

CONDITIONS OF SUCCESS FOR CONNECTED TECHNOLOGIES IN COLLECTIVE IRRIGATION

CONDITIONS DE RÉUSSITE DES TECHNOLOGIES CONNECTÉES DANS L'IRRIGATION COLLECTIVE

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ABSTRACT

Climate change is now an observable reality, with increasing droughts, rising temperatures and growing pressure on water resources, particularly in Mediterranean regions of southern France. In this context, irrigation has become essential for securing agricultural production and improving farm resilience. Since agriculture accounts for nearly 70% of global freshwater withdrawals, improving water-use efficiency has become a major challenge.

Over the last decade, connected irrigation technologies have rapidly developed through advances in digitalisation, sensors, telecommunications and data-processing tools. Smart meters, remote-control systems, IoT sensors and real-time monitoring platforms are increasingly integrated into collective irrigation networks to optimise water distribution and consumption monitoring.

This article analyses the contributions, limitations and conditions for success of connected technologies in collective irrigation systems. This analysis is based on a review of scientific literature, stakeholder exchanges and operational feedback from projects conducted by BRL Ingénierie in France. The analysis considers four complementary dimensions: technical performance, economic viability, organisational integration and socio-governance acceptability.

Results show that connected technologies improve network management through real-time monitoring, leak detection, irrigation control and faster operational response. They also support the transition toward data-driven² irrigation management. Several studies report water savings ranging from 10% to 30% when smart technologies are combined with monitoring and decision-support systems. However, benefits remain highly dependent on infrastructure quality, data reliability, organisational capacity and user support. The study concludes that the effectiveness of connected irrigation systems depends less on the technology itself than on its integration into coherent socio-technical strategies combining adapted infrastructure, human support and collective water governance.

Keywords: Connected irrigation; collective irrigation; smart technologies; water management; irrigation efficiency; water governance; climate change adaptation.

RÉSUMÉ

Le changement climatique est désormais une réalité observable, marquée par une multiplication des sécheresses, une hausse des températures et une pression croissante sur les ressources en eau, en particulier dans les régions méditerranéennes du sud de la France. Dans ce contexte, l'irrigation est devenue indispensable pour sécuriser la production agricole et renforcer la résilience des

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2 Data-driven refers to a decision-making approach that relies on data analysis and empirical evidence rather than intuition or personal experience.

exploitations. L'agriculture représentant près de 70 % des prélèvements mondiaux d'eau douce, l'amélioration de l'efficacité de l'utilisation de l'eau constitue désormais un enjeu majeur.

Au cours de la dernière décennie, les technologies d'irrigation connectée se sont rapidement développées grâce aux progrès de la numérisation, des capteurs, des télécommunications et des outils de traitement des données. Les compteurs intelligents, les systèmes de télécommande, les capteurs de l'Internet des objets (IoT) et les plateformes de suivi en temps réel sont de plus en plus intégrés aux réseaux d'irrigation collective afin d'optimiser la distribution de l'eau et le suivi de la consommation.

Cet article analyse les apports, les limites et les conditions de réussite des technologies connectées dans les systèmes d'irrigation collective. L'analyse repose sur une revue de la littérature scientifique, des échanges avec les parties prenantes et des retours d'expérience opérationnels issus de projets menés par BRL Ingénierie en France. Elle prend en compte quatre dimensions complémentaires : les performances techniques, la viabilité économique, l'intégration organisationnelle et l'acceptabilité sociale et en matière de gouvernance.

Les résultats montrent que les technologies connectées améliorent la gestion des réseaux grâce au suivi en temps réel, à la détection des fuites, au pilotage de l'irrigation et à une réponse opérationnelle plus rapide. Elles favorisent également la transition vers une gestion de l'irrigation fondée sur les données. Plusieurs études font état d'économies d'eau comprises entre 10 % et 30 % lorsque les technologies intelligentes sont associées à des systèmes de suivi et d'aide à la décision. Toutefois, les avantages restent fortement tributaires de la qualité des infrastructures, de la fiabilité des données, des capacités organisationnelles et de l'accompagnement des utilisateurs. L'étude conclut que l'efficacité des systèmes d'irrigation connectés dépend moins de la technologie elle-même que de son intégration dans des stratégies sociotechniques cohérentes associant des infrastructures adaptées, un accompagnement humain et une gouvernance collective de l'eau.

Mots clés : Irrigation connectée; Irrigation collective; Technologies intelligentes; Gestion de l'eau; Efficacité de l'irrigation; Gouvernance de l'eau; Adaptation au changement climatique.

INTRODUCTION

Climate change is increasing pressure on water resources worldwide. In many Mediterranean regions, rising temperatures, decreasing rainfall frequency, and the intensification of drought events are directly affecting agricultural systems and compromising water availability.

In this context, irrigation has become an essential tool for securing agricultural production and maintaining farm resilience in the face of climate-related hazards. However, according to the Food and Agriculture Organization (FAO), agriculture already accounts for nearly 70% of global freshwater withdrawals, highlighting the need to improve water-use efficiency and strengthen the adaptive capacity of irrigated systems.

In response to these challenges, connected irrigation technologies have experienced rapid development over the past decade. Advances in digitalization, smart sensors, telecommunications, and data processing have fostered the emergence of numerous tools dedicated to irrigation management and hydraulic network operation. Smart meters, connected hydrants, remote management systems, IoT sensors, real-time monitoring platforms, and decision-support tools are progressively being integrated into irrigation systems to optimize water applications, reduce losses, and improve consumption monitoring.

Beyond the expected technical benefits, the deployment of these technologies also raises critical issues related to user acceptance and adoption. The use of digital interfaces, mobile applications, and connected management tools represents a notable change in practices for many irrigators and irrigation network managers. The adoption of these solutions, which was far from self-evident only a

few years ago, requires user-friendly tools, appropriate support mechanisms, and the development of new digital skills. Human and organizational dimensions therefore emerge as key determinants of the success of connected irrigation systems.

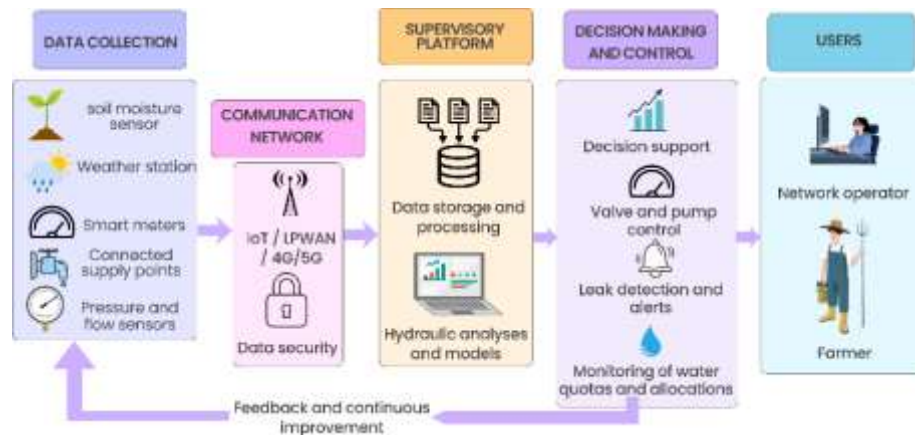


FIGURE I: ARCHITECTURE OF A CONNECTED IRRIGATION SYSTEM

Within collective irrigation networks, these technologies offer promising opportunities to improve infrastructure management and enhance the overall efficiency of water distribution. They enable real-time monitoring of water consumption, improve managers' responsiveness, facilitate the detection of operational anomalies, and support flow regulation and quota management. At the field scale, irrigation scheduling tools also contribute to adjusting water applications according to actual crop requirements and local soil and climatic conditions.

However, despite the promises associated with connected irrigation, field results remain mixed. Numerous studies highlight the potential for water savings and efficiency improvements, yet the actual conditions required for successful deployment and adoption remain insufficiently explored, particularly in collective irrigation systems. Observed performance depends on several factors, including data reliability, the organizational capacity of network managers, user acceptance and support, and water governance arrangements. In some older or insufficiently modernized networks, the integration of connected technologies may face structural, technical, and human constraints that limit their actual effectiveness.

In this context, the key question is no longer whether connected technologies can improve water management, but rather under which technical, organizational, and governance conditions they can contribute to more efficient and equitable collective irrigation management. This article provides a critical analysis of the contributions, limitations, and success factors of connected technologies in collective irrigation systems.

MATERIALS AND METHODS

This article is based on a review of the scientific literature, discussions with various stakeholders from the agricultural sector, and operational feedback gathered through projects conducted by BRL Ingénierie. The objective was to identify the main drivers and barriers to the deployment of connected irrigation technologies in order to better understand their potential contribution to more efficient, resilient, and sustainable agricultural water management in the future.

Literature Review

A review of the scientific and technical literature was conducted to identify the main trends, observed benefits, and limitations associated with connected technologies applied to irrigation. The analysis focused on four complementary dimensions: (i) digital technologies applied to irrigation (sensors, IoT,

remote management systems, and decision-support tools), (ii) their contribution to the performance and efficiency of irrigated systems, (iii) their integration into collective irrigation networks, and (iv) their implications for governance, organizational arrangements, and user adoption.

The review drew upon scientific articles, institutional reports, and technical publications produced by international organizations and research institutes specializing in agricultural water management. Operational documents and feedback reports from stakeholders involved in the connected irrigation sector (BRL Groupe, 2026; Aquadoc, 2024; Weenat, 2022) were also analyzed in order to incorporate practical insights from field applications.

Stakeholder Consultations

The study was further enriched through discussions and feedback collected from a range of stakeholders involved in irrigation and agricultural water management. Interviews and exchanges were conducted with farmers, irrigation network managers, engineering consultancies, technology providers, and institutional stakeholders in France, Australia, New Caledonia, and Spain. These exchanges provided valuable insights into:

- the operational benefits associated with connected technologies;
- the main technical and organizational constraints encountered during deployment;
- the factors influencing the adoption and appropriation of digital tools;
- the perceived impacts on irrigation practices and collective water management.

Case Studies

To complement the analysis, practical field experience was examined through two case studies derived from collective irrigation system development and modernization projects carried out by BRL Ingénierie (BRLi).

The first case study concerns the design and implementation of a newly developed connected irrigation network incorporating metering and control devices from the outset of the project. This type of project provides an opportunity to assess how digital technologies can be integrated into new infrastructure, as well as the technical and organizational choices associated with their deployment.

The second case study focuses on the modernization of an irrigation network managed by an Agricultural Water Users Association (ASA) located in the Pyrénées-Orientales region of southern France. In this project, metering and control devices were evaluated for installation at each irrigation outlet. This case illustrates the challenges associated with integrating connected technologies into an existing, often aging, irrigation network facing specific technical, organizational, and social acceptance constraints.

These case studies provide concrete insights into the practical implementation of connected irrigation systems. They highlight key success factors, constraints encountered from the project design phase onward, and stakeholder expectations regarding performance, ease of use, and efficiency gains.

RESULTS

Improved operational management

The analysis highlights that connected technologies can significantly improve the operational management of collective irrigation networks. Connected hydrants, smart meters, and remote management systems enable real-time monitoring of water consumption and hydraulic network performance, providing managers with greater responsiveness when anomalies occur. Leak detection, pressure monitoring, and remote equipment control contribute to more accurate water distribution management and a reduction in operational losses. Field experience confirms these benefits.

The deployment of connected management systems has improved consumption monitoring and enabled more precise adaptation of network operations according to both water availability and irrigation demand. Connected technologies also facilitate the implementation of water-use regulation measures during periods of resource scarcity. Improved traceability of water withdrawals and greater transparency in consumption data strengthen managers' ability to enforce quotas or water-use restrictions during drought events.

BENEFITS 	LIMITATIONS AND CHALLENGES
Water Saving : 10 to 30 % according to studies	High investment and maintenance costs
Real Time monitoring and improved network visibility	Dependence on connectivity and energy supply
Rapid leak and anomaly detection	Complex integration into legacy networks
Remote control and increased operator responsiveness	Data quality, reliability, and management
Transparency and traceability of water consumption	Social acceptability and perceived surveillance
Support for sustainable and adaptative management	risk of rebound effect

FIGURE II: CONTRIBUTIONS OF CONNECTED TECHNOLOGIES TO COLLECTIVE IRRIGATION SYSTEMS

Water savings and irrigation efficiency

Several studies, stakeholder exchanges, and field experiences confirm the significant potential of connected technologies to improve irrigation efficiency and generate substantial water savings.

These tools allow managers to monitor water consumption and pressure levels in real time while rapidly identifying equipment failures, leaks, or other operational issues within the network. Alert systems can be configured to detect abnormal situations, while safety thresholds may trig.

As a result, managers benefit from a comprehensive tool for network monitoring, supervision, and visualization. Beyond improving day-to-day operations, these technologies contribute to optimizing water distribution and pumping efficiency, generating both water and energy savings.

Such systems also facilitate the implementation of rotational water allocation schemes among irrigators, an increasingly important aspect in the context of potential water-use conflicts during periods of restriction. Network managers can define individual water quotas, while irrigators can reserve irrigation time slots corresponding to their allocated water volumes.

This rotational allocation approach indirectly contributes to water conservation by distributing withdrawals more efficiently over time. It helps smooth demand peaks during critical periods and reduces excessive pressure on both the network and available water resources. This improved distribution of withdrawals can also optimize pumping station operations and generate additional energy savings.

The integration of field-scale irrigation management with collective network management appears to be a particularly promising lever for improving the overall efficiency and sustainability of irrigated systems.

Furthermore, these systems can be connected to a range of monitoring tools and sensors (soil, climate, and consumption monitoring), providing users with additional information to better match water applications to actual crop requirements. Connected technologies therefore become genuine management and decision-support tools for irrigation.

Historical records of irrigation practices and water consumption also allow irrigators to capitalize on their own experience by identifying the most effective irrigation strategies from one season to the next and adapting them to changing conditions.

From empirical irrigation to data-driven management

Field experience highlights a gradual transition from predominantly empirical irrigation practices; where farmers mainly relied on irrigation duration; to a management approach increasingly based on the combined analysis of water consumption data, weather conditions, soil moisture, and crop water requirements.

Traditionally, irrigation decisions relied heavily on farmers' experience, customary practices, or visual observation of fields. Connected technologies promote a more objective and multifactorial approach by providing access to real-time operational data. The integration of sensors, weather stations, and decision-support tools enables more accurate adjustment of irrigation applications by taking into account soil moisture conditions, climatic demand, and water consumption patterns, thereby supporting more responsive and dynamic irrigation management.

This evolution also improves the visibility of water use and strengthens users' awareness of water resource management. Several stakeholders reported that access to real-time consumption data often encourages more responsible behaviour and facilitates dialogue between irrigators and network managers. This "nudge effect"³ may positively influence irrigation practices by making water consumption more visible and easier to understand.

However, field experience also shows that data availability alone does not automatically lead to improved practices. The interpretation of information, the reliability of measurements, and users' ability to integrate these tools into their decision-making processes remain essential conditions for their effective use.

Differences between modern and old irrigation networks

Field experience reveals significant differences in both study requirements and implementation processes between newly developed connected irrigation networks and the modernization of older systems.

The creation of new networks generally allows infrastructure to be designed and sized without major technical constraints. The main challenge lies in accurately identifying users' needs and expectations in order to select the most appropriate technological solution. In contrast, older networks often present significant structural constraints that limit the integration of connected technologies. Existing infrastructure may be poorly documented, equipment may be heterogeneous, and hydraulic systems may not be well suited to digital monitoring and control. These conditions increase installation complexity, maintenance requirements, and operational uncertainties. Several stakeholders also emphasized that, in some aging networks, connected technologies primarily reveal pre-existing

³ Light-touch intervention or device aimed at steering individuals' behaviour in a predictable way, without coercion or obligation, by altering the way choices are presented.

malfunctions rather than directly improving system performance. In such contexts, the integration of connected technologies alone is often insufficient when prior infrastructure rehabilitation remains necessary.

In both situations, user interfaces must remain simple, intuitive, and user-friendly. Particular attention should also be paid to interoperability between existing and future sensors, devices, and digital tools deployed across the network, enabling information to be centralized within a common platform and thereby facilitating network management.

Human and organisational impacts

Beyond their technical benefits, connected technologies also generate significant organizational and social transformations. The introduction of digital tools changes irrigation management practices and requires the development of new skills among both irrigators and network managers.

Many stakeholders emphasized the importance of user support during the deployment of these technologies. Irrigators must now be able to interpret digital data, use connected interfaces, and integrate this information into their irrigation decisions. While this evolution promotes more data-oriented management practices, it may also create difficulties for users who are less familiar with digital technologies.

Connected systems also influence collective water governance by improving the transparency and traceability of water withdrawals. The sharing of operational information can facilitate communication between managers and irrigators and help reduce certain water-use conflicts during periods of resource scarcity.

Nevertheless, there are still several limitations. Some users perceive these technologies as instruments of increased monitoring and control over water use, potentially reducing their autonomy in irrigation management. Others express concerns regarding equipment reliability, maintenance requirements, or the lack of long-term technical support. Economic constraints also remain significant, particularly for small farms and less modernized irrigation networks.

These findings confirm that the success of connected irrigation systems hinges as much on organisational and human adoption as on their technical performance.

DISCUSSION

Why technology works in some contexts



FIGURE III: KEY SUCCESS FACTORS FOR CONNECTED IRRIGATION SYSTEMS

The study shows that the effectiveness of connected technologies is strongly dependent on the conditions in which they are deployed. The most successful projects tend to be associated with modernised infrastructure, reliable hydraulic regulation and transparent governance of the irrigation network. In such contexts, connected tools can significantly enhance network management, control water withdrawal, and optimise water usage.

User support also emerges as a critical success factor. Irrigators and network managers require training, technical assistance, and long-term support to fully understand and effectively use digital tools. The quality, reliability, and readability of data likewise play a key role in technology adoption and in building trust in connected systems.

Finally, collective water governance strongly influences the effectiveness of connected technologies. Clear management rules, effective coordination among stakeholders, and transparent resource allocation mechanisms appear essential to ensure the efficient and equitable use of these technologies.

Towards integrated water management

The findings clearly highlight the need to integrate connected technologies into broader water management strategies combining infrastructure modernization, digital innovation, and sustainable agronomic practices.

Connected irrigation systems can significantly improve water-use efficiency, particularly when combined with complementary measures such as mulching, cover cropping, or the selection of crop varieties that are more resilient to water stress.

The integration of field-scale irrigation management with the supervision of collective irrigation networks also appears essential for optimizing water distribution at the territorial level. From this perspective, connected technologies should be regarded as enabling tools within broader socio-technical systems that combine technological innovation, human support, and collective water governance.

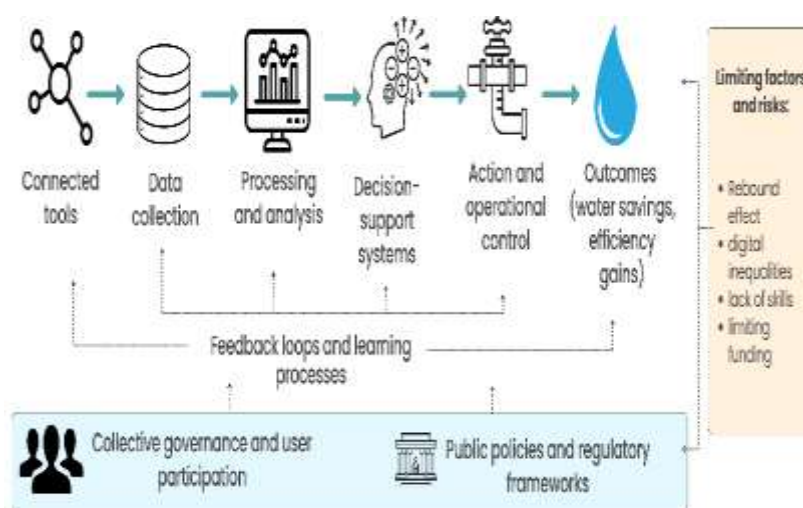


FIGURE IV: SOCIO-TECHNICAL VALUE CHAIN OF CONNECTED IRRIGATION

Limitations of connected irrigation systems

Despite their potential benefits, there are several significant limitations to connected irrigation systems that may hinder their large-scale deployment.

Investment costs remain a major barrier, particularly for small farms and certain collective irrigation networks. The cost of smart meters, remote management equipment, communication systems and digital platforms can range from several hundred to several thousand euros per delivery point, depending on the level of equipment installed.

However, this constraint could be partially offset by increased transparency of water use, improved traceability of consumption, and water savings achieved through these technologies. In the long term, such benefits may facilitate access to environmental labels, certifications, or public support schemes. Nevertheless, this dynamic can only materialize if public policies effectively recognize and reward performance improvements and sustainable water management efforts enabled by these systems. These benefits could also contribute to greater recognition of efforts made in water conservation, particularly when water-use restrictions are imposed. Irrigators who consistently adopt responsible and water-efficient practices throughout the year should not necessarily face the same restrictions as less efficient users. This issue represents a key factor in the social acceptance of connected technologies. Consequently, the development of these systems remains highly dependent on public policies and financial support mechanisms, which largely determine their rate of adoption.

Technical reliability also constitutes a critical challenge. Sensors, communication systems, and digital platforms require regular maintenance and may be affected by connectivity issues, hardware failures, or cybersecurity risks. In pressurized irrigation networks, filtration performance is another key factor. Insufficient filtration can lead to clogging or premature deterioration of connected equipment, increasing maintenance requirements and reducing system reliability. Equipment installed in the field may also be exposed to vandalism or theft. Therefore, equipment robustness, effective filtration, data security, and physical protection of installations are essential to ensure user confidence and the long-term sustainability of these solutions.

The analysis also highlights substantial disparities in users' capacity to adopt digital tools depending on their profiles and territorial contexts. Differences in technical skills, access to training and support services, and familiarity with digital technologies may exacerbate inequalities among irrigators and across regions.

Furthermore, connected technologies alone cannot compensate for structural deficiencies in hydraulic infrastructure nor fully address broader challenges related to increasing water scarcity. In insufficiently modernized networks, the transition toward connected management without prior infrastructure rehabilitation generally results in only limited improvements.

Finally, potential rebound effects must also be considered. Improvements in irrigation efficiency may lead to rebound effects through the expansion of irrigated areas or a shift toward more water-intensive crops (Ward and Pulido-Velazquez, 2008). Such effects may partially offset—or even completely negate—the expected benefits for water conservation if appropriate regulatory and governance mechanisms are not implemented

The risk of techno-solutionism

The rapid development of connected technologies is sometimes accompanied by a technology-centred vision that presents digitalization as a direct solution to agricultural water management challenges. However, the results of this study demonstrate that water-related issues are not solely technical in nature but also involve organizational, economic, social, and political dimensions.

Several authors have warned against techno-solutionist approaches in digital agriculture, emphasizing that technological innovation alone cannot resolve the structural challenges of water governance (Rotz et al., 2019; Klerkx and Rose, 2020). Connected technologies should therefore be viewed primarily as decision-support tools rather than autonomous solutions capable of independently addressing growing pressures on water resources.

Irrigation efficiency depends not only on management technologies but also on agronomic practices, cropping systems, governance capacities, and collective resource management arrangements.

CONCLUSIONS

The analysis of connected technologies applied to collective irrigation systems highlights their significant potential to transform water management practices in a context of increasing pressure on water resources driven by climate change. Digital tools such as smart hydrants, sensors, IoT devices, and monitoring platforms improve real-time consumption tracking, anomaly detection, and the operational management of irrigation networks.

The main benefits identified are multifaceted. From a technical perspective, these technologies enhance hydraulic efficiency by reducing water losses, optimizing water distribution, and facilitating the management of periods of water scarcity. From an organizational perspective, they improve managers' responsiveness and support better coordination among water users. From an agronomic perspective, they contribute to more precise irrigation management based on actual crop requirements through the integration of climatic and soil data. They also promote greater transparency in water use, which may encourage more responsible behaviour and help reduce certain water-use conflicts.

The results also reveal a gradual transition toward a more data-driven approach to irrigation management, in which decisions increasingly rely on measured data that are readily available in real time. This evolution represents an important lever for improving collective water management.

However, these benefits remain highly dependent on implementation conditions. The main limitations identified include investment costs, system reliability, data quality, and users' capacity to adopt and effectively use these technologies. Training needs, user support, and social acceptance therefore emerge as critical factors for success.

Connected technologies should therefore be considered as decision-support tools rather than autonomous solutions. Their effectiveness depends primarily on their integration into coherent socio-technical systems that combine infrastructure modernization, stakeholder support, and collective water governance.

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