

DESALINATION FOR AGRICULTURE DEVELOPMENT: OPPORTUNITIES AND CHALLENGES

DESSALEMENT ET DÉVELOPPEMENT AGRICOLE: PERSPECTIVES D'AVENIR ET DÉFIS

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ABSTRACT

Increasing water scarcity, climate change, and rising food demand are intensifying pressure on conventional freshwater resources and accelerating interest in non-conventional water solutions for agriculture. This paper examines the practical application of desalination in agricultural systems, with particular emphasis on technological performance, agronomic implications, economic feasibility, environmental sustainability, social acceptance and governance challenges.

The study is based on a synthesis of international experiences, scientific literature, and operational case studies from water-scarce regions including the Middle East, North Africa, and Mediterranean countries. Particular attention is given to reverse osmosis technologies, which currently dominate agricultural desalination due to lower energy requirements compared with thermal processes. Recent technological developments have improved energy efficiency and water recovery rates, while emerging approaches such as renewable-energy integration, brine mining, and zero liquid discharge systems are increasingly explored to enhance sustainability.

The analysis explores the influence of global agricultural commodity markets on the adoption of desalinated water, noting that high-value crops often justify this investment especially in arid and coastal regions where conventional water resources are insufficient or degraded. However, several technical constraints remain in desalination for agriculture development, including high energy consumption, elevated production costs, boron toxicity risks, nutrient deficiencies, and long-term soil salinization concerns. Blending desalinated water with groundwater or reclaimed wastewater appears to improve irrigation performance and reduce economic and environmental pressures.

The paper further demonstrates that the viability of desalination in agriculture depends not only on technological progress, but also on supportive governance frameworks, economic incentives, institutional coordination, social acceptance and stakeholder engagement. Successful experiences in countries such as Spain, Israel, and Morocco illustrate the importance of integrating desalination within broader water–energy–food strategies. Overall, desalination can contribute significantly to agricultural water security and climate resilience when implemented as part of an integrated and diversified water management approach.

Keywords: Energy efficiency; nutrient deficiencies; long-term soil salinization concerns; irrigation performance; agricultural water security.

RESUME

La croissance de la pénurie d'eau, le changement climatique et la croissance de la demande alimentaire exercent des pressions intenses sur les ressources en eau douce conventionnelles et accélèrent l'intérêt

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pour rechercher des solutions non conventionnelles d'approvisionnement en eau pour l'agriculture. Cet article examine l'application pratique du dessalement dans les systèmes agricoles, en mettant l'accent sur la performance technologique, les implications agronomiques, la faisabilité économique, la durabilité environnementale, l'acceptation sociale et les défis liés à la gouvernance.

L'étude se base sur une synthèse des expériences internationales, de la littérature scientifique et des études de cas opérationnelles menées dans les régions confrontées à la pénurie d'eau, y compris le Moyen-Orient, l'Afrique du Nord et les pays méditerranéens. Une attention particulière est accordée aux technologies d'osmose inverse, qui dominent actuellement le dessalement agricole en raison de besoins énergétiques plus faibles par rapport aux procédés thermiques. Les développements technologiques récents ont amélioré l'efficacité énergétique et les taux de récupération de l'eau, tandis que des approches émergentes telles que l'intégration des énergies renouvelables, l'extraction des matières utiles des eaux salées et les systèmes à zéro déchet liquide sont de plus en plus explorées pour renforcer la durabilité.

L'analyse explore l'influence exercée par des marchés mondiaux de matières premières agricoles sur l'adoption de l'eau dessalée, en notant que les cultures à haute valeur justifient souvent cet investissement, en particulier dans les régions arides et côtières où les ressources en eau conventionnelles sont insuffisantes ou dégradées. Cependant, plusieurs contraintes techniques existent dans le dessalement pour le développement de l'agriculture, notamment une forte consommation d'énergie, des coûts de production élevés, des préoccupations concernant la toxicité du bore, des carences en nutriments et des préoccupations à long terme concernant la salinisation des sols. Le mélange d'eau dessalée avec des eaux souterraines ou des eaux usées mises en valeur semble améliorer les performances d'irrigation et réduire les pressions économiques et environnementales.

En outre, le document démontre que la viabilité du dessalement dans l'agriculture dépend non seulement du progrès technologique, mais aussi de cadres de gouvernance favorables, d'incitations économiques, de coordination institutionnelle, d'acceptation sociale et d'implication des parties prenantes. Des expériences menées dans des pays tels que l'Espagne, Israël et le Maroc illustrent l'importance de l'intégration de dessalement au sein de stratégies plus larges en matière d'eau-énergie-alimentaire. En général, le dessalement peut contribuer de manière significative à la sécurité hydrique agricole et à la résistance climatique lorsqu'il s'inscrit dans le cadre d'une approche intégrée et diversifiée de gestion de l'eau.

Mots-clés : Efficacité énergétique; Carences en nutriments; Préoccupations concernant la salinisation des sols à long terme; Performance de l'irrigation; sécurité hydrique agricole.

INTRODUCTION

Water scarcity is becoming one of the principal constraints to agricultural development worldwide, particularly in arid and semi-arid regions increasingly affected by climate change, population growth, and rising food demand. Agriculture currently accounts for more than 70% of global freshwater withdrawals, placing growing pressure on conventional water resources and increasing the need for alternative and more resilient water supply solutions.

In this context, desalination has emerged as an important non-conventional water source capable of improving water security in regions facing chronic water deficits, groundwater salinization, and increasing agricultural, urban, and industrial water demand. Rapid technological progress, particularly in membrane-based desalination systems, has considerably improved operational efficiency and expanded opportunities for agricultural applications.

The Food and Agriculture Organization of the United Nations (FAO) has undertaken a comprehensive review of international experiences related to desalination for agriculture in order to better assess its technical, economic, agronomic, environmental, social and institutional implications. Drawing on scientific literature, operational projects, and regional case studies, this paper, based on Maki et al.

(2025), synthesizes current knowledge and practical experiences regarding the use of desalinated water in agricultural systems.

The objective of this paper is to analyze the opportunities and challenges associated with desalination for agriculture, with particular emphasis on operational performance, economic sustainability, environmental impacts, governance frameworks, and farmer acceptance, while focusing primarily on practical implementation experiences and field-based applications.

Prepared within the framework of the 26th ICID International Congress on Water and Agricultural Resilience in the Face of Climate Change, the paper highlights key lessons learned and identifies major conditions required for the sustainable integration of desalination into agricultural water management strategies.

TECHNOLOGICAL ADVANCES AND TRENDS

Desalination dependence and development vary considerably across regions according to water scarcity levels and economic priorities. The Middle East and North Africa (MENA) region remains the global center of desalination, accounting for approximately 50% of worldwide installed capacity, with countries such as Saudi Arabia, the United Arab Emirates, Kuwait, Oman, and Israel relying heavily on desalinated water for strategic water security. In Africa, desalination is rapidly expanding in countries including Algeria, Morocco, Egypt, Ghana, Senegal, and Kenya to address structural water deficits, with Egypt targeting a production capacity of 6.4 million m³/day by 2050.

In the Indo-Pacific region, particularly in China and India, desalination growth is driven by industrial demand and increasing water scarcity, while China aims to reach 2.9 million m³/day by 2025. In the Americas, desalination is mainly associated with specific sectors such as mining in Chile and Peru, water supply in arid regions of the United States, and urban expansion in Mexico. In island regions such as the Maldives, Malta, the Bahamas, Cape Verde, the Canary Islands, and Cebu in the Philippines, desalination has become essential infrastructure due to the severe limitation of conventional freshwater resources.

Desalination technologies are broadly classified into thermal processes, membrane-based processes, and emerging hybrid systems. Among thermal processes, multi-effect distillation (MED) and multi-stage flash (MSF) remain widely used, particularly for large-scale seawater desalination due to their ability to produce very low total dissolved salt water (less than 10 mg/L for multi-effect distillation and less than 50 mg/L for multi-stage flash). However, they are highly energy-intensive, with electricity consumption ranging from 14–21 kWh/m³ (multi-effect distillation) to 19.5–27 kWh/m³ (multi-stage flash) (Soliman et al., 2021).

Membrane technologies dominate modern desalination, with reverse osmosis being the most widely deployed method, with lower energy requirements than thermal processes. Reverse osmosis typically requires 3–4 kWh/m³, depending on plant configuration and feedwater quality. Other membrane technologies such as nanofiltration and electrodialysis represent smaller shares of the market (3% and 2% respectively; Greenlee, 2009) and are mainly applied to brackish water treatment or as pre-treatment systems. For brackish water, energy demand is significantly lower than for seawater desalination, and recovery rates can reach up to 90%, compared to 50–65% for seawater systems.

Brine management remains one of the main technical, environmental, and economic challenges of desalination. Conventional seawater reverse osmosis plants generally require about 2.5 m³ of seawater intake to produce 1 m³ of freshwater and generate approximately 1.5 m³ of concentrated brine. Traditionally, this brine has been discharged or stored, representing an additional environmental compliance cost. However, desalination brine typically contains around 7.5% dissolved solids, including sodium, chlorides, magnesium, sulphates, and trace critical minerals such as lithium, boron, gallium and rubidium.

Several alternative membrane-based technologies for brine concentration and mineral extraction, commonly referred to as “brine mining” or brine valorization, are being developed to transform desalination concentrate into a source of commercially valuable minerals rather than treating it solely as waste.

Extracting minerals such as sodium, bromine, lithium, chloride, and sulfate from seawater brine has been proposed as a potential source of revenue. When extracted at high purity, these minerals can be marketed to various industries as raw materials, offering an alternative to conventional terrestrial mining. Recent investments in Saudi Arabia, Indonesia, and Texas suggest that brine mining can be economically attractive, particularly when projects are carefully planned and developed in collaboration with industrial partners from sectors such as mining and chemical manufacturing, ensuring that sufficient local demand exists for the recovered minerals.

Although zero liquid discharge (ZLD) technologies can significantly reduce the environmental impacts of brine disposal, their large-scale application remains limited due to high operational costs and the low commercial value of mixed salts. Recent integrated ZLD systems combine nanofiltration, reverse osmosis, selective crystallization, and chemical precipitation to separate monovalent and polyvalent ions and recover valuable products from desalination brine (IDRA, 2023).

Calcium is recovered as calcium carbonate using soda ash, while magnesium is precipitated as magnesium hydroxide using sodium or ammonium hydroxide. These recovered compounds can subsequently be processed into magnesium metal and other industrial products. Additional crystallization stages can produce high-purity sodium chloride (99.8%), magnesium chloride, magnesium sulphate, sodium carbonate, and calcium salts. Such integrated systems simultaneously maximize freshwater recovery and minimize liquid waste generation. Overall, desalination is evolving from water production to an integrated water–energy–resource recovery system, where brine is increasingly treated as a valuable source of industrial and strategic materials and a way to reduce environmental impacts, with agronomic implications.

AGRONOMIC OPPORTUNITIES AND CONCERNS

Desalination is increasingly being used to support agriculture in water-scarce regions, particularly for high-value crops and coastal farming systems. However, its global agricultural use remains limited due to high production costs, energy requirements, environmental concerns, and water-quality constraints. Spain is currently the world leader in agricultural desalination, with an installed capacity exceeding 2 million m³/day and more than 300 desalination plants in operation. Approximately 20–22% of desalinated water in Spain is allocated to agriculture, mainly for high-value crops such as tomatoes, peppers, fruits, and vineyards. Most agricultural desalination plants treat brackish water, while only 10% use seawater.

In most other countries, agriculture accounts for only a minor proportion of total desalinated water use despite growing water scarcity. Agricultural use represents approximately 0.5% in Saudi Arabia, despite being the world’s largest desalinated-water producer, 13% in Kuwait, 5% in Italy, 1.3% in the United States, 0.4% in Bahrain, and only 0.1% in Qatar. Oman increasingly relies on small-scale reverse osmosis (RO) desalination because of groundwater and soil salinization.

Around 80% of inland desalination plants use RO and most facilities have capacities below 10,000 m³/day. Israel applies advanced post-treatment practices by adding minerals to desalinated water in order to stabilize water quality and improve its suitability for irrigation. Morocco is also rapidly expanding desalination for irrigation through major projects such as the Agadir plant, which produces 400,000 m³/day and dedicates half of its capacity to irrigating approximately 15,000 hectares. Additional projects include the planned wind-powered Dakhla plant (90,000 m³/day) and the Casablanca desalination plant (825,000 m³/day), of which around 10% is expected to support agriculture.

Desalination provides a reliable and climate-independent water source that can enhance agricultural productivity, improve crop quality, and support the recovery of degraded soils. However, its adoption is

constrained by economic and technical limitations, including high production costs, the need for ionic balance management, risks of boron toxicity, potential aquifer depletion in brackish water systems, and challenges related to brine disposal. Recent technological advances have nevertheless improved boron removal efficiency, increasing the feasibility of seawater desalination for irrigation purposes.

Reverse Osmosis-treated water generally contains very low concentrations of essential nutrients such as calcium and magnesium, while excessive boron concentrations may cause phytotoxicity in sensitive crops. In Israel, desalinated seawater is therefore remineralized after treatment by adding calcium and sulfate in order to stabilize water quality and improve its suitability for irrigation and distribution systems. In Spain, farmers commonly blend desalinated water with groundwater or surface water to optimize salinity levels, reduce nutrient deficiencies and lower irrigation costs. Such practices have contributed to maintaining acceptable crop yields while improving water irrigation quality.

The combined use of desalinated water and reclaimed wastewater is increasingly recognized as a sustainable strategy for irrigation management. Reclaimed water can partially compensate for the nutrient deficiencies of desalinated water by supplying nitrogen, phosphorus and organic matter, thereby improving soil fertility and reducing fertilizer requirements. This integrated approach has been promoted in Mediterranean regions affected by chronic water scarcity, where combining multiple non-conventional water resources contributes to enhancing water security while limiting environmental impacts associated with desalination alone.

Key studies assessing the agronomic and environmental impacts of desalinated and blended irrigation water across different regions and crops indicate that such water sources generally has no immediate negative effects on crop yield or quality. However, some risks appear in the long term, mainly related to sodium and boron accumulation in soil and plant tissues. Blending freshwater with desalinated water can be an effective strategy to maintain productivity, but its sustainability depends on proper salinity management and site-specific conditions.

Furthermore, the valorization of minerals extracted from desalination brines represents a growing interface between water production and agricultural systems, particularly within circular economy approaches. Brine mining opens new perspectives for agriculture through the recovery of valuable minerals that can be reintroduced as fertilizers or soil amendments.

ECONOMIC SUSTAINABILITY AND FINANCING

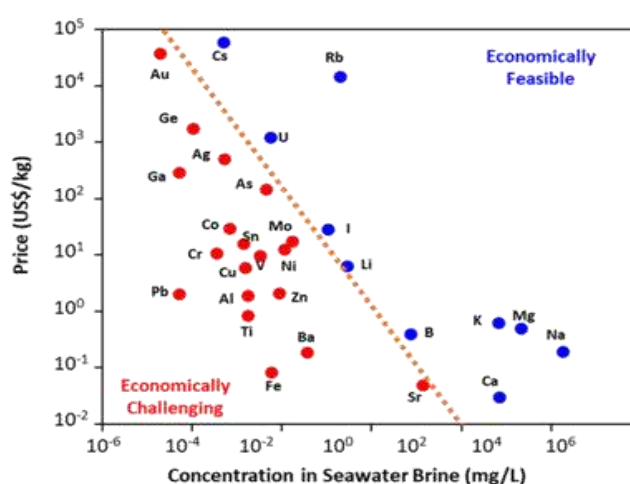
The economic viability of desalination in agriculture is primarily constrained by high energy demand and production costs. Energy consumption represents around 30–50% of total operating costs, although technological progress has reduced seawater reverse osmosis energy use from more than 10 kWh/m³ in the 1970s to approximately 2.5–3.5 kWh/m³ today. Brackish water reverse osmosis is significantly less energy-intensive, requiring only 0.5–1.7 kWh/m³, making it more suitable for inland and medium-scale agricultural systems.

Economies of scale strongly influence costs. Large seawater desalination plants exceeding 400,000 m³/day benefit from lower unit costs, with investment costs ranging from USD 800–1,300 per m³/day of installed capacity, whereas smaller plants below 20,000 m³/day may reach USD 2,000–4,000 per m³/day. Brackish water desalination remains more affordable in operational terms, with production costs estimated at USD 0.2–0.4/m³. However, transportation to inland or elevated agricultural areas can add USD 0.5–1.5/m³, significantly limiting feasibility outside coastal zones.

Economic performance can be improved through blending desalinated water with groundwater, treated wastewater, or drainage water, which reduces costs while increasing irrigation supply. Public–private partnership models have also contributed to cost reductions, with some large-scale plants achieving tariffs of approximately USD 0.27/m³. In addition, renewable energy integration and brine mining through mineral recovery offer long-term cost reduction potential.

Within the context of brine mining and resource recovery, economic feasibility studies indicate that mineral extraction from desalination brines could significantly offset desalination costs under favorable market conditions (Figure 1). For example, a 25,000 m³/day desalination plant in Indonesia could produce sodium chloride (NaCl) at approximately USD 60 per dry tonne, compared to a market price of USD 100 per tonne. Annual production of around 250,000 tonnes of NaCl could generate USD 10 million in annual revenue, exceeding the plant's estimated freshwater production cost of USD 2.74 million and yielding a net annual profit of approximately USD 7.26 million. At larger scales, a 100,000 m³/day seawater reverse osmosis plant could produce 1–1.2 million tonnes of high-purity salt annually. With additional investment in brine mining infrastructure, such a facility could generate approximately USD 65 million in annual sales and around USD 25 million in annual profit from salt recovery alone. However, the profitability of these systems depends on high reverse osmosis recovery ratios, advanced separation technologies, local market demand, and strong institutional and community support.

Figure 1. Economic feasibility of brine mining



Source: Kumar, Amit, Naidu, Gayathri, Fukuda, Hiroki, Du, Fengmin, Vigneswaran, Saravanamuth et al. 2021.
"Metals Recovery from Seawater Desalination Brines: Technologies, Opportunities, and Challenges."
ACS Sustainable Chemistry & Engineering, 9 (23).

Figure 1 highlights that the economic viability of resource recovery from seawater and brine depends on the balance between market price and resource concentration. Elements positioned above the economic threshold line are considered commercially feasible due to either high value or sufficient abundance, whereas those below remain economically challenging to extract profitably.

From an agricultural perspective, desalination is mainly economically viable for high-value crops such as greenhouse tomatoes, peppers, berries, almonds, and pistachios, particularly in Spain and Israel, whereas staple crops such as wheat, maize, and rice remain economically unsuitable due to low profitability and high water demand. Overall, economic feasibility depends on a combination of scale, energy efficiency, and crop value, which naturally leads to an assessment of the environmental constraints that also shape desalination viability.

ENVIRONMENTAL SUSTAINABILITY

Desalination has significant environmental implications related to energy consumption, brine disposal, and ecosystem impacts. Reverse osmosis typically requires 1.5–3.5 kWh/m³, while electrodialysis consumes 0.49–0.91 kWh/m³. Despite efficiency improvements, desalination remains more energy-intensive than conventional water supply systems, and in fossil-fuel-dependent regions this results in increased greenhouse gas emissions. For instance, in Spain's Campo de Cartagena region, irrigation using desalinated water increased energy consumption by 50% and greenhouse gas emissions by 30.3%.

To mitigate these impacts, renewable energy sources such as solar photovoltaic and wind power are increasingly integrated into desalination systems, particularly in arid regions such as North Africa and the Middle East. However, due to intermittency, hybrid systems combining renewable energy, electrical grids, backup generators, and water storage are often required, with water storage during high production periods being more efficient than battery storage in many cases.

Brine management is one of the most critical environmental challenges. Globally, desalination produces approximately 141.5 million m³/day of brine, with about 55% generated in the Middle East and North Africa region. Brine discharge can increase salinity, alter pH levels, and introduce chemicals and heavy metals into marine ecosystems, affecting sensitive habitats such as seagrass meadows. Although engineering solutions such as multi-port diffusers and monitoring systems reduce local impacts, cumulative effects remain significant in densely developed coastal areas.

In inland contexts, brine disposal becomes even more complex, as evaporation ponds and deep-well injection may lead to soil degradation, groundwater contamination, and land-use constraints. Advanced technologies such as Zero Liquid Discharge aim to eliminate liquid waste by recovering water and producing solid salts, although they remain highly energy-intensive, while brine mining offers emerging opportunities for resource recovery and circular economy development.

Beyond environmental pressures, desalination can also generate positive hydrological effects, as illustrated by the Agadir project in Morocco, which is expected to reduce pressure on approximately 9,000 overexploited wells, thereby contributing to groundwater recovery and system resilience, which in turn influences how desalination is perceived socially and politically.

SOCIAL ACCEPTANCE

Social acceptance of desalination in agriculture depends on water cost, crop value, water quality, environmental concerns, and perceptions of equity. Desalinated water typically costs between USD 0.5 and 1.5/m³, while farmers' willingness to pay is often lower, making public subsidies a key requirement for adoption, particularly in Spain where affordability is closer to USD 0.6/m³.

At the Torrevieja desalination plant, farmers pay approximately EUR 0.53/m³ after subsidies compared with a production cost of EUR 1.20/m³. Acceptance tends to be higher for high-value crops where economic returns can offset water costs, while concerns remain regarding water quality issues such as low mineral content, acidic pH, and elevated boron levels.

In southeastern Spain, full substitution of conventional irrigation water can increase production costs by 3.2–35.5%, whereas blending significantly reduces these impacts, and in Gran Canaria about 31% of agricultural land is irrigated with desalinated water supported by blending strategies and wind energy integration.

From a social perspective, acceptance is often constrained by environmental concerns, brine disposal issues, and governance conflicts. The rejection of a major seawater desalination project in California in 2022 after more than 20 years of studies illustrates these tensions, whereas smaller brackish water projects in Antioch and Camarillo show higher acceptance due to their localized and adaptive nature. These contrasting cases highlight that social acceptance is closely linked to governance quality and stakeholder engagement, which directly connects to institutional and policy frameworks.

CAPACITY BUILDING

Capacity building is essential due to limited availability of local expertise in desalination technologies, as well as in the operational, technical, and managerial competencies required for effective system performance and long-term sustainability.

At the operational level, capacity building focuses on plant operation, maintenance, and monitoring. Modern desalination systems increasingly rely on automation, remote control, and predictive maintenance, which reduce the need for intensive on-site expertise. Small plants producing less than 100 m³/day may require limited training when maintenance is outsourced, while organizations such as the International Desalination and Water Reuse Association and platforms such as Desaldata provide technical support and knowledge transfer.

At the agricultural level, farmers require training in irrigation management, water quality interpretation, and cost-reduction strategies, including blending desalinated water with groundwater or treated wastewater. Farmer field schools and exchange networks contribute to improving adoption and efficiency in irrigation practices.

At the institutional level, policymakers and planners require capacity building to integrate desalination into water, energy, and food system strategies. International platforms and observatories support data sharing and policy learning across countries.

Overall, capacity building must operate across technical, agricultural, and institutional levels in an integrated manner, which naturally leads to the need for coherent governance structures capable of coordinating these different actors.

POLITICAL, INSTITUTIONAL, REGULATORY FRAMEWORK AND GOVERNANCE

Desalination requires strong governance frameworks beyond technology and financing, integrated within the Water–Energy–Food–Ecosystem (WEFE) nexus in order to manage interdependencies and avoid fragmented policy decisions.

Policy frameworks often link desalination to food security strategies, prioritizing high-value crops and export-oriented agriculture, while climate change increases the strategic importance of water-secure production systems. Water pricing is a key policy instrument. While subsidies can facilitate access and adoption, they may also weaken incentives for water conservation, thereby encouraging the implementation of tiered pricing schemes that differentiate between essential consumption needs and higher levels of use.

Environmental regulation is essential, particularly for brine discharge and water quality management. Reverse osmosis processes also remove essential minerals such as calcium and magnesium, requiring re-mineralization before agricultural use. In California, regulatory frameworks impose strict requirements to minimize marine life mortality associated with water intake systems.

Public–private partnerships are widely used due to high capital requirements, but they must ensure both financial viability and social affordability over the long term. Spain illustrates this governance model through international companies such as Acciona Agua and Sacyr Sadyt, while Israel provides an advanced example of integrated water governance combining desalination, wastewater reuse, pricing reforms, and long-term planning up to 2050.

However, governance effectiveness strongly depends on stakeholder participation. Limited engagement has contributed to delays or cancellation of desalination projects in both France and California, whereas more integrated and coordinated systems, such as Spain's Segura Basin, which combines desalinated, surface, and reclaimed water, and Morocco's Agadir plant, which irrigates 15,000 hectares while integrating wind energy, demonstrate improved coherence and acceptance. These cases illustrate that effective desalination governance can only be achieved through a coherent WEFE approach that aligns economic, environmental, and social dimensions.

CONCLUSION

The integration of desalination into agricultural systems represents a potentially transformative response to increasing water scarcity driven by climate change. Technologically, desalination has advanced considerably, particularly through reverse osmosis, which enables the treatment of both seawater and brackish water. Despite these improvements, the high capital and operational costs, alongside significant energy requirements, continue to limit its large-scale agricultural deployment. Ongoing innovations in energy efficiency, brine management, and resource recovery from desalination by-products are expected to enhance its future feasibility and sustainability.

From an agronomic perspective, desalinated water can support high-value crop production and contribute to food security in arid and water-stressed regions. However, its low nutrient content and specific chemical properties may induce soil imbalances and phytotoxic effects if not properly managed. To mitigate these risks, strategies such as blending desalinated water with conventional water sources and adjusting fertilization regimes are required to maintain soil health and crop productivity.

Economically, the viability of agricultural desalination is highly context-dependent, influenced by crop value, proximity to desalination infrastructure, and access to financial support mechanisms. Given the high cost of desalinated water, its adoption often relies on targeted subsidies, public–private partnerships, and innovative financing models, particularly in developing countries. Further research is needed to evaluate its cost-effectiveness for strategic food security crops such as cereals and animal fodder in water-scarce environments.

Environmentally, desalination raises significant concerns due to its energy intensity and the challenges associated with brine disposal. Transitioning toward renewable energy sources and developing brine valorization techniques are critical for reducing its ecological footprint. Additionally, desalination may offer environmental benefits by reducing pressure on overexploited freshwater aquifers and potentially supporting groundwater recharge. Overall, while desalination presents a promising tool for agricultural water management, its sustainability depends on careful technological, economic, and environmental optimization.

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