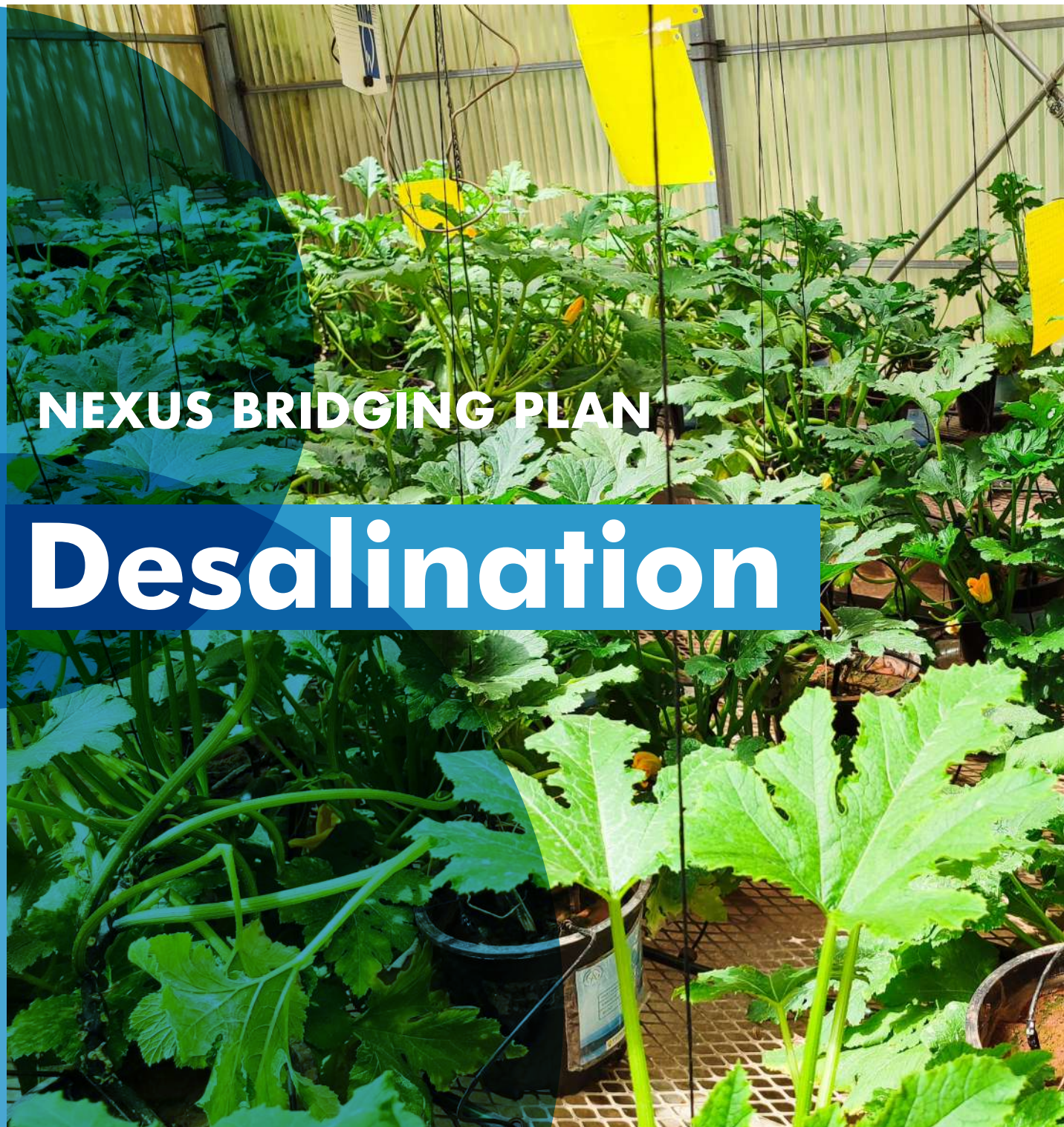


NEXUS BRIDGING PLAN

Desalination



Souss-Massa, **Morocco**



PRIMA
PARTNERSHIP FOR RESEARCH AND INNOVATION
IN THE MEDITERRANEAN AREA



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NEXUS BRIDGING PLAN

Desalination

In Souss-Massa, **Morocco**

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Framework Implementation in the
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BONEX
Boosting Nexus Framework
Implementation in the Mediterranean



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Executive summary

The *Chtouka* region, located in the *Souss-Massa* plain in Morocco, is facing a growing water shortage, worsened by climate change, overexploitation of groundwater, and soil salinisation. These issues threaten agricultural productivity and the livelihoods of local populations. To address them, a seawater desalination plant has been commissioned. Using reverse osmosis technology, it provides high-quality freshwater, intended to meet municipal needs and, for the first time, to irrigate agricultural land.

The **BONEX project**, in partnership with the Hassan II Agronomic and Veterinary Institute and the Regional Office for Agricultural Development (ORMVA) of *Souss-Massa*, is a Mediterranean initiative that aims to promote integrated resource management through the **Water-Energy-Food-Ecosystems (WEFe)** Nexus approach. As part of the project, and in order to strengthen the strategy for using desalinated water in irrigation under this WEFe approach, a **Nexus Bridging Plan (NBP)** was developed. It is one of seven NBPs deployed in the Mediterranean region by BONEX to guide the practical implementation of solutions adapted to local contexts. In *Souss-Massa*, the NBP emphasises the synergy between the use of desalinated water for irrigation and the integration of renewable energy sources, such as solar power, to ensure both ecologically and economically sustainable solutions.

As part of the project, agronomic research was conducted to **assess the effectiveness of various mixes of desalinated water and well water in irrigating zucchini crops**, a strategic crop for the region. The results revealed that a blend of 25% to 50% desalinated water optimised water use while promoting good plant growth and limiting CO₂ emissions. At the same time, other experiments focused on **soilless cultivation systems** incorporating several innovations: **desalinated water, magnetic water treatment, biofertilisers, and solar-powered irrigation**. This integrated approach demonstrated positive effects on yields, crop resilience, and the reduction of environmental

footprint, illustrating the potential of technological synergies to address Nexus-related challenges.

Based on these findings and additional surveys, a central element of the project was the development of a practical guide for farmers, created in collaboration with researchers, agricultural institutions, and local producers. This guide offers recommendations for the optimal use of desalinated water combined with complementary technologies to improve yields, enhance plant nutrition, and reduce environmental impacts. To encourage adoption, a training program was launched, including field demonstrations, workshops, and educational tools.

At the same time, a systemic model was developed through **participatory workshops**, and using the REWEFe tool to analyse the interconnections between water, energy, food, and socio-economic factors. The simulations revealed significant potential to improve production while also identifying the trade-offs that need to be managed regarding natural resources.

In conclusion, the intervention carried out in the *Souss-Massa* region, based on the integrated WEFe Nexus approach, has enabled significant progress in the sustainable management of essential resources. By fostering synergies between the WEFe sectors, the project not only strengthens the resilience of the local agricultural system but also offers a replicable model for other arid or semi-arid regions facing similar challenges.

the NBP emphasises the synergy between the use of desalinated water for irrigation and the integration of renewable energy sources

Methodological approach

As part of this research and innovation mission, the Bonex Project has played a pivotal role in promoting sustainable natural resource management in the *Souss-Massa* region through the WEF Nexus approach. In this framework, a rigorous **methodological process** was applied to the development of water desalination solutions, taking into account the region's specific natural, economic, and social constraints.

The project began with a detailed feasibility study to assess the energy requirements of desalination and to evaluate the potential integration of local renewable energy sources, particularly solar power. This phase was followed by the implementation of pilot systems designed to test and validate the most appropriate technologies under real-world agricultural conditions.

The solutions developed within the BONEX project are instrumental in addressing the pressing challenges of water scarcity and quality, particularly in the context of DP Morocco Desalinated Water. This case study highlights a situation where stakeholders were already aware of several interrelated constraints: limited availability of freshwater resources, high energy demands of desalination processes, the financial

burden of operating and maintaining desalination infrastructure, and socio-economic tensions linked to competition over water for agricultural and domestic needs. The BONEX project applied innovative, context-specific approaches to overcome these challenges. These include strategies to optimise the blending of desalinated and well water, improve irrigation efficiency, integrate local renewable energy sources to reduce energy dependency, and manage environmental risks such as brine disposal. Through this multidimensional response, the project enhances water-use efficiency and supports a more resilient and sustainable water management system in *Souss-Massa*.

On the other hand, to ensure a participatory and inclusive approach, the BONEX project organised a series of three collaborative workshops involving a diverse range of stakeholders, including actors from the water, energy, agriculture, and environmental sectors, as well as academia, civil society, and farmers. These workshops were structured to progressively build a shared understanding of the WEF Nexus and identify actionable strategies related to the use of desalinated water in Morocco. The first workshop focused on scoping the WEF Nexus elements relevant to the region. The second workshop emphasised co-creating solutions while identifying key barriers and enabling factors. The third workshop served to present the project results and outline practical actions to overcome the remaining obstacles to the adoption of desalinated water in agriculture. The outcomes of these workshops include validated causal loop diagrams (CLDs), co-developed solutions, and the integration of these findings into final-year student projects, reflecting the project's commitment to both research and real-world application.



Context description

The 'Souss-Massa' region is characterised by social and administrative factors, encompassing a diverse population, including urban communities in cities and rural populations. Administratively, the Souss-Massa region is part of the Agadir Ida-Outanane province and the Chtouka Ait Baha province (Figure 1).

This administrative structure is crucial for water and natural resource management, as it requires coordination among various levels of governance:

urban municipalities, rural municipalities, prefectures, and regional ministries.

From a biophysical perspective, the Souss-Massa region is characterised by a semi-arid climate, with significant variation in the distribution of water resources. The hot and dry climate, combined with irregular rainfall, results in significant water stress. The coastal area of the region, bordered by the Atlantic Ocean, offers a potential source of water for desalination, but biophysical conditions such as water salinity and

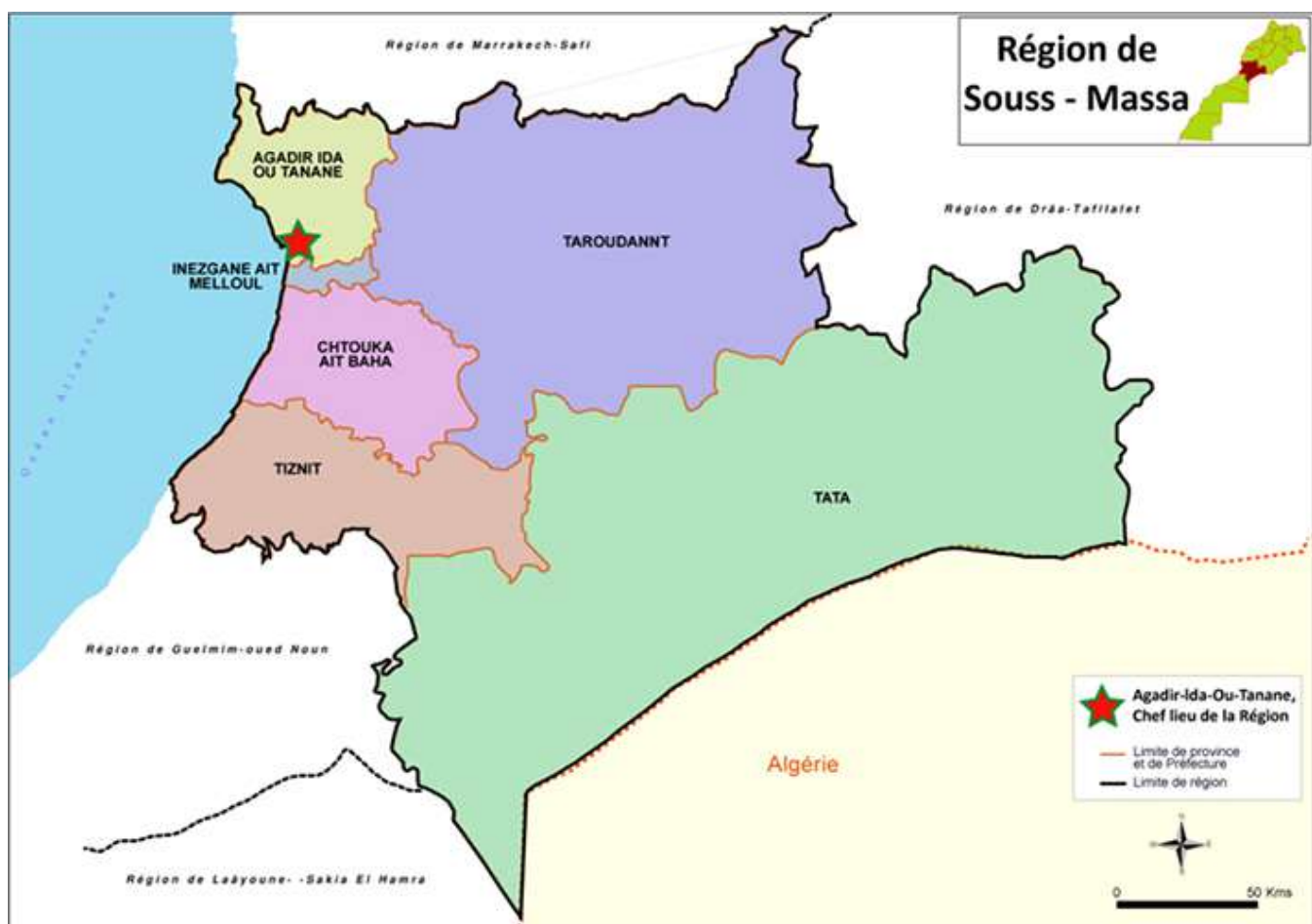


Figure 1 – Map of the 'Souss-Massa' Region.



the environmental impact of seawater extraction must be considered. The region is also traversed by the *Souss* River, one of the main sources of freshwater, but this resource is increasingly threatened by urbanisation and intensive agriculture. Additionally, soils in some agricultural areas are affected by salinisation, complicating water use for irrigation, especially when the water comes from saline sources.

The ***Souss-Massa* region** is a key economic hub in Morocco, heavily reliant on **agriculture, tourism, and a growing industrial sector**, all of which drive **high water demand**. However, **semi-arid conditions, groundwater overuse, and pollution** threaten water availability. Climate change worsens these issues, causing **droughts, rising sea levels, and soil salinisation**.

The **WEFe Nexus** includes multiple challenges, including **water scarcity for agriculture, high energy costs for desalination, and land degradation due to excessive fertiliser use**. Implementing a **desalination project** under this framework is complex due to **high costs, sectoral coordination issues, and farmers' concerns about soil salinity**. Future trends suggest **growing water stress, land degradation, and rising energy demand**, making **renewable energy integration crucial** despite storage challenges. Additionally, **urbanisation, biodiversity loss, and coastal erosion** require **socio-environmental considerations** in project planning. Addressing these challenges **through a coordinated WEF Nexus approach** is essential for ensuring **long-term resource sustainability and economic viability**.

WEFe Nexus issue

The challenges related to the WEF Nexus within the framework are deeply interconnected, influencing the critical dimensions of water, energy, food production, and ecosystems. In terms of water resources, the region is experiencing escalating water stress driven by growing demand from agriculture, industry, and tourism. This situation is further aggravated by climate change, which amplifies drought periods and depletes water reserves. Moreover, groundwater contamination caused by agricultural chemicals and untreated wastewater exacerbates the crisis.

These combined pressures have substantially reduced water availability, endangering both agricultural production and domestic supply. The resulting competition between sectors fosters conflicts and deepens water insecurity, particularly affecting the livelihoods of farmers.

Through a Causal Loop Diagram (CLD) developed by stakeholders (Figure 2), the importance of an integrated approach to solving the challenges related to water, energy, agriculture, and human development is highlighted. Effective coordination between sectors is essential to maximise the benefits of each loop while minimising negative impacts. Indeed, the CLD highlights a complex network of interactions between various factors in the context of natural resource management in Morocco.

The CLD illustrates a dynamic system where multiple interlinked factors contribute to water insecurity and environmental degradation, especially under pressure from population growth and climate variability. One of the central problems is the increasing demand for agricultural productivity, which requires more irrigation water. This rise in irrigation water

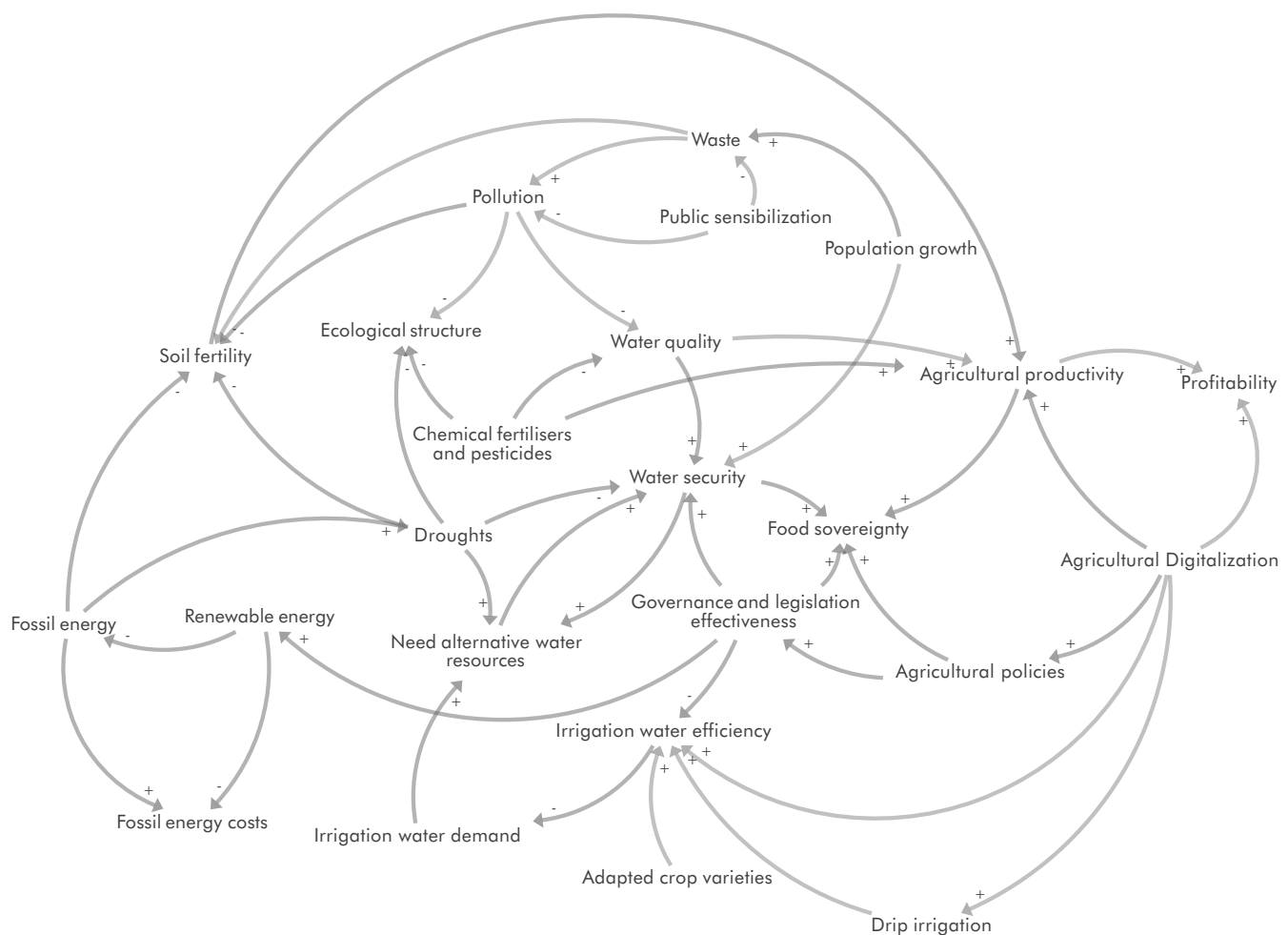


Figure 2 – Causal Loop Diagram of the Interactions Between Water Security, Sustainable Agriculture, and Socio-Economic Development Based on Water Desalination Technology in Morocco: A Systemic Model Based on Adaptation Solutions and Environmental Challenges.

demand directly strains water security and encourages the use of chemical fertilisers and pesticides. These inputs degrade water quality and soil fertility and negatively affect the ecological structure. In turn, this decline in ecological health feeds back into reduced agricultural productivity, forming a vicious cycle.

Additionally, the overuse of fossil energy to meet growing demands increases greenhouse gas

emissions, contributing to climate change and intensifying droughts. Droughts further exacerbate the need for alternative water resources, creating stress on water systems. Moreover, pollution from waste and chemical inputs further degrades the environment, weakening both water quality and soil systems.

These effects are interconnected: poor water quality, loss of fertility, and ecosystem decline all limit long-term agricultural outputs.

However, the CLD also shows leverage points that can help break these negative cycles. Introducing adapted crop varieties, improving irrigation water efficiency through smart technologies (e.g., drip irrigation), and promoting agricultural digitalisation can enhance productivity while conserving water. Additionally, transitioning to renewable energy and strengthening governance and legislation are critical to reducing fossil energy dependence and ensuring effective implementation of sustainable practices. Public sensitisation and improved agricultural policies can also support this transformation.

Technological interventions shape stakeholder perceptions. Desalination is seen as key to reducing water shortages, though some worry about soil salinity. Drip irrigation is widely accepted for its efficiency, while solar and wind energy are praised for cost reduction but face intermittency challenges. Sustainability depends on integrated resource management and responsible technology adoption within the WEF Nexus, yet concerns over environmental and socio-economic impacts persist.

Overall, the diagram emphasises that enhancing water security and agricultural sustainability requires an integrated approach that addresses both technological and ecological dimensions while reinforcing governance and public awareness. Ultimately, the diagram underscores that long-term water, food, and energy security, within the WEF Nexus, depends on integrated, cross-sectoral strategies that balance technological advancement with ecological stewardship and inclusive governance.

Non-monetary values

The main objective of this method is to identify and assess the various types of value and

dimensions of human-nature connections, which extend beyond the monetary or market-based values associated with WEF components. It seeks to uncover the additional benefits that the WEF Nexus can generate within a specific social-ecological context or local community.

In the *Souss-Massa* region of Morocco, 21 surveys were conducted with stakeholders closely involved in agriculture sector. The stakeholders emphasised the region's reliance on natural resources for economic stability and food security, reflecting the fundamental role of water, energy, and ecosystems in sustaining agricultural activities. While economic considerations dominated responses, some participants also highlighted the cultural and social connections tied to these natural systems.

This case study provides a valuable perspective on the WEF Nexus in Morocco, illustrating how local communities perceive and value their environment and offering key insights for sustainable resource management in the region ([Figure 3](#)). Considering each WEF element, respondents expressed a range of emotions, benefits, and associations, shaped by their lived experiences and interactions with their environment.

The case study in Morocco highlights a strong emphasis on material and economic connections to socio-ecological systems. While experiential and cognitive dimensions reflect an overall positive relationship with the environment and a solid awareness of local ecological challenges, there remains room to further strengthen education and engagement. The philosophical dimension reveals a deep cultural appreciation for nature and its resources, reinforcing the need for sustainability-focused strategies. These insights contribute to a more integrated approach to managing the WEF Nexus in Morocco, ensuring that both economic needs and long-term environmental resilience are taken into account.

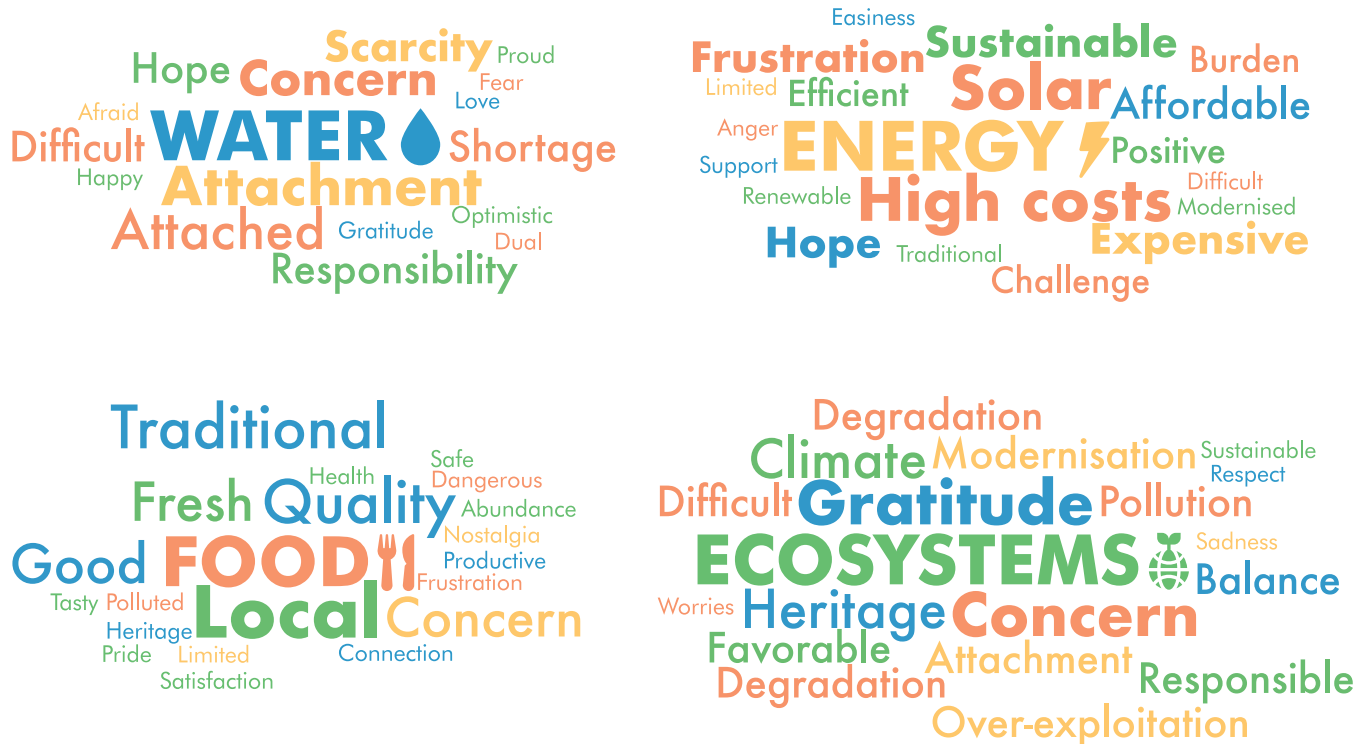


Figure 3 – Word cloud with the value given by the interviewees to the four components of WEF.

WEFe solution: Seawater desalination

The **Chtouka region**, located in the *Souss-Massa* plain in Morocco, is a strategic agricultural area, particularly renowned for its export crops such as fruits and vegetables. However, this region is facing an increasing scarcity of water resources, accentuated by the effects of climate change, overexploitation of groundwater and salinisation of agricultural soils. To meet these challenges, a **seawater desalination plant was set up, using reverse osmosis technology**. This installation represents an innovative solution to secure water supply, by gradually replacing excessive withdrawals from the water table with high-quality desalinated water. Indeed, the water obtained by reverse osmosis has a low salinity and

is suitable for agricultural use, subject to controlled management. However, although the technology is now operational, scientific agronomic research was necessary to optimise its use. The water produced by reverse osmosis technology has advantageous characteristics, such as low electrical conductivity (EC), which makes it a soft water suitable for irrigation, and the absence of excess salts, thus reducing the risks of soil salinisation. In addition, this water is of high purity, without chemical or organic contaminants. However, its composition in macro-elements and trace elements may require adjustments to ensure an adequate nutritional balance for plants. This requires rigorous monitoring of physicochemical parameters and the adoption of appropriate



Figure 4 – Soilless cultivation system of zucchini in a greenhouse with experimental monitoring of growth conditions

agricultural strategies to preserve soil fertility and ensure sustainable agricultural production.

As part of the optimisation of the use of desalinated water for irrigation, extensive scientific research has been conducted to evaluate the impact of different combinations of desalinated water and well water on zucchini (*Cucurbita pepo* L.) production. These studies, carried out in an integrated WEF nexus approach, aim to improve agricultural productivity while minimising the environmental impacts related to water and energy consumption.

The first study tested the irrigation of two varieties of zucchini, *Radia* and *Kayssar*, by combining varying proportions of desalinated water and well water (Figure 4). The results



showed that mixtures with 25% desalinated water represented a good compromise between plant growth, water consumption and CO₂



Figure 5 – Greenhouse Irrigation System Using Desalinated Water within the BONEX Project

while the hydraulic uniformity of the irrigation system reached a satisfactory level of 80%.

The second study, conducted under controlled conditions, explored a sustainable strategy integrating desalination, magnetic water treatment, biofertilisers, and solar energy to improve the efficiency of desalinated water in soilless systems (Figure 5).

emissions. This treatment consumed 17.47 litres of water per kilogram of zucchini produced, with emissions of 23 g of CO₂/kg, unlike irrigation with 100% desalinated water, which required 115 litres of water/kg and emitted 237 g of CO₂/kg. In terms of growth, the best performances (height, number of leaves and fruits) were obtained with the treatments containing 50% and 25% desalinated water,

The results showed that the combination of magnetic treatment and biofertilisers significantly improved crop yields, nutrient availability, and plant resistance to stress. The biofertilisers enhanced soil fertility by promoting nutrient absorption, while the use of solar energy for irrigation helped reduce costs and environmental impacts.

These studies demonstrate that irrigation with mixtures of desalinated water, combined with innovative agricultural techniques such as magnetic treatment and the application of biofertilisers, can achieve satisfactory agricultural yields, reduce water consumption, and minimise CO₂ emissions. They also confirm that precise adjustments in irrigation doses and optimised resource management are essential to ensure the sustainability of agricultural systems in regions affected by water stress and climate change.

In the *Souss-Massa* region, improving agricultural practices requires rigorous management of water resources, especially for high-value export crops such as tomatoes, peppers, raspberries, cucumbers, and zucchinis. After determining the optimal doses of desalinated water in combination with complementary technologies like magnetic water treatment and the use of biofertilisers, **a third study was developed to provide a comprehensive guide for the region's main export crops.** This guide serves as an essential reference for farmers, offering tailored agricultural practices for the efficient use of desalinated water. It is based on a precise assessment of the water and nutrient needs of different crops, taking into account the specific composition of irrigation water, whether it is desalinated, well water, or surface water.



Figure 6 – participatory workshop within the BONEX project in Morocco.

The study proposes concrete strategies for adjusting the quality and quantity of water based on the specific needs of each crop, including calculating specific ratios to ensure balanced inputs of essential nutrients. By aligning these parameters, the document aims to support plant health, improve agricultural yields, and promote sustainable use of water resources in a context marked by water stress.

Barriers and complementary measures

During the 2nd and 3rd BONEX workshops in *Souss-Massa* ([Figure 6](#)), several key barriers to the adoption of sustainable innovations—namely **solar energy**, waste management, soilless cultivation systems, and biofertilisers—were highlighted. For solar energy, high purchase and installation costs, limited energy storage solutions, and insufficient tax incentives or government support were recurrent challenges. Technical issues, such as maintenance needs, sizing errors, and risks of theft, further complicated adoption. In **waste management**, participants emphasised the lack of infrastructure for treating waste and brine from desalination plants, the absence of recovery solutions, high operational costs, and insufficient regulation. Regarding **soilless systems**, barriers included high energy needs for recycling, technical complexity, sensitivity to failure, and salt accumulation risks, particularly critical under the specific agroclimatic conditions of *Souss-Massa*. Meanwhile, for **biofertilisers**, farmers reported limited availability and knowledge, high initial costs, lack of standards and certification, longer action times compared to chemical fertilisers, and concerns about compatibility with local practices.

In response, the 3rd workshop proposed **complementary measures to overcome these constraints**. These include **scaling up financial incentives and subsidies** for clean technologies, developing **training programmes** to build local capacity, **improving technical support services**, and **reinforcing legislative frameworks** for waste regulation and biofertilizer certification. Other measures involve encouraging **public-private partnerships** to improve market access and support local manufacturing, fostering awareness campaigns, and **promoting research-extension linkages** to tailor solutions to local agro-ecological realities. Together, these recommendations aim to ensure the operational feasibility, social acceptability, and environmental integrity of Nexus-based interventions in the region.

REWEFe

To assess the status of water, energy, food and ecosystem resources, both individually and jointly, the REWEFe (Rapid Evaluation of Water-Energy-Food-ecosystem nexus) tool was used as it provides quantitative insights on the balance and resource use (production, consumption, incoming and outgoing) of water, energy and food. It also accounts for the main positive and negative ecosystem impacts in monetary terms. For the application of the tool to this case study, two scenarios were defined to assess the effects of the water' desalination in the context of WEFe nexus in in *Souss-Massa*.

The REWEFe tool was deployed to quantitatively assess the impacts of enhanced the use of desalinated water for irrigation as base line, and the use of solar energy for water distribution

system (S1) and an upscaled scenario where a higher adoption rate was assumed (S2) – (Figure 7).

- **Water consumption** remains higher than the volume of water available within the nexus unit through precipitation and desalination. While groundwater and surface flows are also available, the blue water and green water stress levels remain high through all the scenarios due to significantly higher water demands.
- The **upscaled scenario**, representing doubled solar power generation and desalination capacity, is still not able to meet the water demands within the nexus unit.
- The **energy consumption** increases as desalination operations are expanded leading to higher CO₂e emissions and hence more adverse impacts on the ecosystem.
- **Food production** increases in the upscaled scenario as blue water availability increases in the nexus unit due to increase in desalination volume.

Observed synergies and trade-offs: In a context of water resource scarcity, where increased groundwater extraction is not a sustainable alternative, expanding desalination operations has a significant impact on meeting water demand. Moreover, the increased availability of water within the nexus unit through desalination allows for greater food production, thereby contributing to food security. However, desalination is an energy-intensive process that leads to substantial CO₂ emissions. The current challenge is to power desalination plants with low-carbon energy sources, notably through the use of renewable energy. Additionally, responsible management of brine disposal must be ensured to protect ecosystems.



WATER (MCM/y)



ENERGY (GWh/y)

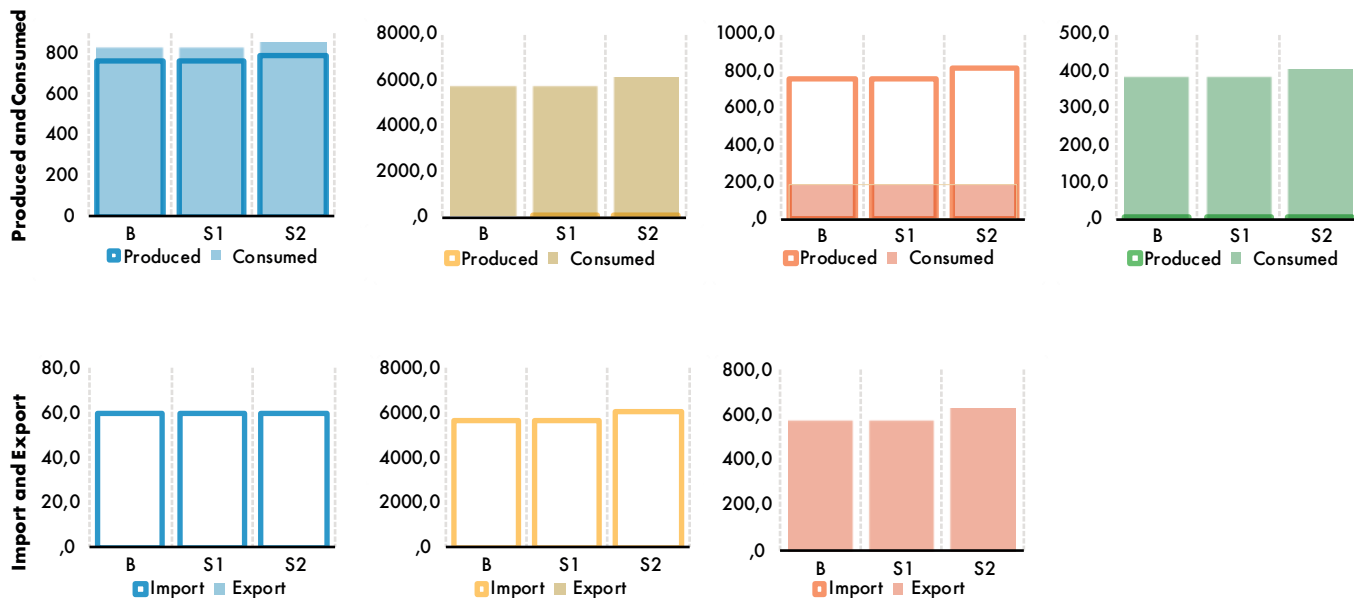


FOOD (Mkg/y)



ECOSYSTEM (mEUR/y)

RESULTS



CHANGE COMPARED TO BASELINE

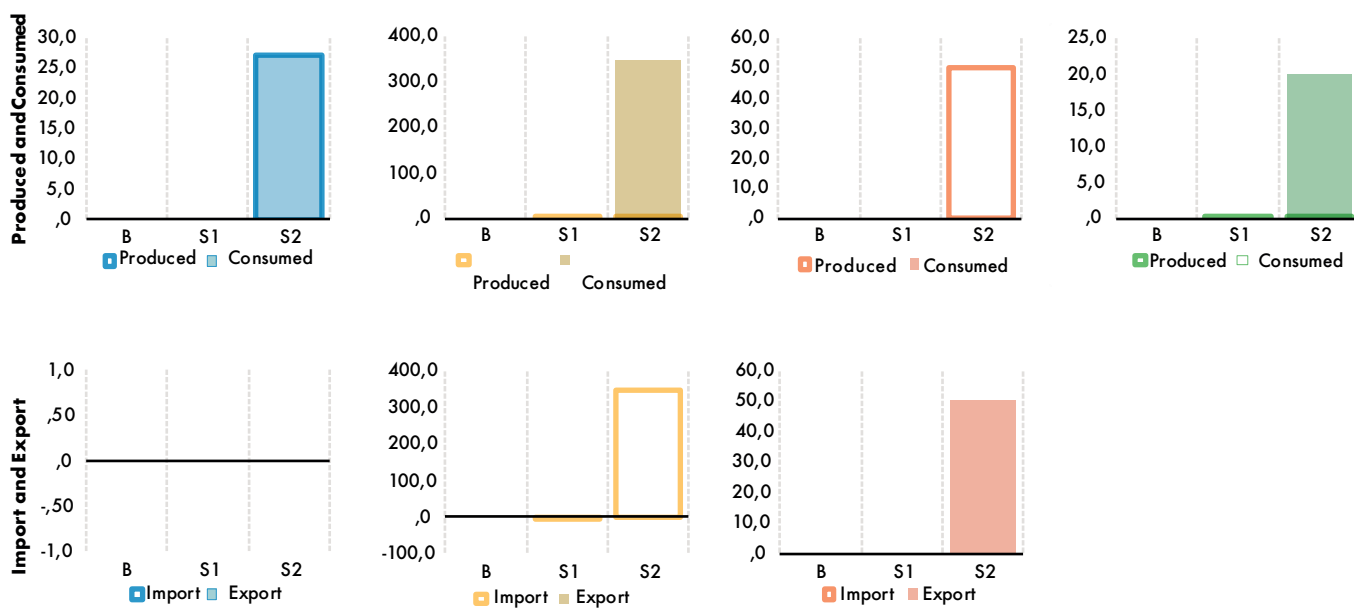


Figure 7 – Results of the three REWEF scenarios. Scenarios: **Baseline (B)**– Use of desalinated water for irrigation; **Scenario 1 (S1)** – Solar energy for water distribution system; and **Scenario 2 (S2)** – Upscaled scenario reflecting a higher adoption of the BONEX intervention

Conclusion

The seawater desalination initiative in the Souss-Massa region, framed within a comprehensive Water-Energy-Food-Ecosystem (WEFe) Nexus approach, represents a pivotal step forward in addressing the intertwined challenges of water scarcity, agricultural sustainability, and climate resilience.

By integrating advanced technological solutions, such as reverse osmosis desalination, solar-powered irrigation systems, magnetic water treatment, and the application of biofertilisers, this initiative has demonstrated that it is possible to reconcile water efficiency with enhanced agricultural productivity, all while minimising environmental impacts. The evidence generated from scientific trials indicates that combining desalinated water with innovative agronomic practices not only improves yields but also significantly reduces water consumption and CO₂ emissions per unit of production. For instance, strategic mixing of desalinated and well water, coupled with precision irrigation, resulted in optimised plant growth and resource use, offering practical alternatives for sustainable agriculture in arid zones.

Beyond the technological innovation, the project underscores the critical importance of stakeholder engagement and knowledge transfer in ensuring the long-term success of such interventions. Through participatory workshops, co-designed practical guides, and pilot field demonstrations, the BONEX project has fostered a sense of ownership and built trust among farmers, researchers, public authorities, and private actors. This inclusive process has enhanced local capacities and supported behavioural shifts towards more sustainable water and land management practices. The systemic use of tools like the REWEFe framework and causal loop diagrams has also allowed for a deeper understanding of synergies and trade-offs between water, energy, food, and ecosystems. These models have proven essential in planning and evaluating scenarios,

helping stakeholders make informed decisions aligned with both short-term agricultural goals and long-term ecological preservation.

At the governance level, the project highlights the urgent need for coherent and integrated policies that bridge the gap between sectors. Effective coordination

The evidence generated from scientific trials indicates that combining desalinated water with innovative agronomic practices (...) significantly reduces water consumption.

between water authorities, energy providers, agricultural institutions, and environmental agencies remains a cornerstone for amplifying the impact of Nexus-based interventions. The lessons from *Souss-Massa* indicate that while desalination offers a technically feasible solution to water scarcity, it must be complemented by investments in renewable energy, soil health, education, and policy reforms to truly achieve sustainability. Moreover, the project's attention to non-monetary values—such as cultural ties to land, social equity, and ecological integrity—demonstrates a more holistic vision of

development, one that respects both human well-being and environmental boundaries.

In conclusion, the integrated approach implemented in the *Souss-Massa* region provides a replicable and scalable model for other water-stressed territories facing similar socio-environmental pressures. By combining scientific innovation, stakeholder inclusion, and policy alignment, this project contributes not only to regional food and water security but also to the broader agenda of climate adaptation, rural development, and ecosystem resilience. As such, it exemplifies how a Nexus-driven strategy can move beyond sectoral silos and deliver transformative change that is technically sound, socially accepted, and environmentally sustainable.

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