheduling and optimal allocation; finally, it discusses countermeasures and suggestions for promoting water resource scheduling and optimal allocation in farmland water conservancy projects in the new era from aspects such as strengthening informatization construction of water conservancy projects, enhancing basic data collection and monitoring, continuously advancing the construction of water resource scheduling models, optimizing water resource scheduling and allocation strategies, and strengthening comprehensive water resource management. It is hoped that this paper can provide some reference for the industry.
***Keywords*:** Farmland water conservancy projects; water resource scheduling; optimal allocation; problems and challenges; countermeasures and suggestions

## 1. Introduction

Water resources are an important national strategic resource. China is a country severely lacking in water resources, with per capita water availability only one-fourth of the world average, and distribution is extremely uneven. Agriculture is the foundation of the national economy and a major water consumer. Continuous and stable agricultural water supply is a crucial prerequisite for ensuring healthy and stable agricultural development and safeguarding national food security. Farmland water conservancy projects are important agricultural infrastructure responsible for regulating, conveying, and distributing agricultural water resources. Their scheduling and allocation levels directly determine the efficiency of water resource utilization. Strengthening water resource scheduling and optimal allocation in farmland water conservancy projects is of great significance for improving agricultural water use efficiency and benefits, promoting agricultural water conservation and green development, and supporting agricultural modernization and rural revitalization. Currently, there are still some shortcomings and deficiencies in water resource scheduling and optimal allocation in China's farmland water conservancy projects that urgently need improvement, making research on this topic of important practical value.

## 2. The Concept, Importance, and Main Technical Methods of Water Resource Scheduling and Optimal Allocation

### 2.1 The Connotation of Water Resource Scheduling and Optimal Allocation

(1) Water resource scheduling: Refers to the process of temporally and spatially adjusting, distributing, and conveying water resources through engineering and administrative means, based on the upstream water sources, reservoir storage conditions, and the water demand of the target area.

(2) Water resource optimal allocation: Refers to the application of systems engineering and optimization theory methods to reasonably allocate limited water resources to different regions and various types of water-use sectors, achieving a balance among economic, social, and ecological benefits under the premise of ensuring people's livelihood.

(3) Relationship between the two: Scheduling is an important means and process to realize allocation, while allocation is the goal orientation of scheduling. An optimal allocation plan needs to be executed through scientific and reasonable scheduling; the effect of scheduling directly determines the degree to which allocation goals are achieved. In farmland water conservancy systems, the two are closely integrated, jointly serving the refined management of agricultural water resources.

## 2.2 The Importance of Water Resource Scheduling and Optimal Allocation

Strengthening water resource scheduling and optimal allocation in farmland water conservancy projects has important economic, social, and ecological significance. First, water resource scheduling and optimal allocation play a crucial role in improving water use efficiency, preventing water resource waste, and alleviating the contradiction between water supply and demand, effectively ensuring industrial and agricultural development. Second, farmland water conservancy projects can regulate reservoir water levels and control river flow to effectively retain floodwaters during flood periods, reduce peak flood flows, and mitigate flood threats to downstream areas, thus playing a role in flood control and drought resistance. Finally, scientifically and reasonably allocating water resources helps maintain water volumes in rivers, lakes, wetlands, and other ecosystems, ensures ecological water demands, sustains ecosystem stability, protects biodiversity, and improves ecological environment quality.

## 2.3 Main Technical Methods of Water Resource Scheduling and Optimal Allocation

With the rapid development of information technology today, water resource scheduling and optimal allocation mainly rely on various front-end data acquisition devices to massively collect surface water, groundwater, rainwater, and other water resource information, integrate multi-source data such as meteorology, soil, and crops, accurately analyze water usage in various regions through various model algorithms, predict crop water demand using machine learning, and formulate dynamic scheduling plans for scientific scheduling and decision-making. Meanwhile, some regions have realized real-time monitoring and automatic allocation of all elements, significantly improving scheduling efficiency and promoting optimal water resource allocation. The specific operations of water resource scheduling and optimal allocation in farmland water conservancy projects mainly depend on water storage, water conveyance, water distribution, flow control, optimization of irrigation methods, and promotion of efficient water-saving irrigation technologies.

# 3. Problems and Challenges in Water Resource Scheduling and Optimal Allocation in Farmland Water Conservancy Projects

## 3.1 Existing Problems in Water Resource Scheduling and Optimal Allocation in Farmland Water Conservancy Projects

(1) Insufficient data collection, monitoring, and sharing capabilities.

Scientific water resource scheduling and optimal allocation rely on a large amount of accurate, reliable, and comprehensive information data. The richer the data, the stronger the support for scheduling decisions. Since the 18th National Congress of the Communist Party of China, various regions have actively promoted informatization construction of data related to farmland irrigation, hydrometeorology, and water conservancy projects. Data collection and processing capabilities have significantly improved. However, overall coverage has not yet been achieved; some areas have imperfect network monitoring systems, insufficient real-time monitoring stations for water sources, canal systems, field water conditions, soil moisture, and engineering status. Data collection capacity is weak, data quality is low, updates are untimely, and information transmission channels are obstructed, resulting in delays and errors. Information barriers between different departments such as agriculture, water conservancy, meteorology, and emergency management have not been fully broken, causing insufficient interconnection and interoperability.

(2) Uneven technical capabilities and water resource scheduling models needing improvement.

Farmland water conservancy project scheduling and optimal allocation require high information technology capabilities. Currently, technical capabilities vary across regions; some areas lack sufficient monitoring capacity, use outdated technical methods, and apply emerging technologies such as GIS, RS, GPS (Beidou) less frequently, resulting in weak service capabilities. Regarding the construction and use of digital source scheduling models, large rivers and lakes such as the Yangtze, Yellow, and Pearl Rivers have models developed and continuously improved by national-level water research institutes. However, in some regions, tributaries or small farmland water conservancy projects have started applying water resource scheduling models relatively late, with practicality and accuracy still needing improvement. Moreover, in some areas, water resource scheduling models are complex to operate, requiring grassroots personnel to spend considerable time learning, which affects efficiency.

(3) Insufficient systematicness, coordination, and foresight in scheduling management.

Water resource scheduling and allocation is a complex, multi-dimensional dynamic system influenced by external environments, internal demands, local policies, and production activities. It requires comprehensive consideration of various factors and reasonable planning. However, most existing models and plans are based on historical data and current demand, lacking precise analysis and prediction of future water resource trends. They do not sufficiently analyze the impact of farmland water conservancy projects on water resource regulation, nor adequately predict upstream and downstream demands. The scheduling and allocation are largely reactive, with little proactive intervention and early involvement.

### 3.2 Challenges Faced by Water Resource Scheduling and Optimal Allocation in Farmland Water Conservancy Projects

(1) Uncertainty of hydrometeorology and inherent conflicts.

Although meteorological forecasting technology in China has continuously improved, achieving precise predictions remains difficult. Variations in data caused by meteorological changes—such as rainfall amounts, river runoff, and evaporation—are even harder to predict, increasing the difficulty of formulating long-term stable scheduling and allocation plans. Additionally, due to seasonal rainfall patterns, there is an inherent conflict between water supply and the peak water demand periods of crops, requiring counter-cyclical adjustments that further complicate scheduling.

(2) Complexity of supply systems and diversity of demands.

Large irrigation districts involve diverse types of farmland water conservancy projects and complex systems that include various water sources such as rivers, lakes, reservoirs, and groundwater, multi-level main canals, and a vast number of valves and pumping stations. The system's topological structure is complex, hydraulic resource connections are tight, and there are many decision variables and engineering constraints (capacity, water level, flow, etc.), making modeling and solution difficult and scheduling decisions challenging. Meanwhile, variations in soil moisture, different meteorological conditions, various crop types, and differing water needs at growth stages require coordinated and integrated scheduling, which increases the difficulty of scheduling and allocation.

(3) Conflicts among multiple objectives and institutional mechanism constraints.

Water resource use must consider economic, social, and ecological benefits in an integrated manner. In practice, these multiple objectives may conflict and cannot all be optimized simultaneously, requiring a balance to be sought. Moreover, China's current water rights system and mechanisms are still imperfect, especially with lagging agricultural water pricing reforms. In many regions, water prices are lower than costs, limiting the price signal's effectiveness. Farmer water user cooperatives and group management organizations have not been fully effective, and management work is insufficient, so agricultural water conservation still faces heavy challenges.

## 4. Countermeasures and Suggestions for Water Resource Scheduling and Optimal Allocation in Farmland Water Conservancy Projects

### 4.1 Strengthen Informatization Construction of Water Conservancy Projects and Enhance Basic Data Collection and Monitoring

Regions should adhere to the principles of "doing what they can" and "doing their best," and in accordance with local fiscal conditions, carry out technical renovations on traditional canals and irrigation equipment, add intelligent metering devices and data transmission modules, and strengthen the construction of informatized metering management systems for farmland water conservancy projects. Key data such as flow, temperature, humidity, rainfall, and soil moisture should be collected and monitored in real time to improve the level of front-end data collection. Relying on remote sensing (RS), geographic information systems (GIS), global positioning systems (GPS), and Internet of Things (IoT) technologies, a comprehensive big data platform for water resource scheduling should be established to break data barriers between agriculture, water conservancy, meteorology, environmental protection, emergency management, and other departments, ensuring real-time data sharing and effective interconnection to provide sufficient data support for the establishment and updating of water resource data models as well as water resource scheduling and allocation. Fully utilizing big data, artificial intelligence, and other technologies, data collection, aggregation, analysis, and mining for farmland water conservancy projects should be strengthened to accurately predict trends in water supply and demand changes and formulate response measures in advance.

### 4.2 Adhere to Local Conditions and Categorized Implementation, and Continuously Promote Water Resource Scheduling Model Construction

While continuously advancing informatization of farmland water conservancy projects, regions should further promote the construction of water resource scheduling models. For large lakes and rivers within the region, water resource scheduling models should be further optimized and improved, and updated timely based on annual data changes to enhance efficiency. For tributaries or small farmland water conservancy projects not yet included in models locally, clear work objectives and timelines should be established, expert teams organized promptly, historical data compiled, and local water resource scheduling models accelerated. Existing but immature or incomplete models should be further optimized and improved in light of practical conditions to enhance practicality and accuracy, while also focusing on operability and convenience to facilitate frontline staff operation and use. Model construction and optimization should fully consider comprehensive economic benefits, water resource renewability, diversity of water demands, characteristics of water conservancy projects, operational stability, and ecological environment constraints to ensure models sufficiently reflect water resource system conditions.

## 4.3 Optimize Scheduling and Allocation Strategies, and Strengthen Regional Coordination and Cooperation

Under central coordination and combined with actual conditions, regions should further optimize water resource scheduling strategies for farmland water conservancy projects and strengthen cross-regional water resource coordination and cooperation to continuously improve allocation efficiency. Implement total water volume control and quota management, determine agricultural water use red lines for regions/irrigation districts, formulate irrigation water quota standards for different regions and crops, and enforce water-saving management. Coordinate water sources including rivers, lakes, reservoirs, groundwater, and rainwater, and rationally allocate water use plans based on water quality, quantity, distance, cost, and other factors. Accurately allocate water volumes according to crop production cycle water demands. Actively promote high-standard farmland construction, strengthen field water management and soil moisture monitoring for crops, and implement water-saving irrigation systems such as deficit irrigation, regulated deficit irrigation, and controlled alternate root-zone irrigation to improve agricultural water productivity. Establish and improve cross-basin and cross-regional water resource coordination mechanisms for farmland water conservancy projects, formulate watershed water resource plans, and sign regional cooperation agreements to maximize comprehensive water resource utilization. Establish benefit compensation mechanisms and information technology exchange mechanisms to protect stakeholders' rights and interests and enhance overall regional water resource allocation capacity and level.

## 4.4 Strengthen Comprehensive Water Resource Management and Improve Personnel Competence

Continue to deepen comprehensive agricultural water pricing reform, explore establishing agricultural water pricing mechanisms in pilot areas, implement progressive pricing systems for usage beyond quotas, and reinforce water cost constraints to stimulate water-saving enthusiasm. Establish and improve water-saving reward and drought water-use mechanisms to protect farmers' basic water rights and compensate for water-saving investments. Further strengthen the construction of farmer water user group management organizations, explore models of farmer-led construction, use, and management to improve water resource utilization efficiency. Form farmer water user cooperatives and village-level water associations to solidly manage water use, project maintenance, water fee collection, water allocation, and dispute mediation, thereby stimulating farmers' initiative and intrinsic motivation in water conservancy construction and management. Enhance training for farmland water conservancy management departments, irrigation district management agencies, and members of farmer water user organizations to popularize modern water resource management concepts, strengthen education and training in information and intelligent technologies, and improve professional quality and operational skills to ensure high-quality development of water resource scheduling and optimal allocation work.

## 4.5 Thoroughly Implement Ecological Civilization Thought and Strengthen Ecological Environmental Protection

Promoting water resource scheduling and optimal allocation in farmland water conservancy projects must always adhere to Xi Jinping's Thought on Ecological Civilization as guidance, placing ecological environmental protection in an important position to ensure organic coordination among economic, social, and ecological benefits. Relying on model algorithms, accurately predict agricultural water demand, reasonably set water intake amounts for each system according to the ecological coordination characteristics of water sources, and safeguard the ecosystem functions of rivers, lakes, and wetlands. Actively explore achieving water volume adjustment and ecological environment improvement through water resource scheduling and optimal allocation in farmland water conservancy projects. For example, during dry seasons, increase downstream river flow appropriately through reservoir water retention and inter-regional water transfer to alleviate river drying and protect wetland ecosystems. Strengthen monitoring of ecological environmental impacts during construction and operation of farmland water conservancy projects, intervene timely to prevent ecological damage. For instance, regularly monitor water quality and temperature parameters during reservoir operation to ensure no adverse impact on downstream ecological environments.

## 5. Conclusion

Water resource scheduling and optimal allocation in farmland water conservancy projects are important means to address agricultural water shortages, ensure food security, and achieve sustainable agricultural development. Water resource scheduling and optimal allocation involve multiple fields and dimensions including natural, social, economic, and engineering aspects, facing difficulties and challenges such as meteorological and hydrological uncertainties, complexity of water demand, and system integration. In the new era, further strengthening water resource scheduling and optimal allocation in farmland water conservancy projects requires a dual approach of empowering with information technology and comprehensive management, fully leveraging the guiding role of policies and mechanisms as well as the support of models and data, promoting more efficient use of agricultural water resources, and providing a solid water conservancy foundation for accelerating rural revitalization and agricultural modernization.

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