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Discourse over the sustainability of irrigation with desalinated water in light of the water-energy-food nexus

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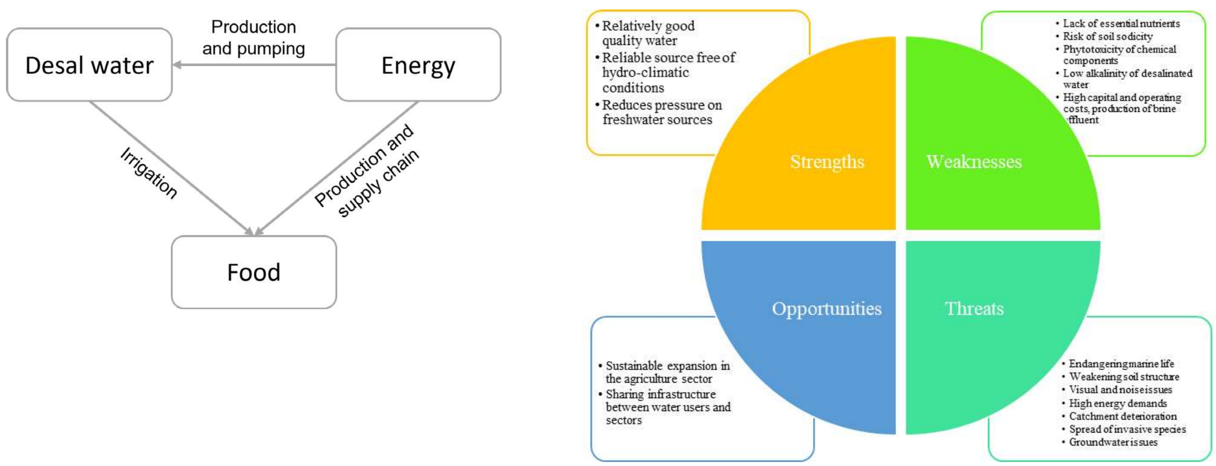
Introduction

Desalinated seawater has gained increasing popularity as an option for water-stressed regions worldwide to meet a general increase in water demand across most sectors. Considering current water and food crises that are exacerbating in many regions, desalination has gained traction as a suitable solution to alleviate these problems as a potentially limitless alternative water source. The agricultural industry is the largest global water consumer and the sector that is most likely to benefit from this technology to meet the increasing demand for irrigation. Despite the technology's considerable potential, there are numerous issues related the technology's sustainability that may prevent it from becoming a widely used solution for irrigation purposes. However, being affected by numerous interconnected factors, water resources problems are nuanced and multi-disciplinary. To account for these intricacies in the evaluation of the sustainability of this option for irrigation, the concept of the Water-Energy-Food (WEF) Security Nexus can be used. This paper provides a preliminary evaluation of the sustainability of the use of desalinated water for irrigation considering the WEF Security Nexus.

Materials and methods

Figure 1 depicts the general role of desalinated water in the WEF nexus. Though the impacts of irrigating with desalinated water are ideally determined on a case-by-case basis, there are general concerns that are similar across cases. From an agronomic perspective, these concerns are (I) a lack of essential nutrients; (II) phytotoxicity of chemical components such as Boron, Chloride, and Sodium; (III) risk of soil sodicity; and (IV) low alkalinity of desalinated water (Martin-Gorriz et al. 2021). These problems could, in turn, be manifested in reduced crop quality, crop yield, and disease resistance. Concerning environmental impacts, some of the most frequently cited issues are: (I) marine ecosystem impingement and entrainment; (II) visual and noise impacts; and (III) the overall greenhouse gas (GHG) emissions. GHG emissions are mostly related to the energy-intensive nature of this technology. The use of this technology, however, could also have some potential environmental benefits. Introducing desalinated water to a region for irrigation can be viewed as an additional component of the local hydrological cycle, which could help support the condition of the cycle at a regional scale (Pistocchi et al. 2020). This could also reduce the pressure on other exhausted water resources. The economic issues are another aspect that need to be addressed, as the overall cost of desalinated water is often high enough to leave little to no profit margin for most commercial crops. Figure 2 depicts a SWOT (strengths, weaknesses, opportunities, and threats) analysis for irrigation with desalinated water.

Experience has shown that while these issues can cause significant problems if not addressed correctly and promptly, they are manageable for the most part. Nevertheless, case-by-case evaluation is required to determine the applicability of these strategies. However, evaluating the effectiveness of such strategies comprehensively requires a perspective that goes beyond the conventional framework. The WEF Security Nexus is a relevant concept to shape such discourse regarding the sustainability of irrigation with desalinated water. Our studies show that based on the WEF-based paradigm of thinking, there are two main ideas to address the previously mentioned problems, namely, *prophylactic,* and *reactive* strategies. Prophylactic methods tend to address a problem before any significant impact appears. These strategies are based on regionally specific planning and management decisions that optimize the system for specific conditions. These include creating a monitoring and regular maintenance plan, choosing an appropriate desalination technology or incorporating a cost-effective energy source. Socio-economic-oriented solutions can also be seen as prophylactic strategies. For instance, *water markets*, if put in place prior to operating the desalinated water supply, could be seen as a socio-economic strategy. Southeast Spain has temporarily exercised this strategy on a limited scale (Aznar-Sánchez et al. 2017). Planning renewable energy resources at the same time as planning the desalinated water supply is another prophylactic move that can mitigate the environmental impacts of desalination (Tubi and Williams 2021). Reactive strategies, on the other hand, aim to devise a procedure to address a specifically targeted issue. These are, for the most part, ad-hoc approaches that must be personalized to site-specific circumstances. Filtering sludge and brine, mixing different water resources to create a more suitable batch on farm sites, or installing energy recovery devices in the desalination units are some of the most known reactive strategies. In practice, a combination of prophylactic and reactive strategies is needed to address the potential impacts of desalination.



(a) **(b)**

Figure 1. a) The general role of desalination in the WEF nexus; b) SWOT analysis for irrigating with desalinated water.

Concluding remarks

With the water and food crises exacerbating worldwide, it is essential to reconsider how water resources management must adapt to this new era. While the use of desalinated seawater looks to be an important part of the solution, there remain concerns regarding the sustainability of using desalinated water for irrigation. These concerns need to be investigated and understood to allow appropriate mitigation measures to be developed to avoid adverse impacts. Given the multi-faceted nature of the context and related issues, conventional assessment frameworks are not the ideal tool for sustainability analysis. Reinterpreting this issue within the context of the WEF Security Nexus may provide a more realistic and applicable understanding of the benefits and drawbacks of this technology. Overall, our findings suggest that, while there are problems with this practice in the context of the agriculture industry, these issues can be managed through the right strategic course of action on a case-by-case basis. A more comprehensive analysis that considers multiple case studies across different contexts will help develop the understanding of the sustainability of the use of desalinated seawater for irrigation and support the development of mitigation strategies.

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