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Enhancing the Efficiency of Irrigation Infrastructure Systems for Agricultural Production in Vietnam

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Abstract: To improve the effectiveness of irrigation infrastructure systems and enhance management capacity for Irrigation Management Companies, the Ministry of Agriculture and Rural Development has focused on upgrading infrastructure, training, and capacity building for irrigation personnel nationwide. Efforts have been made to standardize management, supervision, and evaluation of irrigation systems. In response to frequent and widespread droughts in recent years, aside from investing in new construction projects which are costly, it may be time to focus on repairing and upgrading existing infrastructure to enhance capacity. This should be accompanied by innovation in management, dissemination, guidance, and the application of water-saving technologies and techniques. Vietnam's traditional agriculture relies heavily on paddy cultivation, with a tropical monsoon climate and harsh natural conditions characterized by heavy seasonal rainfall, often leading to storms, floods, and inundation. Dry seasons often bring droughts, saltwater intrusion, and water shortages. Climate change warnings predict even more complex natural disasters. Moreover, rapid industrialization, urban development, and population growth increase the demand for water, making irrigation development essential. The development of irrigation is crucial infrastructure for agricultural production, contributing significantly to increasing productivity, output, and quality of agricultural and aquatic products, providing water for domestic use and other economic sectors, water consumption, flood prevention, and mitigation of natural disaster damage, aiming at sustainable socio-economic development.

Keywords: Irrigation infrastructure, agriculture, Vietnam

I. Introduction

The rapid processes of urbanization and industrialization in recent times have led to a shift in agricultural production towards market-oriented approaches, centralized production, seasonal distribution, and changes in the structure and scale of agricultural production. This trend has resulted in an increasing demand for water in both agricultural and non-agricultural sectors. However, difficulties arising from insufficient funding for upgrading and maintaining infrastructure systems, along with incomplete mechanisms and policies for management, operation, distribution, and water regulation, have led to existing irrigation systems failing to meet the requirements for serving multiple objectives, flexibility, and sustainability.

In response to these challenges, the Ministry of Agriculture and Rural Development has focused on investing in the upgrading and improvement of irrigation systems using ODA (Official Development Assistance) funds and domestic counterpart funds in recent years. Alongside the development and enhancement of irrigation infrastructure, various approaches such as participatory irrigation management, integrated water resources management, etc., have been implemented to increase investment efficiency, transitioning from a "service" to a "service-oriented" approach to maximize the benefits of water use and irrigation projects. Maximizing the involvement of organizations in water management to improve service quality for water users is also being researched and applied. Activities to strengthen the management organizations of irrigation works, improve and supplement policy and legal frameworks, and enhance the efficiency of irrigation systems management to address these challenges are being actively pursued by the Ministry of Agriculture and Rural Development as well as the irrigation sector.

Despite the achievements made in serving agricultural production, current irrigation systems still face challenges such as inefficient use of investment capital and incomplete management mechanisms. These are the issues that need improvement to expect enhancements in the efficiency of irrigation system management.

II. Current Status of Irrigation Serving Agricultural Production and Rural Areas

2.1. Characteristics of Water Resources

According to the United Nations assessment, in the 21st century, the world's population has tripled while water resources exploitation has increased sevenfold. With the current population growth rate, the world's population is projected to reach 8 billion in 2020 and 10 billion by 2050. Consequently, the demand for water is expected to increase

by 650% over the next 30 years. By 2025, over 3.5 billion people on the planet will be living in water-stressed conditions. Vietnam possesses water resources at an average level compared to the world. The amount of water generated per capita on the territory was about 4100 m3/year in 2000. With the current population growth rate, the average water per capita continues to decrease by 18-20% every decade. Due to the strong influence of topography and the interaction between the two monsoon wind systems, the rainfall distribution is uneven both spatially and temporally. The rainy season accounts for 75-85% of the total annual rainfall. Meanwhile, the dry season receives very little rainfall, with several months experiencing no rain at all. Spatially, there are areas with rainfall reaching 3000-5000mm/year, while others receive less than 1000mm/year. This difference can be up to 3-5 times.

Uneven rainfall distribution leads to uneven surface flow, with large rainfall areas having a flow module of 60-80 liters/s/km2, while smaller rainfall areas only reaching 10 liters/s/km2. During the rainy season, flow volume accounts for 70-80% of the annual flow, whereas in the months with the lowest flow, it only makes up 1-2%. Groundwater resources with natural dynamic reserves across the entire territory (excluding offshore areas) are approximately 50-60 billion m3 equivalent to 1513 m3/s. However, these resources are also unevenly distributed across different hydrogeological regions. Given these characteristics of water resources, drought and water scarcity occur every dry season to varying degrees. Floods also frequently occur during the rainy season. Over the past five years, Vietnam has faced water-related disasters every year. Severe droughts, particularly in the central and Central Highlands regions, and widespread droughts in the Mekong Delta, South Central Coast, and Central Highlands have caused significant damage to agriculture, aquaculture, and forest fires in Kien Giang and Ca Mau, primarily due to drought influenced by El Niño.

2.2. Current Status of Irrigation Serving Agriculture

After years of investment, primarily aimed at ensuring national food security and progressing towards exports, Vietnam now boasts 75 medium and large-scale irrigation systems, along with numerous small-scale systems, with a total fixed asset value of around 60 trillion VND (excluding the value of land and the contribution of people's efforts). These irrigation systems have ensured irrigation for 3 million hectares of cultivated land, drainage for 1.4 million hectares of natural land in northern provinces, saltwater intrusion prevention for 700,000 hectares, and land reclamation for 1.6 million hectares of saline-alkaline land in the Mekong Delta. In recent years, the irrigated rice area has reached nearly 7 million hectares, accounting for 84% of the total rice area. Additionally, irrigation systems also irrigate over 1 million hectares of vegetables, industrial crops, and fruit trees. The amount

of water used for agriculture is significant, with estimates indicating 41 billion cubic meters, accounting for 89.8% of total water consumption, and 46.9 billion cubic meters, accounting for 90%. Particularly during the rainy season, the Irrigation sector directly coordinates with scientists to inspect, calculate scenarios, and conduct rational and flexible water management, actively retaining water and minimizing flooding in downstream areas, ensuring the safety of important reservoirsơ. Additionally, task forces are deployed directly to support localities in operating and maintaining infrastructure safely and reducing flooding in downstream areas. Thanks to irrigation measures and other agricultural measures over the past decade, grain production has increased by an average of 1.1 million tons/year. The total grain output in 2022 reached 34.5 million tons, increasing the average grain per capita from 330 kg in 2021 to 444 kg in 2022. Vietnam has transitioned from food scarcity to a major rice exporter, with an export volume of nearly 4 million tons/year.

2.3. Irrigation Work Serving Aquaculture and Rural Clean Water Supply

Vietnam has significant potential for aquaculture development, and many irrigation systems have been designed to incorporate water supply for aquaculture. When constructing water reservoirs, the development of aquaculture within the reservoirs is also considered. In recent years, due to the effectiveness of aquaculture, especially shrimp farming, many coastal areas have been developed into concentrated aquaculture areas. However, the construction of irrigation systems to meet production requirements has not been adequately emphasized, lacking planning and comprehensive solutions. Most constructions are self-initiated and organized by the community based on experience. In many areas, there have been instances of aquatic diseases and mass shrimp deaths due to inadequate water environments related to water supply and drainage systems. Some regions have disputes between shrimp farming and rice cultivation related to saltwater intrusion and freshwater boundaries, which is also a matter for irrigation work to consider and resolve. Aquaculture development in water reservoirs is also limited. In most medium and large reservoirs, natural aquatic resources are primarily exploited, resulting in depletion in a short period. This is a significant potential that has not been well organized or invested in. Irrigation systems provide domestic water sources for the majority of rural residents, especially during the dry season. With 80% of the population living in rural areas, most irrigation systems directly provide water for domestic use or raise water levels in dug wells. Even in mountainous regions with dispersed populations, areas with secure domestic water sources often have irrigation systems passing through them. Typical irrigation projects providing water for domestic use, such as Dau Tieng, Song Quao, Nam Thach Han, Ngoi La, Phai Quyen, have provided domestic water for tens of millions of rural residents, especially during the dry season.

2.4. Organizational Systems and Policy Mechanisms

Alongside state management agencies, the development of irrigation in recent years has formed two areas for managing and operating irrigation works: the area of state-owned enterprises managing large systems including main works, main channels, and channels to communes. The area of farmers self-managing small works and canal systems within the commune. As of now, the country has 172 state-owned enterprises with nearly 20,000 employees, including 1,800 university and postgraduate degree holders. In recent years, state-owned enterprises operating irrigation works have focused on all three management aspects: managing infrastructure, water management, and economic management. However, most enterprises face financial difficulties, deteriorating infrastructure, and low living standards for workers, leading to suboptimal operational efficiency.

In the area of farmer self-management, when agricultural cooperatives still existed, each cooperative had specialized irrigation teams responsible for water conveyance and infrastructure repairs within the cooperative's scope. These irrigation teams collaborated with enterprises operating irrigation works to form a comprehensive network from the main facilities to the fields. After the shift in mechanisms, farmers gained autonomy in production and business on allocated land. The irrigation teams of agricultural cooperatives have almost disbanded. Due to the essential need for cooperation among households sharing water from a canal, in many places, farmers have organized themselves under various forms such as water cooperative unions, water association cooperatives, water user groups, or management boards. In some areas, farmers take direct responsibility for managing and operating the irrigation system in the fields. Overall, the current grassroots water management organizations are still inefficient, limiting the effectiveness of irrigation works.

Regarding policy mechanisms in management and operation, alongside the Irrigation Law No. 08/2017/QH14, Circular 73/2018/TT-BTC dated August 15, 2018, guiding the use of financial resources in the management and operation of irrigation works using state funds, the financial mechanisms of enterprises still remain inadequate. Most enterprises operating irrigation works struggle with insufficient revenue to cover expenses, and the compensation provided is often insufficient. In areas with sufficient budget resources, only partial compensation is provided, while in financially challenged areas, compensation is irregular. In such financial circumstances, enterprises must operate on a shoe-string budget. According to calculations, to ensure the annual safety, maintenance, and management of the irrigation system, an investment of 1,200-1,500 billion VND is required. However, the revenue from irrigation fees only reaches 350-400 billion VND,

and the budget support is around 100 billion VND, which only covers about 40% of the necessary expenses.

3. Current situation and causes of water waste in agricultural production

3.1. Main phenomena causing water waste in agricultural irrigation

Losses in conveying water from the main structures to the fields, due to seepage, sedimentation in channels, erosion, etc., hindering flow and lacking water regulation structures for each irrigation area. Frequent flooding irrigation: This is a traditional irrigation method suitable for rice cultivation. However, according to the results of many research projects, irrigating rice following the "flood, drain, dry" process will bring the most economic efficiency, meaning there are periods when water supply must be restricted, and fields must be drained and dried according to the growth requirements of crops. Frequent flooding irrigation throughout the season, following farmers' practices, has caused significant water waste, not to mention the excess water flowing from fields into drainage channels.

There is no proactive measure to limit surface evaporation: This natural phenomenon also causes significant water losses. The data from the Tuyen Quang and Phan Rang – Ninh Thuan stations measured at various stations are shown in the table below:

Table 1. Water evaporation and rainfall at stations

Station	Total annual water evaporation (mm/year)	Average annual rainfall (mm/year)
Tuyen Quang	1.193,9	1.145,8
Thap Cham – Ninh Thuan	1.730	815

From the table above, the total average evaporation at Tuyen Quang station is 1,193.9 mm/year, rainfall is 1,145.8 mm/year; At Phan Rang – Ninh Thuan station, the average total amount of evaporated water is 1,730 mm / year, while the rainfall is 815 mm / year. In the past, farmers had a movement to cover the open surface of the field with duckweed, around the base of the crop, while limiting evaporation and compost, increasing the nitrogen content in the soil. Currently, that movement is no longer available, some localities, people use plastic to cover some crops, but the cost is expensive.

Overflow irrigation, beyond the area where irrigation water is usable: This happens for the water supply of industrial trees, fruit trees, when we water to spillage on the ground. Excessive irrigation causes water to penetrate too deeply compared to the depth of the root system: Plants are only capable of absorbing water within the range of the roots, if we water

a lot, the water will seep deeper than the depth of the root system, causing waste. Water-saving irrigation and economical use of water are measures to supply water according to the requirements and the ability to absorb water according to each growth period of the crop, limiting the amount of excess water but not affecting the yield and quality of crops.

An Giang Department of Plant Protection has experimented to build a water-saving irrigation model for rice on an area of 17.3 hectares of 19 farmer households in My Thoi Ward, Long Xuyen City, An Giang Province (of which: 8.3 hectares of 9 farmer households use water-saving irrigation methods; 9 hectares of the remaining 10 farmer households use irrigation methods system for control). By placing a tube to monitor the water level in the field and applying the alternating dry wet irrigation method of the International Rice Research Institute (IRRI), the experimental farmers reduced the average of 4 times pumping water into the field in 1 rice crop, compared to 8 times pumping water according to farmer practice, saving irrigation water, less pests and diseases, reducing 7.9% of the fallen area, the rate of sure accounting for 78.2%, yielding 5.8 tons / ha, an increase of 0.5 tons / ha compared to the control field. The production cost of the "economical irrigation" field is only 1,142 VND/kg of rice, while the control field is up to 1,382 VND/kg, the difference is 240 VND/kg.

Therefore, the use of traditional irrigation methods has led to significant water wastage. Perhaps it is time for the Ministry of Agriculture and Rural Development to establish a program aimed at saving and preventing waste in agricultural production through water-saving irrigation methods, using water efficiently, in order to reduce construction costs, manage water resources, lower expenses, and enhance agricultural productivity for farmers.

3.2. Causes of Water Waste and Loss for Agricultural Production

Apart from infrastructure and equipment issues due to lack of investment in construction and upgrades, water waste and loss are also caused by limitations in management. Specifically:

Irrigation works managed by enterprises and water user cooperatives: Most localities have not clearly delineated which works are managed by enterprises and which are managed by water user cooperatives. Violations of the protected area boundaries are becoming increasingly serious, significantly affecting the water supply efficiency of the works. Even for works that have been delineated, roles and responsibilities are not clear. For works managed by enterprises, the lack of management funds leads to a "fix-as-needed" approach, focusing mainly on repairing machinery and equipment while neglecting the infrastructure. Although these works are owned by the state and entrusted

to enterprise directors for management, due to inconsistent management policies and insufficient funds, the works deteriorate without anyone taking responsibility.

Works managed by water user cooperatives (mostly agricultural service cooperatives): Cooperative leaders are elected by village members, with low salary regimes, resulting in limited responsibilities. The technical expertise of irrigation officials is almost nonexistent, relying mainly on experience and enthusiasm. Since these works are owned collectively by cooperative members, there is no specific individual accountable, and when the works are operational, the cooperatives manage them, but when they are damaged, they are handed over to the state. Legal regulations on the management and operation of irrigation works are still lacking and inconsistent, such as regulations on organizational management, financial systems, and work decentralization. Additionally, many localities have not fully implemented existing regulations.

Farmers' water usage awareness: Farmers often view water as "free" since the state invests in irrigation works, and they have already paid irrigation fees, so they tend to use water liberally. Most farmers have limited knowledge of water usage requirements for different crop growth stages, leading to excessive water usage. Responsibilities between water supply units and beneficiaries are executed through economic contracts but are not clear and not strictly enforced. According to the Law on Exploitation and Protection of Irrigation Works, water supply units and water users are responsible for signing economic contracts at the beginning of each crop season as a basis for implementation and settlement at the end of the production season. However, in practice, many localities witness cases where water users sign contracts for less area than actually served and delay in paying irrigation fees. This constitutes a violation of economic contracts, but the state has not implemented specific sanctions. As a result, water supply units lack funds for maintaining works and ensuring water flow.

3.3. Existing Issues

3.3.1 Investment Issues and Infrastructure Challenges

Over the past two decades, total investment in irrigation infrastructure has always played a significant role in agricultural investment activities. Irrigation work has focused on building irrigation systems, resulting in a significant expansion of agricultural cultivation areas, changing the landscape of the agricultural sector in the nation-building and development process, and contributing to Vietnam's agricultural and aquatic product exports. However, this does not necessarily mean that all investments in irrigation have been effective, as infrastructure barriers have not been completely resolved.

Previously, the preparation process for loan projects was carried out by foreign consultants through international bidding, and the experience of international experts was crucial in accessing loan sources and improving the level of domestic consultancy. However, due to limited experience in project areas and difficulties in local access (language barriers), surveying, planning, and project development still face many shortcomings. The funding for surveying, project preparation, appraisal, and investment decisions is very limited, leading to representative surveying still occurring, resulting in deficiencies in investment project approval documents when implementing investment, requiring project adjustments and consuming much time. There is still a lack of close participation and collaboration between management and exploitation units and consulting and design units in surveying work, with many domestic consultants being passive in the face of conclusions from foreign experts, leading to the planning and construction of many projects not being suitable, and projects being built not meeting the actual needs of the locality. Many project items on the investment system are not synchronized due to lack of funding, resulting in projects not fully realizing their investment efficiency.

Therefore, it is necessary to continue investing in upgrading, improving, and modernizing irrigation infrastructure. To do so, a vision for the irrigation system needs to be defined through assessing the current situation, identifying services and operational requirements to meet service demands, and outlining a modernization roadmap for the system to serve as a basis for system design and upgrades. Based on the successes and lessons learned from the VWRAP project, tools from the FAO (Food and Agriculture Organization) such as RAP, MASSCOTE/MUS are very suitable for this task.

3.3.2. Organizational and Hierarchical Management Issues of Infrastructure

Management Organization: According to the Law on Management and Exploitation of Irrigation Works, the current irrigation system is managed in four levels from central to commune levels. Direct exploitation management is under the responsibility of the Irrigation Sub-department for State management; exploitation and production management are assigned to state-owned enterprises operating for public interest, with management scope from the intake to the head sluice of internal canals; grassroots irrigation teams manage internal canal structures. However, at the provincial level, many areas have not established state-owned management companies for irrigation works. Works at the district level are assigned to agricultural departments or functional offices of the district, and at the commune level, responsibilities are often assigned to officials handling transportation-irrigation-construction duties, causing difficulties in management and implementation of investment strategies for sector development.

Current management organization models in some places are still overlapping and local-oriented, lacking clear scientific basis, and overlapping between the roles of state management and production management. Due to dependence on various factors such as land conditions, soil fertility, characteristics of works, farming practices, and water needs of crops and livestock in different regions, management forms at different levels are diverse and complex. Responsibility allocation mechanisms and monitoring and evaluation mechanisms are not clear, making it difficult to assign management responsibility to specific units or individuals. Responsibilities and authorities in handling actions that harm irrigation works are not assigned to the units directly managing them but involve multiple related units, leading to a situation of shifting responsibility and lack of decisiveness in handling, resulting in increasing incidents of harm to irrigation works.

Regarding irrigation enterprises: Firstly, these enterprises are not truly financially independent, with budgets approved annually based on financial reports. The pricing mechanism for water supply services is not based on market prices but on policies set by the state. Economic-technical norms, production cost norms, labor norms, etc., are not appropriate, with the creators and timing of creation not keeping pace with the fluctuations of service costs and actual production costs, leading to imbalances in revenue and expenditure. These enterprises cannot actively source capital for production activities, and revenue from irrigation fees is their main income source, making them passive in operations. When maintenance or repairs are needed due to natural disasters, the resolution process involves multiple levels, and the annual budget allocation for management operations from local authorities is much lower than actual needs, resulting in insufficient funds for regular maintenance, leading to delays in addressing incidents affecting operation of the works. Secondly, these enterprises do not have full autonomy in recruitment, capacity building for staff, human resource arrangements, salary payments, with many decisions still depending on various levels of management. Irrigation service activities are still dominated and pressured by authorities, and enterprises do not have the right to refuse irrigation services when water users do not sign contracts or pay irrigation fees. Enterprises find it difficult to penalize activities that infringe upon or harm the works, affecting the production service activities of the system.

Regarding water user cooperatives, there are currently about 16,000 active water user cooperatives nationwide, but the management organization model is not unified, and the legal framework for establishment, operation, hierarchical structure, management, evaluation, and operational guidance is unclear, leading to their activities not achieving desired effectiveness. By empowering local and state authorities to continue improving the legal framework, policies to improve organizational models and management of irrigation works, in management, operation, and water distribution, aim to increase the quality of

service supply and activities of IMCs, water users, ensuring efficient and sustainable irrigation systems. Enhancing access to services through improved financial management mechanisms, monitoring, and evaluation (M&E). Water management and distribution mechanisms aim to maximize the participation of beneficiaries, clearly defining the roles, responsibilities, and rights of IMCs and WUAs based on equality and mutual benefit through institutional improvement and capacity building at all levels in irrigation system management. Unified water user cooperative models, full regulations on organizational forms, legal basis, hierarchical establishment and management, evaluation, operational guidance... create operating mechanisms for these organizations to continue developing.

Infrastructure Management Hierarchy: In many areas, decisions on the hierarchical management of irrigation works according to Circular No. 65 have not been made. Localities that have reviewed and carried out hierarchical management encounter many difficulties, and these decisions still need further refinement.

Irrigation system management does not adhere to the principle of system management but still manages according to administrative boundaries, making it difficult to monitor and evaluate the effectiveness of system exploitation management. Currently, there are 110 state-owned enterprises managing and exploiting irrigation works nationwide, with many systems within the same area divided among several independent management entities. Management based on administrative boundaries still exists in most localities, without clear scale, scope of responsibilities, causing difficulties in management, coordination, and operation to serve production. Systems and projects invested by the central government have been re-planned and aimed at managing irrigation systems according to hydraulic boundaries, but due to the lack of synchronized and complete arrangements for water control and regulation structures, monitoring and evaluating management, water distribution activities cannot be effectively carried out.

Investment management decentralization according to Government Decree 112/2009, with investment management delegated to district level investors, is hindered by the lack of experience in hydraulic works at the district level, leading to deteriorating quality of irrigation works upgraded or renovated due to inadequate local management. Irrigation works managed by local authorities deteriorate rapidly, with low efficiency and service quality due to insufficient management personnel at district and commune levels, mostly lacking expertise in irrigation. In many areas, due to geographical conditions, soil fertility, farming practices, small and scattered fields, applying criteria for project scale, head canal area allocation for local management is difficult to implement, as irrigation areas in these areas are usually small, ranging from a few hectares to several tens of hectares... Additionally, in many places, water user cooperatives have not been

strengthened, capacity improved, with some cooperatives established only for the duration of project investment, and when the project ends, these cooperatives either operate minimally or disband due to limitations in personnel, finance, organizational mechanisms, and operation...

3.3.3 Institutional Issues and Policies for Evaluating the Effectiveness of Irrigation Management Systems

The development process of water management in the irrigation sector still demonstrates low sustainability due to current regulations for assessing the effectiveness or inefficiency of an irrigation system, or evaluating the cost-effectiveness of investment for a specific case, being quite complex, especially in water irrigation management and infrastructure management.

For water irrigation management: Units managing irrigation systems receive orders and planning tasks based on "area (ha) or volume (m3) of water irrigated, water consumed, and water supplied." To accurately determine how much water has been irrigated/consumed, it is necessary to establish comprehensive, standardized, and harmonized water measurement and control structures within the irrigation system. Currently, many systems still use floats to measure flow rates, and most systems have not completed operational management procedures, guidance, or regulations for monitoring and controlling water sources. For example, according to technical requirements, water measurement facilities need to be allocated at "upstream and downstream water intake culverts, regulating dams (inlets and on channels), water distribution structures for each household," which can lead to misunderstandings due to the varying number of facilities across systems, making application inconvenient. Additionally, data monitoring, recording, and distribution on the system are not comprehensive or regular: water measurements at Clusters and Stations are recorded and stored locally and reported to the company daily, but this data is stored only as handwritten records, lacking guidelines or regulations for units to compile, analyze, digitize, calculate, or use for production planning, management effectiveness evaluation, or station cluster activities. As a result, water irrigation management activities do not reflect the current usage status, the need to increase land productivity, the water supply situation, or the efficiency of water use within the system. Monitoring and evaluation (M&E) activities do not reflect the satisfaction of water usage needs, timely delivery, fairness, or the direct water distribution capacity to fields/capacity of the canal system.

For infrastructure management: According to regulations, correctly "determining the value of assets" for irrigation works, equipment serving management are assets assigned by the state to enterprises for management before operation, or "annually

assessing the condition of works, machinery, equipment, and operation capacity of works, systems..." to develop orders, lacks guidelines, criteria, or bases for determining asset values or the condition and operation of works, causing difficulties for units managing infrastructure during the evaluation process. State management is also facing challenges as it cannot evaluate the investment efficiency, economic benefits, or production service capabilities of each irrigation system, assess operational cost needs, maintenance plans, or have appropriate financial plans.

To enhance the efficiency of irrigation services, institutionalize and implement benchmarking systems, encourage enterprises managing irrigation works to invest in and use SCADA for water control in each irrigation system, and share data publicly through an IT system to support planning, monitoring, information disclosure, and customer feedback. The state needs to continue innovating irrigation service supply contracts through ordering mechanisms, planning tasks, and competitive bidding in managing and exploiting irrigation works, promoting specialization in volume-based water supply, transferring management to users.

3.4. Expectations

3.4.1. Investing in Upgrading and Enhancing Irrigation Systems

Projects invested in recent years, in addition to constructing urgent works, are aimed at improving existing irrigation systems through comprehensive investment from system-level to internal structures and related infrastructure. This includes enhancing the monitoring and control capabilities of water sources, water quality through the provision of equipment, strengthening data updating and analysis, and installing measurement devices to monitor water supply for various user groups within the management system.

3.4.2. Improving Management Organization Models and Enhancing Awareness of Relevant Organizations in Water Management and Distribution

The Ministry of Agriculture and Rural Development has been gradually developing medium and long-term strategies to innovate and restructure the irrigation sector to optimize the effectiveness of irrigation works. Focus areas include the development of irrigation for irrigation, water supply to support economic restructuring, industrialization, and modernization of agriculture and rural areas, and the development of socio-economic sectors. Specifically, efforts are concentrated on upgrading and modernizing existing irrigation systems to maximize design capacity. Furthermore, there is a continued effort to improve organizational structures, financial management mechanisms, actively apply and innovate cooperative water use organization models, improve regulations, provide guidance for irrigation system planning to serve the "concentration of agricultural

production" in building new rural areas, and enhance capacity-building at all levels in irrigation system management to effectively utilize investment resources for irrigation services, improve the quality of irrigation services, ensure sustainable development, and align with the agricultural production characteristics and practices of different regions.

3.4.3 Legal Framework and Related Policies Enhancement

In recent years, the State and the Ministry of Agriculture and Rural Development have been gradually strengthening and improving the legal framework and administrative documents supporting the management and exploitation of irrigation systems. For instance, the Irrigation Law 08/2017/QH14 issued on June 19, 2017, effective from July 1, 2018, and Decree No. 143/2003/ND-CP dated November 28, 2003; Decree No. 115/2008/ND-CP dated November 14, 2008; and Decree No. 67/2012/ND-CP dated September 10, 2012. To synchronize and implement the contents of Decree No. 115/2008/ND-CP, the Ministry of Agriculture and Rural Development issued Directive No. 1268/CT-BNN-TL on May 12, 2009, regarding enhancing the management and exploitation of irrigation works. Circular No. 05/2018/TT-BNNPTNT dated May 15, 2018, provides detailed regulations of the Irrigation Law. Additionally, to harmonize and support these policies, Circular No. 73/2018/TT-BTC dated August 15, 2018, by the Ministry of Finance guides the use of financial resources in the management and exploitation of irrigation works using state funds and the financial management regulations of state-owned companies tasked with managing and exploiting irrigation works, reflecting the activities of the units managing and exploiting irrigation works through water management and financial accounting management as the basis for compensating irrigation fees.

Regarding the management of enterprise operations exploiting irrigation works, Government Decree No. 60/2021/ND-CP dated June 21, 2021, regulates the rights to self-governance, responsibility for performing tasks, organizational apparatus, and finances for state-owned enterprise units. Moreover, Prime Ministerial Decision No. 224/2006/QD-TTg dated October 6, 2006, on issuing regulations on monitoring and evaluating the efficiency of state-owned enterprises' operations, has provided a legal corridor for consolidating and stabilizing the organization of enterprises managing and exploiting irrigation works. Additionally, Ministerial Decision No. 2891/QD-BNN-TL dated October 12, 2009, guides the establishment of economic and technical norms in the management, exploitation, and protection of irrigation works. Subsequently, Circular No. 56/2010/TT-BNNPTNT dated October 1, 2010, by the Ministry of Agriculture and Rural Development regulates certain activities of organizations managing and exploiting irrigation works. Circular No. 40/2011/TT-BNNPTNT dated May 27, 2011, stipulates the conditions and capacities of organizations and individuals participating in the management and operation

of irrigation systems. These are essential documents that have been and are being applied, providing a legal basis to help localities and units managing and exploiting irrigation works implement synchronized mechanisms and policies, while strengthening the management and exploitation of irrigation works.

The new irrigation fee policy is indeed a turning point in the management and exploitation of irrigation works. Government Decree No. 67/2012/ND-CP dated September 10, 2012, amends and supplements some provisions of Government Decree No. 143/2003/ND-CP dated November 28, 2003, detailing the implementation of some provisions of the Law on Exploitation and Protection of Irrigation Works. This decree adjusted the fee rates to be appropriate to the actual costs incurred by units managing and exploiting irrigation works compared to the irrigation fee rates stipulated in Government Decree No. 115/2008/ND-CP, with an average increase of 1.5 times. It also standardized the irrigation fee rates as compensation levels for projects invested with state budget and non-state budget funds, ensuring 100% of additional irrigation fee exemptions for central irrigation units and localities receiving subsidies from the central budget. With this new irrigation fee policy, it will be one of the positive solutions for investing in agriculture in rural areas, implementing the Party Central Committee's three agricultural policies, and also one of the practical tasks to serve social security policies, having strong impacts on macroeconomic policies to encourage farmers in difficult areas, limited in production conditions, to invest more positively in agricultural production, shifting production from rice to other economically efficient crops.

From 2000 to 2023, the Ministry of Agriculture and Rural Development has directed the review, supplementation, upgrading, and construction of new national standards to meet the country's socio-economic development requirements, integration with the world's advanced techniques and technologies, and ensure adaptation to natural disasters and climate change. The Ministry is continuing to develop, improve, and issue several documents regulating the quality assessment of irrigation services, policies creating proactive mechanisms for enterprises in managing and exploiting irrigation works. The benchmarking system will gradually be institutionalized and implemented to assess and evaluate the quality of service provision and activities of IMCs, water users based on appropriate criteria, ensuring the efficiency of investment and enhancing the operational benefits of irrigation systems towards multipurpose water supply,...

4. **Conclusion**

Regarding the state management system for irrigation, disaster prevention, the sector has continuously improved its machinery from central to local levels. Simultaneously, the construction and improvement of legal documents have been

attentively implemented. Notably, laws such as the Water Resources Law, the Dyke Law, the Disaster Prevention Law, and the Regulation on Exploitation and Protection of Irrigation Works have been promulgated. A system of guiding documents for implementation and enforcement has been established and issued.

In the field of scientific research and technology serving the restructuring of the irrigation sector, GIS technology (Geographic Information System based on computer technology) and remote sensing for monitoring and forecasting crop productivity, rice yields have been applied. The combination of GIS, remote sensing with mathematical models for managing droughts, saline intrusion, flooding, erosion, and riverbank protection is now being applied in the Mekong Delta and many other regions nationwide. Furthermore, the sector has researched and developed irrigation regimes, applied advanced irrigation technologies, and water-saving techniques for drought-prone areas in the South Central region. Drip irrigation, sprinkler irrigation in Dak Lak, irrigation for sugarcane in Quang Ngai, Binh Duong, flower and tomato irrigation in Son La, and medicinal plant irrigation in Phu Tho have been implemented.

Currently, the sector is researching the design of surface water drainage systems and water-saving irrigation techniques to help control diseases in pepper plants in the Central Highlands and the Southeast region. Despite the achievements, the irrigation sector still faces many difficulties. Many irrigation systems are currently designed to serve small-scale agricultural production, unable to meet the diverse and modern agricultural production requirements. The area under advanced, water-saving irrigation is still limited; the water quality of some systems does not guarantee clean and safe agricultural production; irrigation infrastructure serving aquaculture has not met the demand. Additionally, the construction of some urban, industrial, and transportation infrastructure has hindered flood drainage, increased water demand, and added pressure to irrigation systems.

Scientific and technological advancements in the irrigation sector are not closely aligned with production requirements, and the application in practice is limited. Additionally, the adoption of advanced technologies in forecasting, monitoring droughts, floods, saline intrusion, etc., is slow. Notably, the understanding of some management leaders and the public about current policies in managing, exploiting, and protecting irrigation works, especially policies on exemption, reduction of irrigation fees, is not correct or sufficient. Most perceive the policy of exempting or reducing irrigation fees as eliminating them entirely, whereas it is a government support measure to reduce the burden of agricultural production costs for farmers and provide funds for infrastructure maintenance and upgrades. Therefore, the active participation of the public in managing

and exploiting irrigation works, especially communal irrigation works, has not been fully realized.

Promoting the application of advanced, water-saving irrigation techniques to enhance productivity, quality, efficiency, and minimize risks for major crops with stable markets such as coffee, pepper, cashews, sugarcane, tea, fruit trees, and other dry crops. Simultaneously, integrating advanced, water-saving irrigation techniques with crop cultivation and aquaculture techniques to improve productivity and reduce production costs. For irrigation serving aquaculture, reviewing the irrigation planning for aquaculture, proposing and adjusting irrigation investment projects for aquaculture, and conducting research and applying sustainable water drainage solutions to serve aquaculture.

Regarding dam safety management, enhancing institutional systems, and policies in dam safety. Improving standards, economic-technical norms guiding dam safety management tasks such as dam safety assessment standards, guidelines for preparing flood inundation maps for downstream areas in emergency flood release situations, and dam breach. Enhancing the application of science and technology, international cooperation in dam safety management, such as monitoring technology, dam surveillance, forecasting, and real-time warning technologies to serve operation.

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