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Revenue collection and financial efficiency in irrigation projects: systematic review

Recaudación y eficiencia financiera en proyectos de irrigación: revisión sistemática

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Abstract
The objective of this study was to synthesize the existing literature on revenue collection and financial efficiency in irrigation projects in various countries. The PRISMA methodology was used to conduct a systematic review of international databases such as ProQuest, Scopus, Google Scholar, PubMed, Redalyc, and EBSCO. The search was conducted using keywords in Spanish and English related to irrigation projects and financial efficiency, considering publications between 2015 and 2025, without restriction by country. The results show that water tariff collection is a fundamental pillar for the financial sustainability of irrigation projects; however, in many cases, these revenues do not cover operating and maintenance (O&M) costs, compromising their viability. It is observed that tariffs established per surface area are insufficient, while volumetric tariffs can increase revenues and promote more efficient water use. Likewise, technological modernization, drip irrigation, and the reuse of treated water are identified as key strategies for improving the profitability and sustainability of the system. It is concluded that strengthening collection mechanisms, modernizing infrastructure, and encouraging community participation are essential actions to ensure the financial and operational efficiency of irrigation projects.

Keywords: water collection, financial efficiency, irrigation projects.

Resumen
El objetivo del presente estudio fue sintetizar la literatura existente sobre recaudación y eficiencia financiera en proyectos de irrigación en diversos países. Se empleó la metodología PRISMA para realizar una revisión sistemática en bases de datos internacionales como ProQuest, Scopus, Google Scholar, PubMed, Redalyc y EBSCO. La búsqueda se efectuó mediante palabras clave en español e inglés relacionadas con proyectos de riego y eficiencia financiera, considerando publicaciones entre 2015 y 2025, sin restricción por país. Los resultados evidencian que la recaudación de tarifas de agua constituye un pilar fundamental para la sostenibilidad financiera de los proyectos de irrigación; sin embargo, en numerosos casos, dichos ingresos no cubren los costos de operación y mantenimiento (O&M), comprometiendo su viabilidad. Se observa que las tarifas establecidas por superficie resultan insuficientes, mientras que las tarifas volumétricas pueden incrementar los ingresos y promover un uso más eficiente del agua. Asimismo, la modernización tecnológica, el riego por goteo y el reúso de agua tratada se identifican como estrategias clave para mejorar la rentabilidad y sostenibilidad del sistema. Se concluye que fortalecer los mecanismos de recaudación, modernizar la infraestructura y fomentar la participación comunitaria son acciones esenciales para garantizar la eficiencia financiera y operativa de los proyectos de irrigación.

Palabras clave: recaudación hídrica, eficiencia financiera, proyectos de irrigación.

Introduction
Irrigation is widely regarded as a critical component of agricultural production on a global scale. However, financial efficiency and optimal water application rates in these projects remain areas that require more systematic and in-depth analysis (Habteyes & Ward, 2020). Despite significant investments made in irrigation infrastructure

across various countries, many projects fail to achieve their initially projected gains or face serious long-term sustainability challenges. This situation underscores the urgent need for comprehensive assessments of both the economic and technical performance of these systems (Urfels et al., 2024).

The global expansion and modernization of irrigation schemes have generated a growing interest in understanding not only the physical efficiency of water use but also the financial viability of irrigation services as a whole. This encompasses aspects such as the costs of constructing initial infrastructure, operational and maintenance expenses, and sustainable financing mechanisms to ensure their continuity (Gany et al., 2019). International organizations like the Food and Agriculture Organization (FAO) and the World Bank emphasize the necessity of integrating clear financial criteria from the project design phase, as well as defining institutional arrangements to regulate system operations (Pérez-Blanco et al., 2020).

In this context, the literature examining the theory and practice of water pricing for agricultural use reveals a persistent tension. On one hand, it is argued that rates should reflect the marginal costs of service and the environmental externalities associated with water use. Nonetheless, the implementation of these principles faces political barriers, social equity considerations, and technical measurement limitations, such as the lack of monitoring devices or reliable data on actual consumption. As a result, many applied rates are set below the true cost of service, leading to inefficient and ineffective billing mechanisms (Pagliettini et al., 2020).

Overall, the literature highlights that financial efficiency in irrigation systems must combine economic instruments with appropriate institutional arrangements designed to reduce transaction costs and enhance the management capacity of organizations responsible for water governance (Berbel & Expósito, 2020). In various regions of the world, the efficiency of water use in agriculture has become a priority due to the increasing scarcity of water resources. This necessitates a thorough understanding of the economic implications of irrigation practices and their associated costs (Velasco-Muñoz et al., 2018), thereby justifying the present systematic review.

Consequently, the central question guiding this study was: Does water collection influence the financial efficiency of irrigation projects in different countries? Additionally, the following specific questions were formulated:

1. Does water collection contribute to the profitability and economic flow of irrigation projects across various countries?
2. Does water collection enhance the financial governance of these projects?
3. Does water collection improve cost-effectiveness and operational performance in irrigation projects?

Methodology

Eligibility criteria

The review included studies that met the following selection criteria: publications from 2015 to 2025, primarily indexed scientific articles from recognized databases, without geographical restrictions, addressing themes related to water resources in irrigation projects. The included studies employed various methodological approaches (quantitative, qualitative, or mixed), with the aim of analyzing findings from multiple perspectives. Opinion pieces, systematic or narrative reviews on the same topic, books, newsletters, monographs, and studies published in languages other than Spanish, English, or Portuguese were excluded.

Information sources

Studies were sought from the following academic databases: ProQuest, Scopus, Google Scholar, PubMed, Redalyc, and EBSCO. The last search was conducted in the final week of September 2025.

Search strategy

To identify studies, combinations of keywords in both Spanish and English were employed, such as: "irrigation projects," "hydraulic infrastructure," "irrigation systems," "financial efficiency," "profitability," "collection," and "costs." Before storing the records, date filters were applied according to the established inclusion criteria.

Selection process

Titles and abstracts were initially reviewed by the authors. Subsequently, full texts were read to confirm their relevance and final inclusion in the review. The Rayyan tool was utilized during the screening phase to control duplicates. Articles that showed the highest relevance and a direct relationship with the study variables were selected one by one.

Presentation of results

To organize and present the included studies, tables were created using Excel software. This tool facilitated the clear summarization of information such as author and year, journal, country, and key findings. The results were thematically organized according to objectives and findings, following a manual inductive coding process in which categories emerged from patterns identified in the data (Braun & Clarke, 2006). The coding grouped the findings into central themes linked to collection and financial efficiency, allowing for a coherent integration of the selected evidence.

Results

Figure 1
PRISMA diagram

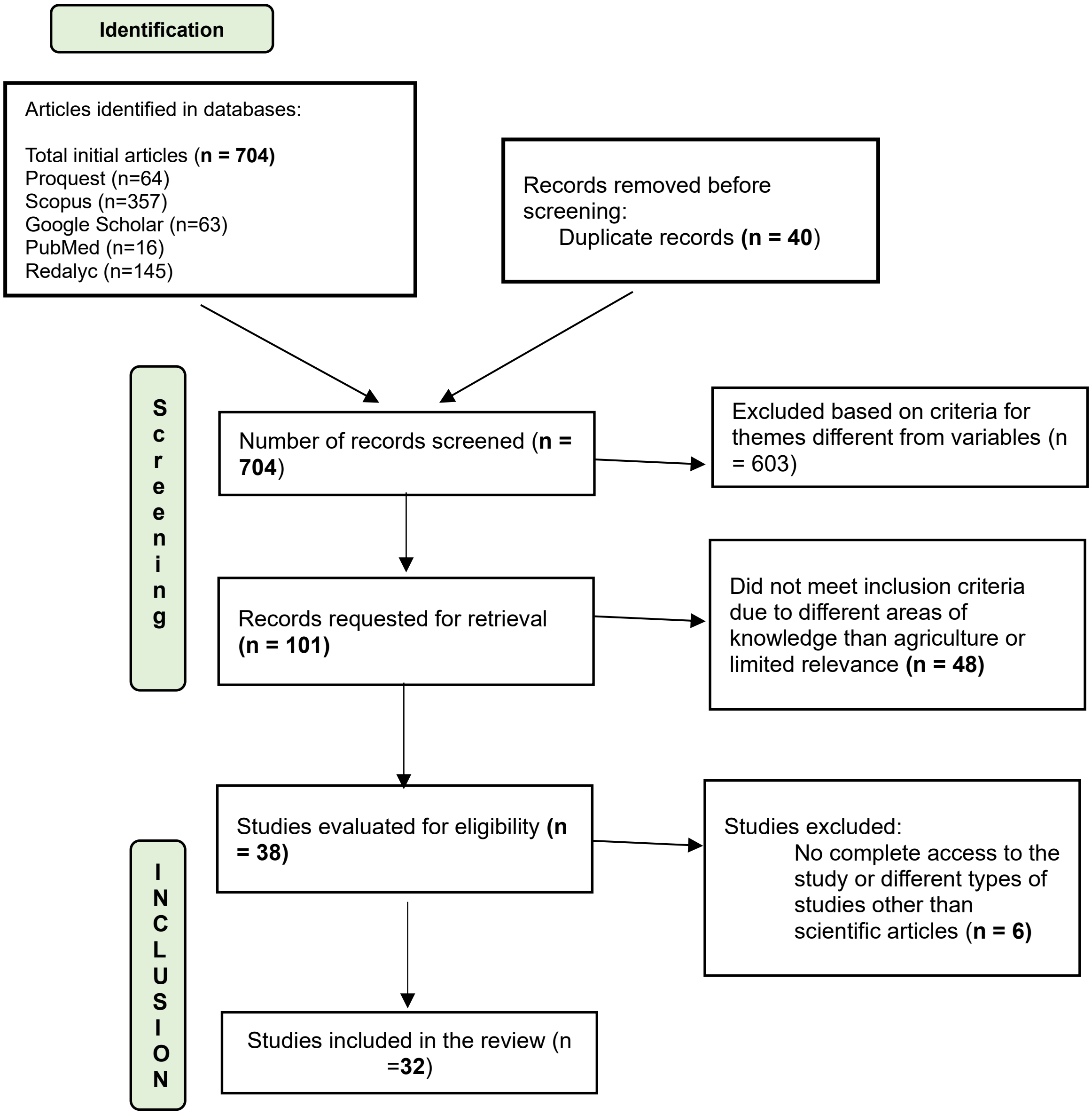


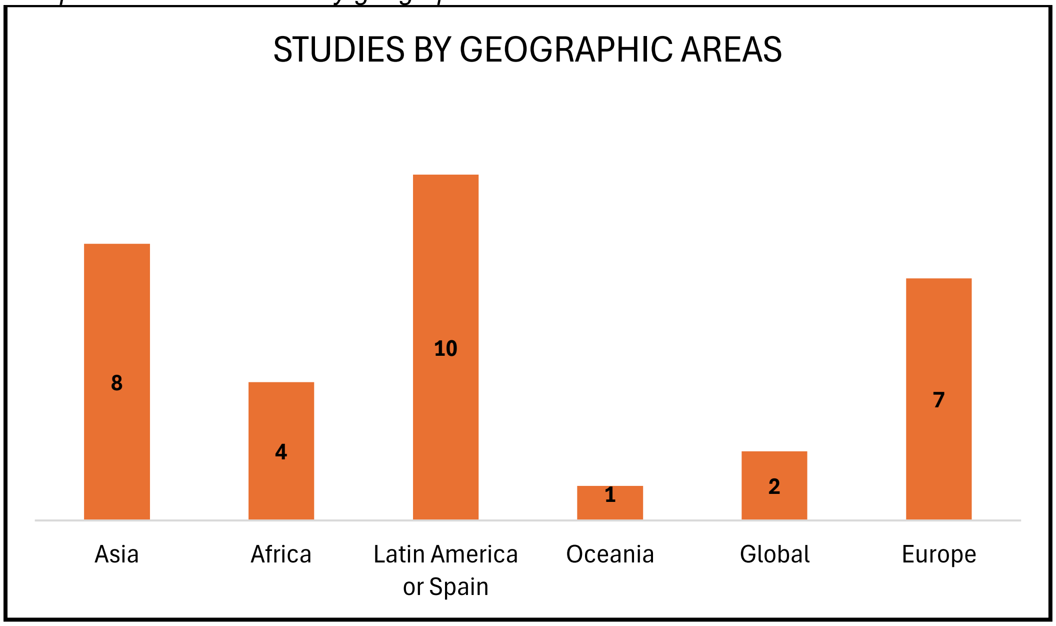
Table 1
Matrix of results from synthesis of records

Author-Year	Journal	Country	Financial findings on irrigation projects
(Akram et al., 2019)	Custos e @gronegócio on line	Pakistan	The average profit per hectare of conventional wheat exceeds that of organic, which is highly significant. Water costs and total costs vary between districts; however, conventional agriculture generally has higher total costs per hectare.
(Al-Kathiri et al., 2025)	Journal of Environmental and Earth Sciences	Oman	Drip irrigation has the highest efficiency in water use (80–90%) compared to traditional methods such as surface irrigation (50–65%), implying better economic return on water resources.
(Aldaya et al., 2023)	Agricultural Water Management	Spain	An increase of €0.1/m³ in the price of water can cause losses of €400/ha. The drier and more productive regions are more sensitive to increases in water prices. Rising water prices lead to reduced water usage per hectare.
(Ali et al., 2020)	Irrigation and Drainage	Egypt	Investment in drip irrigation (DIS) is profitable, achieving a 67% increase in net yield per hectare compared to conventional irrigation. The Benefit-Cost Ratio is 1.35, and the Net Present Value is $1,720.
(Arslan et al., 2024)	Agricultural Water Management	Turkey	Effective financial management led to reduced O&M costs, attributed to qualified personnel (managers, technicians), implementation of good agricultural practices, an increase in beneficiaries, better control of diversion structures, and lower repair costs.
(Bui et al., 2018)	Sustainability	Vietnam	There is a significant difference in irrigation investment between regions; lowland areas have more benefits, while highland areas must invest on their own, spending an average of 7.5 million on piping systems.
(Canaj et al., 2021)	Journal of Cleaner Production	Italy	The total cost (internal and external) confirms that the reuse of treated wastewater for irrigation yields external benefits that outweigh costs. The internal cost of supplying treated water (€0.42/m³) is comparable to groundwater extraction.
(Chalas et al., 2020)	Aqua-LAC	Dominican Republic	The current surface water fee does not cover operational and maintenance costs; the service is unsustainable. The total value of water lost annually (water, including state investment) exceeds 512 million RD$/year. The average irrigation efficiency is critically low (31.8%).
(Csortan et al., 2020)	PLOS ONE	Australia	Small orchards have higher ongoing operational costs per square meter than large orchards. The payback period varies significantly; as low as 0.5 years for mixed-bed orchards and as high as 4.6 years for laying hen operations.
(Darma et al., 2025)	Sustainability	Indonesia	Irrigation systems are sustainable if flexible payments and collaborative financing exist. Cost-sharing models and public-private partnerships help reduce climate and financial risks, improving agricultural resilience to floods and droughts.
(Echchelh et al., 2021)	Agricultural Water Management	Qatar	Mixing treated and desalinated water may be viable for irrigation in arid climates; management costs can be up to 2.5 times greater than disposing of the water. The value provided by crops and sustainable alternatives justifies the investment and reduces negative impacts on soil and crops.
(Esperon-Rodriguez et al., 2025)	Sustainable Cities and Society	Global (109 cities in 21 countries)	Differences in infrastructure and economic resources between the Global North and South influence water management and irrigation practices. However, the impact of water pricing and infrastructure was not quantified.

(Franco Sánchez et al., 2018)	Revista Mexicana de Ciencias Agrícolas	Mexico	The irrigation water quota is considered an indirect production cost. Export-oriented units have lower production costs and higher profitability compared to those focused on the domestic market.
(Ghosh et al., 2025)	Rasayan Journal of Chemistry	India	Economic profitability indicates that using clean water (effluent), previously designated for limited irrigation or waste, to produce green hydrogen generates higher revenues. This new utility increases total profit over 10 years, yielding 20 times more than the traditional system.
(Hamam et al., 2023)	Economia agro-alimentare / Food Economy	Global (Review of Studies)	Efficient irrigation management in cost-benefit terms is financially key in countries like India and China. Improving practices such as using irrigation scheduling tools can significantly enhance economic efficiency in production.
(Kettani et al., 2025)	Agricultural Water Management	Morocco	Modernizing irrigation networks allowed for pressure adjustment and resizing of pipes, making them efficient. Using drip irrigation and low-pressure sprinklers reduces energy-water costs and improves accessibility for farmers. Including cost-benefit analysis and participatory governance ensures economic sustainability.
(Kovalenko et al., 2020)	Journal of Water and Land Development	Ukraine	Investment in the reconstruction and improvement of rice irrigation systems proved feasible. Improvement projects demonstrate high profitability, with a Return on Investment Index of 2.47 and an Internal Rate of Return of up to 9.37%.
(Flores et al., 2017)	CIENCIA ergo sum	Mexico	Bean production with pumped irrigation is unsustainable due to low water productivity; although the cost of water is low ($0.48/m³), agricultural efficiency does not compensate, necessitating more efficient strategies.
(Boguniewicz-Zabłocka & Capodaglio, 2020)	Sustainability	Poland	Using rain gardens or tanks to capture rainwater is mentioned as a long-term economical option, as it reduces water costs through reuse.
(Echchelh et al., 2020)	Agricultural Water Management	Arabia	The cost of recycled water is $0.45/m³ while desalinated water is $0.89/m³. Such rates are important for calculating sustainable irrigation costs when mixed with wastewater, yielding results cheaper than traditional disposal methods.
(Manikowski & Strapasson, 2016)	Frontiers in Environmental Science	Senegal	For a yield of 6 tons per hectare, the irrigation project generated a return of 6.1% but had a negative present value. For a medium budget, the return was negative.
(Marshall et al., 2021)	Aqua-LAC	Chile	An average irrigation water savings of 28% to 40% was achieved between the first and second seasons. This improved water and electricity use efficiency, as well as revenue generated per cubic meter of water used.
(Medina-Matute et al., 2024)	Journal Scientific MQRInvestigar	Ecuador	The Chambo-Guano Irrigation System offers the highest short-term return on investment with a yield of 12.5%. All evaluated hydraulic projects are considered financially viable.
(Musz-Pomorska et al., 2020)	Sustainability (Switzerland)	Poland	The analysis aims to determine the economic sustainability of rainwater harvesting system designs by comparing the present value of benefits against costs.
(Pacheco-Vega, 2015)	Región y sociedad	Mexico	Industries that consume large amounts of water in arid areas are problematic. The reuse of treated wastewater was a strategy to irrigate parks and gardens. The privatization of water supply was criticized for service deficiencies.

(Petrović & Csambalik, 2025)	Land	Czech Republic, Slovakia, Poland, Hungary	The economic viability of precision agriculture technologies (PATs) is a crucial factor for their successful adoption in agricultural systems.
(Salazar Guevara, 2022)	Thesis	Peru	There were financial losses in 2019 and 2020 (negative Return on Assets and Financial Return), with insufficient available funds to cover immediate debts. The proposed financial planning projects a 9% profit.
(Steyn et al., 2016)	Field Crops Research	South Africa	34% of energy used comes from fertilizers and 30% from irrigation. The energy required to pump water is linked to the amount of irrigation and the pumping depth; significant differences in resource efficiency exist between producers and regions.
(Tinco Aspilcueta & Vidal Laguna, 2024)	Thesis	Peru	The use of concrete canvas resulted in a budget 14% lower than traditional concrete for rural channels. The placement time for concrete canvas is only 16 days, optimizing costs and construction time.
(Tsagkoudis et al., 2025)	Water	Greece	Key economic indicators analyzed focus on costs (capital, functional, administrative), cost per volume, revenue per volume, and the ability to recover expenses through tariffs.
(Zagonari, 2017)	Water	Iraq	The irrigation project yielded a return of 7.1%. The viable cost of water should be between $0.32 and $0.57 per cubic meter; loan interest should be below 3.0%. The project is financially viable for 13.6% of reliable solutions.
(Zavala-García & Valencia-Zambrano, 2021)	Polo del conocimiento	Ecuador	Fee collection covers operational and maintenance costs. Water boards do not collect enough to cover these expenses, which is insignificant ($432 annually for 1,200 ha) compared to what is needed.

Figure 2
Statistics on the prevalence of studies by geographic areas



Note. The figure shows the number of studies considered in the review by geographic areas, emphasizing studies in Spanish

Frequencies of studies

A total of 32 studies were analyzed, with a greater concentration of publications in recent years (2020-2025), comprising 22 articles (69%). This reflects an increasing interest in sustainability and financial efficiency within irrigation systems. Regarding geographic distribution, studies from Spanish-speaking countries (Mexico, Peru, Chile, Ecuador, Dominican Republic, and Spain) accounted for 10 articles (31%). Additionally, research conducted in Asian countries (Pakistan, Oman, Egypt, Turkey, Vietnam, India, Indonesia, and Qatar) yielded 8 articles (25%), while Europe (Italy, Poland, Ukraine, Hungary, Czech Republic, Slovakia, and Greece) contributed 7 articles (21%). Studies from Africa (Egypt, Morocco, Senegal, and South Africa) included 4 articles (13%), and global and Australian studies comprised 3 articles (10%). Methodologically, quantitative studies and those based on financial modeling predominated (20 articles, 62%), followed by qualitative studies (12 articles, 38%). The observed methodological diversity and geographical breadth among the 32 reviewed studies reinforce the relevance of analyzing revenue collection and financial efficiency as key indicators for guiding future research, as well as for the design and implementation of public policies in the field of irrigation.

Discussion

The collection of water tariffs is a key component for the financial efficiency of irrigation projects; however, in many cases, this collection fails to cover the costs of operation and maintenance, jeopardizing the long-term viability of these systems. For instance, Chalas et al. (2020) demonstrated in the Dominican Republic that surface-based tariffs do not cover O&M costs, resulting in significant economic losses due to unrecovered water volumes and critically low average irrigation efficiency (31.84%). Similarly, Zavala-García and Valencia-Zambrano (2021) reported that in the irrigation system of a dam, the revenue collected is insufficient, barely reaching $432 annually for 1,200 hectares, which jeopardizes the basic maintenance of infrastructure. These results align with the findings of Tsagkoudis et al. (2025), who propose that volumetric tariffs, rather than fixed surface tariffs, can enhance cost recovery and promote more rational use of water resources.

In Iraq, the establishment of accessible tariffs and credits enabled the viability of irrigation projects (Zagonari, 2017). Likewise, in Morocco, the modernization of irrigation involved significant investments sustained through an efficient revenue collection scheme (Kettani et al., 2025), reaffirming that financial sustainability relies on appropriate tariff structures. Similarly, studies in Egypt and Qatar demonstrated that the economic efficiency of drip irrigation and treated water reuse is closely linked to sound financial management, where monitoring technologies and joint financing models make these projects more profitable (Ali et al., 2020; Echchelh et al., 2020).

Category 1: Cost recovery in irrigation projects

Revenue collection for irrigation projects continues to be insufficient to cover operation and maintenance costs, especially in socioeconomically vulnerable contexts. Madrigal Delgado (2023) notes that local governments in Mexico exhibit serious fiscal imbalances, with self-generated revenues accounting for only 24% of the total, limiting their capacity to finance essential services such as irrigation. Furthermore, the lack of transparency in water management and regulatory conflicts hinder efficient tariff implementation (Pacheco-Vega, 2015). Consistently, studies in the Dominican Republic and Ecuador show that current tariffs also fail to cover required costs, leading to losses and weakening the sustainability of systems (Chalas et al., 2020; Zavala-García & Valencia-Zambrano, 2021). This problem is characteristic of countries with low financial autonomy, where local revenue collection is limited.

Category 2: Profitability and economic flow

Agricultural profitability depends on both water use efficiency and effective financial management. While drip irrigation may enhance agricultural yields, low tariff collection undermines the system's sustainability (Chalas et al., 2020; Zavala-García & Valencia-Zambrano, 2021). Technological modernization and treated water reuse become feasible when clear financial governance exists (Canaj et al., 2021; Kettani et al., 2025). However, the fiscal limitations of local governments challenge initial investment in these technologies (Madrigal Delgado, 2023). As Velasco-Muñoz et al. (2018) argue, water use efficiency contributes to both environmental and productive sustainability but requires integrated and coordinated approaches. In contrast, research in Mexico (Flores et al., 2017) and Senegal (Manikowski & Strapasson, 2016) indicates that traditional systems yield marginal or negative returns due to high energy costs and inadequate tariffs.

Category 3: Financial governance

Governance and financial management are decisive elements for the sustainability of irrigation systems. The lack of coordination among government levels and limited fiscal autonomy restrict the capacity to improve revenue collection mechanisms (Madrigal Delgado, 2023). The literature agrees that effective governance involves technical training, transparency in administration, and efficiency in resource usage. In contrast, the absence of institutional oversight and insufficient revenue collection limits the continuity and maintenance of projects (Chalas et al., 2020; Zavala-García & Valencia-Zambrano, 2021).

Category 4: Cost-effectiveness and operational performance

Cost-effectiveness analyses show that technological modernization favors the sustainability of irrigation projects. Technologies such as precision irrigation and soil moisture conservation can increase agricultural productivity and reduce environmental costs. Nevertheless, fiscal constraints hinder access to these innovations (Madrigal Delgado, 2023). Pérez-Blanco et al. (2020) emphasize that although these technologies enhance efficiency, initial investment and incentives are required for their implementation. In Italy and Qatar, treated wastewater reuse has proven to be a cost-effective alternative, but its implementation depends on strong institutional structures (Canaj et al., 2021; Echchelh et al., 2020).

In summary, strengthening revenue collection and financial governance, along with promoting efficient technologies, is essential for the sustainability of irrigation systems. These actions directly contribute to achieving SDG 6 (clean water and sanitation) and SDG 13 (climate action), by improving the availability, responsible use, and resilience of water resources in the agricultural sector.

Conclusions

Overall, the findings identified across various countries indicate that, in the future, it is essential to address the lack of fiscal autonomy and the influence of external factors that limit local governments' capacity to finance efficient irrigation systems. The necessity of prioritizing the implementation of volumetric tariffs is emphasized, as they enhance both revenue and the rational use of water. Additionally, technological modernization and the adoption of drip irrigation are identified as essential elements for increasing profitability and promoting the sustainability of irrigation systems.

Therefore, the management of water resources can benefit from an integrated approach that combines technological modernization, transparency in revenue collection systems, and community participation. Such an approach would contribute to ensuring the financial and operational sustainability of irrigation projects, thereby strengthening their continuity and effectiveness over time.

Regarding the study's limitations, due to restricted access to information, the review focused solely on five databases and research published in the last ten years. Future studies could expand the analysis by incorporating additional recognized databases, such as Web of Science, as well as widening the temporal range. Furthermore, including articles in Portuguese could significantly increase the number of studies available for analysis.

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