

NEXUS BRIDGING PLAN

Hydroponic Agriculture

Wadi Al Wala **Jordan**



This project is part of the PRIMA programme supported by the European Union.



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Hydroponic Agriculture

in Wadi Al Wala, **Jordan**

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Framework Implementation in the
Mediterranean (BONEX), 2025

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BONEX Project is funded by PRIMA program



This project is part of the
PRIMA programme supported
by the European Union.



Executive summary

The WEFEF provides a structured approach to evaluating and implementing interventions that address the complex interconnections of the WEFE Nexus in the *Wadi Al Wala* area in Jordan and integrates multiple methods, including participatory workshops, stakeholder interviews, literature reviews, and surveys.

As part of the [BONEX project](https://bonex-prima.eu)¹ the WEFE Bridging Framework (WEFEF) was applied to evaluate potential solutions to the region's WEFE Nexus challenges and propose implementation pathways. The present Nexus Bridging Plan (NBP) is the main outcome of this exercise. This NBP focuses on the assessment of two years of implementation of the BONEX demonstration pilot in the *Wadi Al Wala* area in Jordan, featuring a context-adapted hydroponic system, powered by off-grid solar PV panels.

At the core of the Water-Energy-Food-ecosystems (WEFe) nexus in Jordan is the issue of food security, where ensuring the needs of a growing population is a central concern. This is closely tied to sustainable agricultural practices and the broader economic impact on farming systems. Water scarcity is another critical factor in Jordan, where climate change, reduced precipitation, drought, and competition for water resources across different uses heavily impact water availability. The cost of energy is another major concern in the country. Climate change, with its associated extremes and volatility, exacerbates these challenges, making it increasingly difficult to maintain resilient food and water systems. Economically, the WEFe nexus problem also includes balancing growth, business models, and private sector involvement, while accounting for the vulnerabilities of smaller producers. Ensuring the safety, employment, and income of these vulnerable populations is essential, and it highlights the social dimensions of the issue.

Within this context, BONEX in Jordan is focusing on the *Wadi Al Wala* area within the *Wadi Mujib* basin, which is located in the central part of the country and

is characterised by socio-economic tensions and environmental issues. To create economic opportunities, contribute to food security, promote efficient use of water resources, and the deployment of renewable energy, the Demonstration Pilot of BONEX in Jordan is a soilless substrate culture (hydroponics using volcanic tuff, sometimes referred to as semi hydroponic) located in *Dhiban* Municipality and specifically in *Wadi Al Wala* area within *Wadi Mujib* watershed (central Jordan). The demonstration pilot is operated by *Dhiban* Youth Cooperative, a CBO formed by unemployed young farmers and agricultural engineers. To facilitate end-users' adoption, market uptake, and policy integration of the WEFe nexus, the system was developed aiming at adapting it to fit the rural Mediterranean context and its technological readiness level. BONEX demonstration pilot in Jordan is established in an area that is still at a low level of technology development and sustainable approaches, with high poverty rates, and characterised by acute land degradation and very scarce water resources.

The soilless system yields absolute water savings and significantly higher productivity

Results of almost two years of implementation of the BONEX hydroponic system provide evidence that the soilless system yields absolute water savings and significantly higher productivity than traditional greenhouse agriculture. In addition to the technical performance of the intervention, the approach followed by BONEX in Jordan highlights the need for capacity building and active involvement of local communities in addressing the WEFe nexus.

¹ <https://bonex-prima.eu>



Methodological approach

The **BONEX project** has implemented a comprehensive WEFe Bridging Framework (WEFeF) methodology to assess the interconnections within the Water-Energy-Food-Ecosystem (WEFe) Nexus and identify suitable interventions. WEFeF integrates multiple methods, including interviews, literature reviews, questionnaires, and participatory workshops. It relies on stakeholder feedback to pinpoint key challenges, prioritise interventions, and co-develop solutions. A central component of this approach is the use of Causal Loop Diagrams (CLDs) to visualise system dynamics through participatory processes. The culmination of this effort is the development of the present Nexus Bridging Plan (NBP).

Accordingly, in Jordan, the selection of the intervention emerged through a structured, participatory dialogue involving multiple stages and stakeholders. Researchers from the German Jordanian University (GJU) and the International Union for Conservation of Nature (IUCN), the BONEX project partners in Jordan, steered the process, engaging with the Ministry of Agriculture to identify community-based organisations (CBOs) in the *Wadi Mujib* area that could potentially lead the project. This dialogue led to the shortlisting of three CBOs, after which the Ministry identified the *Dhiban* Youth Cooperative as the most suitable partner due to its alignment with the project's goals and capacity to operate effectively in the region.

Following the selection of the cooperative, BONEX researchers shifted focus to selecting the appropriate intervention, considering local primary needs, capacity, and acceptance by the local communities. This was done via a series of bilateral meetings with experts and local farmers who had experience and influence in the area. These discussions were essential for gaining insights into the specific challenges faced by farmers, particularly within the context of the WEFe nexus.

The conversations centred around identifying technologies that could address the key nexus issues,

such as improving water management, enhancing energy efficiency, and increasing agricultural productivity to sustain income generation and create employment opportunities for otherwise marginalised groups, such as youth and females.

Important issues that were considered were the significant financial constraints of the local farmers, who have limited resources to invest in new technologies and limited income possibilities to recover costs. A further issue that was raised and had to be considered is the low rate of technology adoption in the basin, which posed a further challenge to implementing advanced solutions. As a result, the intervention had to be not only technologically feasible but also affordable and accessible for the farmers, ensuring that the proposed solutions could be realistically adopted and sustained in the long term. As a result of this process, BONEX intervention in Jordan is not only providing a technical solution for local farmers to address the previously mentioned cross-sectoral challenges but is



also introducing a social innovation by building capacity, spreading awareness, and incorporating gender inclusivity within the WEFe framework.

The participatory approach ensured that the selected intervention fostered community ownership by being both context-specific and grounded in the needs and capacities of the local community, enhancing the chances of successful implementation and long-term impact. Additionally, the diversity of stakeholders contributed to a holistic understanding of the cross-sectoral challenges.

Context description

Jordan DP is located in the *Mujib* basin, which crosses west central Jordan from east to west, some 60 km south of the capital *Amman*. It is considered one of the major basins of Jordan, occupying an area of 6727 Km², which is about 7% of the total area of the Kingdom (*Figure 1*). It consists of two main subcatchments, *Mujib* and *Wala*.

The catchment area of *Wadi Mujib* covers 4770 km², lying at elevations ranging from 1,030 m above sea level down to 160 m. The average rainfall varies from 70 mm to 350 mm from south to north of the basin. It has significantly dropped over the last 30 years and is suffering from extreme events. The total annual discharge of the river is estimated at 84 MCM/y. *Mujib* dam and *Walah Dam*, with, respectively, reservoir capacities of 30 MCM to store the flood and the base flow and about 25 MCM, increased from an initial capacity of about 8 MCM (after raising the dam body) to be used for artificial recharge for downstream aquifers and irrigated agriculture, are constructed. Groundwater is used for domestic purposes in *Karak* and *Madaba* cities and other areas (e.g., *Amman*) and for irrigation. The basin hosts many industrial and mining activities like the phosphate and potash industry, using respectively about 6 MCM and 12 MCM of water (*Figure 1*).

Within the large area of the *Wadi Mujib* basin, the DP is located in *Wadi Al Walah* area, in the district of *Dhiban*, *Madaba* governorate, at the premises of *Dhiban Youth Cooperative* (<https://maps.app.goo.gl/5uKjtWzckUmSreCn8>)

Socio-economic and ecological context

Jordan is one of the most water-stressed countries worldwide, and water scarcity increasingly constrains economic and social development. In addition, Jordan is also highly

vulnerable to climate change. Jordan has less than 60 m³/ capita/year of annual renewable water, significantly below the water poverty line of 500 m³/ capita/year. Its total national water supply equated to 147 m³/ capita/year before the refugee crisis. The steady population growth caused by the refugees, as well as the high natural birth rate, has aggravated the problem. The current domestic supply capacity is around 126 litres/ capita/year (including the high percentage of the non-accounted for water of about 40%). Climate change is expected to exacerbate challenges facing Jordan's natural resource endowment in the years to come. With annual precipitations decreasing at a rate of 1.2mm per

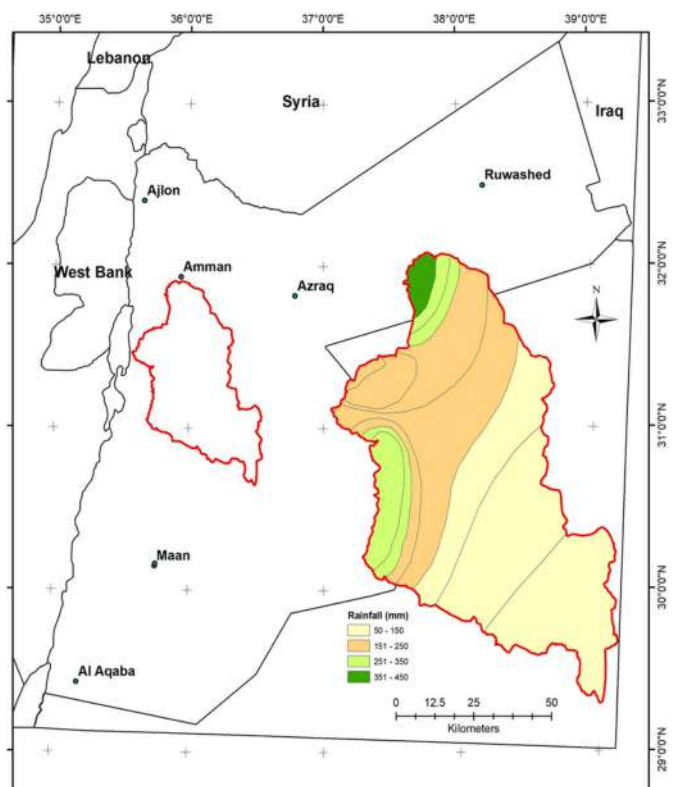


Figure 1 – Wadi Mujib Basin, Jordan.



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year and temperatures increasing by 0.03 degrees per year, Jordan will most likely experience periods of droughts with longer periods of dry days, which will affect the agriculture sector and leave the country to deal with serious and complex environmental problems.

The country's food security will be affected by more frequent, longer, and more intense heat extremes and droughts. The farming activities of food producers, particularly in remote and marginal environments dependent on rain-fed agriculture, will be impacted by water shortages and extreme climate change events. Measures to help farmers cope with drought, to increase farming productivity,

and to diversify away from farming will be key to improving their resilience and food security. Heat extremes are likely to contribute to concerns over food safety, particularly in conjunction with increased competition over water.

Poor consumers in rapidly growing urban areas are likely to be most vulnerable due to income insecurity and poor access to safety nets and basic services. Ensuring their food security will require broad pro-poor development efforts, including management of climate risk in the economy and employment, the design of social safety nets, the maintenance of strategic food reserves, and improvements in food storage and supply systems.

WEFe Nexus issue

The **WEFe nexus**, in the *Wadi Mujib Basin* in Jordan revolves around several interconnected challenges. A comprehensive view on these interconnections is provided by the causal loop diagram, which was developed based on the stakeholders' perspective collected during a workshop, and provides a comprehensive view of the interconnected dynamics within the WEFe nexus (Figure 2).

The causal loop diagram provides a detailed visualisation of the complex relationships between agriculture, water availability, and socioeconomic factors. In the context of Jordan, the interactions depicted are highly relevant, reflecting the country's pressing challenges, particularly concerning water scarcity and agricultural sustainability.

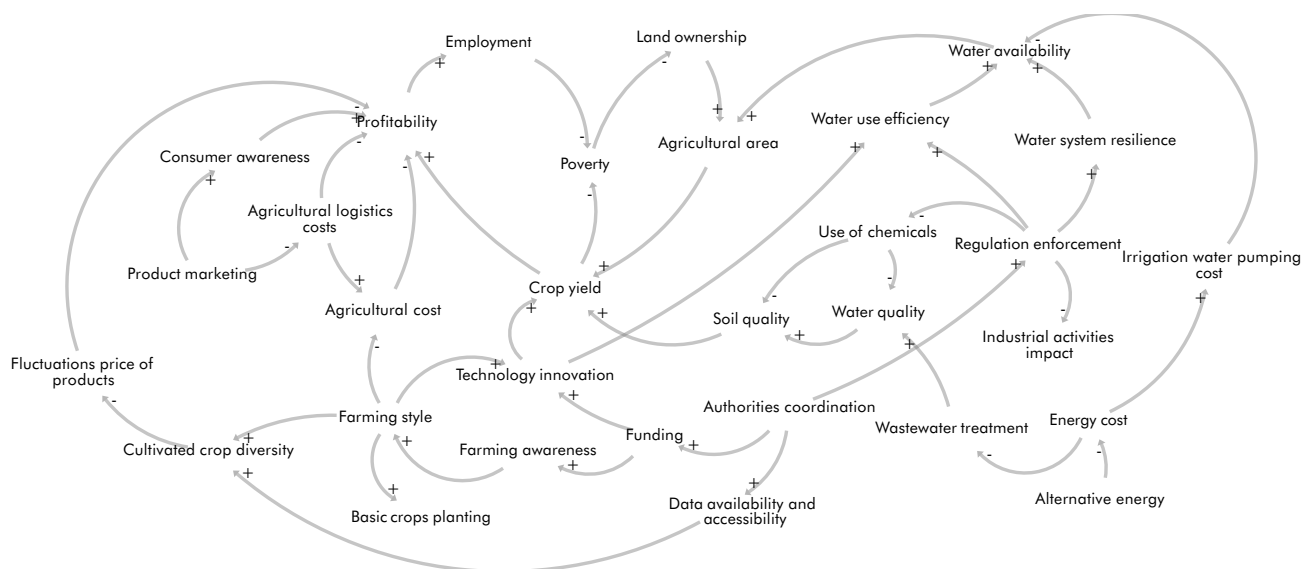


Figure 2 – Causal Loop Diagram.



Water availability plays a pivotal role, directly influencing crop yields. Water scarcity is a significant constraint on agricultural productivity in the *Wadi Mujib* and Jordan, in general. As water availability decreases, crop yields fall, which exacerbates rural poverty and diminishes employment opportunities in agricultural sectors. The interdependence between these variables illustrates the cyclical nature of poverty and water scarcity in Jordan's rural communities, where limited water supply restricts agricultural growth, which in turn fuels economic hardship.

Poverty, as shown in the diagram, is linked to land ownership and agricultural area. In Jordan, many smallholder farmers struggle to expand their agricultural activities due to financial limitations. This restricted access to land traps them in a cycle of low productivity and poverty, further complicating efforts to alleviate rural economic disparities. The feedback loop between poverty and agricultural area highlights how economic hardship in Jordan's rural areas is both a cause and a consequence of limited agricultural capacity.

Technology innovation is another critical aspect. The role of advancements in farming techniques and water use efficiency is essential for breaking the reinforcing cycles of scarcity and poverty. In Jordan, the adoption of water-saving technologies, such as drip irrigation, has been promoted as a way to maximise the efficient use of limited water resources. Technological improvements in farming practices could significantly enhance water use efficiency, leading to better agricultural yields and more stable employment opportunities, thus offering a potential

solution to some of the reinforcing negative loops identified in the diagram.

The diagram also touches on the regulatory framework, particularly the enforcement of regulations around chemical use and its impact on soil quality and water resources. Weak enforcement of agricultural regulations can result in the overuse of chemicals, contributing to soil degradation and water contamination. This issue is a growing concern, as the over-reliance on chemical inputs can lead to long-term damage to the agricultural ecosystem, further diminishing the productivity of the land and the availability of clean water for irrigation.

Energy costs also feature prominently in the CLD, linked to water availability through the cost of water pumping. In Jordan, energy-intensive water extraction from underground aquifers is necessary to meet agricultural needs, but the high cost of energy makes this process financially burdensome. The link between energy cost and profitability is

critical, as higher energy costs reduce the profitability of farming, which in turn affects employment and rural livelihoods. This dynamic is a key challenge for Jordan's agricultural sector, where both water and energy resources are limited and expensive to access.

Market dynamics, as depicted in *Figure 2*, highlight the importance of product marketing and consumer awareness. For Jordanian farmers, access to markets and the ability to promote their products effectively can help stabilise incomes and reduce the

impact of fluctuating product prices. By raising consumer awareness of locally grown crops and promoting domestic agricultural products, farmers

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may improve their profitability and reduce their vulnerability to market volatility.

Finally, the diagram includes the role of wastewater treatment, which is increasingly important in the *Wadi Mujib* and Jordan. As the country faces severe water scarcity, treated wastewater is becoming a critical non-conventional water source for agriculture. Improvements in wastewater treatment infrastructure could increase the availability of water for irrigation, thereby supporting agricultural productivity and alleviating some of the pressure on scarce freshwater resources.

Overall, the causal loop diagram reflects many of the key issues facing Jordan's agricultural sector, including the interplay between water availability, technology, market access, and poverty. The diagram suggests potential leverage points for improving outcomes, such as investing in water-efficient technologies, enforcing environmental regulations, and improving market access for farmers. These interventions could help break some of the reinforcing cycles that currently hinder agricultural development in Jordan.

Stakeholders analysis

As part of the preliminary assessment

conducted in the first phases of BONEX, the main stakeholders for BONEX intervention in Jordan were identified and classified according to degree of influence and power (*Figure 3*).

As visualised by Figure 3, specific ministries directly involved in the BONEX intervention include the Ministry of Agriculture, Jordan Co-Operative Corporation (JCC), and the Ministry of Water and Irrigation, both of which have shown high power and high interest in the intervention, as they were involved at different levels in giving the necessary approvals, shaping and supporting the implementation of BONEX. Since the DP is operated by a Cooperative, the cooperative is also supervised and audited by the JCC, and it has to report on all activities, events, and circumstances related to the DP site.

On the other hand, the Ministry of Environment, categorised as having high power but low interest, has been less directly engaged due to the small size of the BONEX demonstration site. Other ministries, such as the Ministry of Planning and International

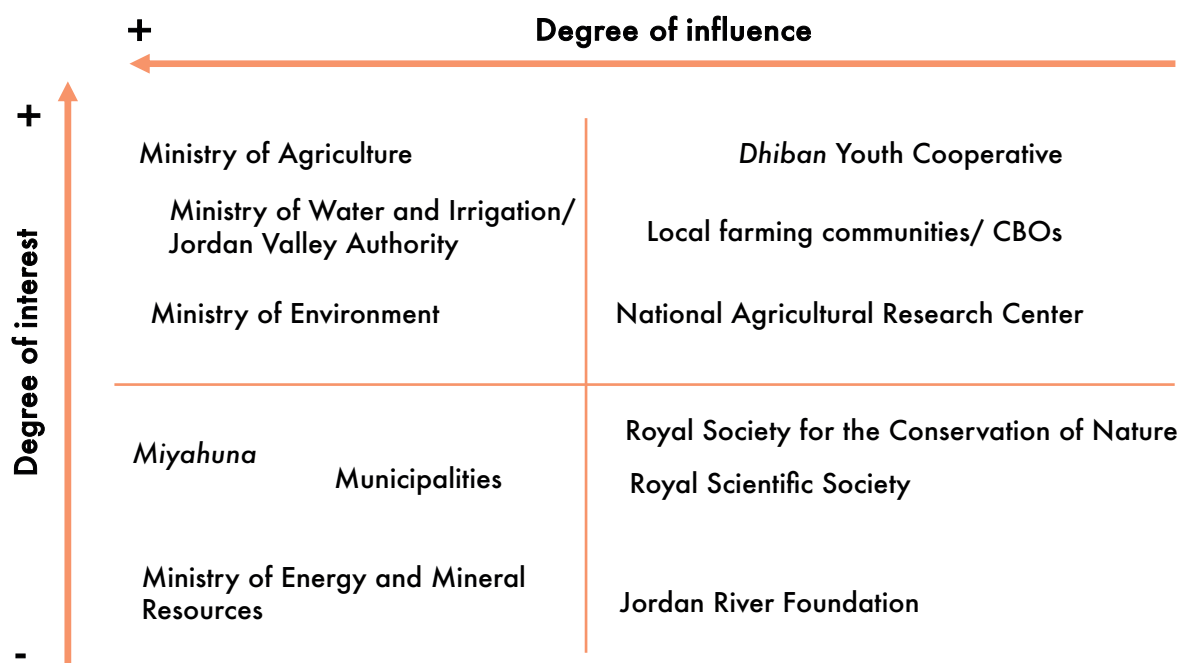


Figure 3 – Main stakeholders of BONEX intervention in Jordan (Source: BONEX scoping assessment).

Cooperation, the Ministry of Energy and Natural Resources, and the Ministry of Finance, could be considered in a similar position in terms of high power but low interest. In general, efforts have been made to raise their interest through news dissemination and workshops, highlighting the broader implications of the intervention, as they might prove crucial in any upscaling efforts. Recently, the Royal Court has shown a big interest in the activities of the DP, which prompted the ministries to grant more attention to the DP activities. Notably, the Acting Secretary General of the Ministry of Environment attended the third stakeholder workshop of BONEX in Jordan. Stakeholders with low interest and low power, such as local NGOs and educational institutions, have been involved primarily to spread awareness about BONEX in Jordan, inviting them to workshops to build understanding and advocacy for the intervention.

Finally, stakeholders with low power but high interest, such as local farmer associations and community-based organisations, have been actively engaged in co-creating the BONEX intervention, contributing valuable insights and ensuring the intervention is grounded in local needs. Regarding these stakeholders, identifying their perceptions of the ecosystem services was very important to complement the WEF nexus picture to the ecosystem services' direct beneficiaries.

Non-monetary values

The results of interviews on non-monetary values which were conducted among 21 local stakeholders from the farming communities, reveal a strong focus on instrumental values, with 67% of respondents highlighting the critical role that water, energy, and ecosystems play in sustaining agricultural production, economic activities, and food security (Figure 4). These resources were viewed as vital for survival, particularly in a water-scarce region like Jordan, where agriculture and local economies heavily rely on the availability of water and energy. Interestingly, none of the respondents acknowledged relational values, meaning there was no significant recognition of the social, cultural, or community connections to the environment. The absence of relational values suggests that in Jordan, stakeholders primarily view natural resources through a utilitarian lens, with a focus on their direct benefits to human survival and economic stability. On the other hand, 33% of respondents emphasised intrinsic values, reflecting a recognition of the natural environment's inherent worth beyond its utility. These respondents expressed concern about the preservation of ecosystems and biodiversity, recognising the importance of maintaining ecological balance and sustainable use of resources for future generations.



Figure 4 – Localisation of farms where NbS were implemented.

WEFe solution(s): Interventions and complementary measures

The pilot consists of two alternative technologies and specifically of System 1: two hydroponic production systems (46.5 m x 9 m, 418.5 m² each) powered by a solar PV system and System 2, two other traditional-farming greenhouses (control) (Figure 5).

The hydroponic irrigation system is drip irrigation with soilless growing medium, which is volcanic tuff (locally available).

The water is collected from the Al Wala valley stream originates from springs upstream, filtered, and circulated in a closed loop throughout the hydroponic greenhouses. The fertilizers are supplied and dozed based on a self-adjusting fertigation system.

The intervention features therefore a smart agricultural technique characterized by saving water, equipped with solar irrigation (drip irrigation) adapted to the rural Mediterranean context improving end-users adoption, market

uptake and policy integration of WEFe Nexus in an area that is still at a low level of technology development and sustainable approaches, high poverty rates, and characterized by acute land degradation and very scarce water resources. To the best of our knowledge, the BONEX Demonstration Project in Jordan features among the first closed-loop hydroponic systems used for productive purposes (not experimental) in the country.

A first technical innovative aspect is the introduction of smart agricultural techniques to save water and increase productivity in the area. A second innovative aspect is the use of locally abundant volcanic tuff as substrate for the soilless system (hydroponic). A third social innovative aspect is also the introduction of hydroponic solutions to facilitate the inclusion of a cooperative of unemployed youth agriculture engineers, about 50% of them are women.

The BONEX DP in Jordan has been operational since May 2023. So far, three crop cycles have been



Figure 5 – Interventions within the BONEX Demonstration Pilot in Jordan. (Left) System 1: Hydroponic greenhouses powered by solar PV system, drip irrigation, soilless growing medium (tuff substrate) (Right) System 2: Traditional greenhouses powered by a solar PV system, drip irrigation, and soil growing medium

Cycle	Crop	Hydroponic		Traditional (control)		Water saving with hydroponic (%)	Productivity increases with hydroponic (%)
		Production	Water consumption	Production	Water consumption		
1	cucumber	2.6 t (3.1kg/m ²)	288 CM	1.3 t (1.5 kg/m ²)	383 CM	24.8 %	106.6%
2	peas	1.3 t (1.5kg/m ²)	328 CM	0.97 t (1.15 kg/m ²)	462 CM	29.0 %	30.4%
3	cucumber*	0.6 t (0.7kg/m ²)	468 CM	about 0.1 t (complete crop damage)	754 CM	37.9 %	Non representative
4	red cabbage	ongoing	ongoing	ongoing	ongoing	na	na
*repeated heat waves, average temperature 46.5°C							

Table 1 – Production and water consumption in hydroponic and traditional greenhouses.

completed, and the fourth one is ongoing. To test the adaptability of the intervention while diversifying crops to sustain agricultural productivity, different cash crops were chosen for cultivation: in order, cucumbers, peas (based on seasonality), cucumbers, and, currently, red cabbage. Across all cycles, the hydroponic system provided absolute water savings compared to traditional greenhouse systems and increased productivity. Depending on crop and season, the hydroponic system enabled a reduction between 25% and 38% of water for irrigation, while increasing production from 25% to 106% (Table 1).

The first cycle of cultivation during May to September 2022 provided the highest increases in productivity: while the yield in traditional greenhouses was 1.5 kg cucumbers per square meter, the hydroponic systems enabled to doubling of production to 3.1 kg/m². Increased productivity and absolute water savings were also registered under extreme climatic conditions. That was the case of the third cycle, which took place between June and August 2024, witnessing an extreme heat wave that severely damaged crops. Temperature ranging between 40- 49.9 °C inside the greenhouses, with an average of 46.5o degrees for the entire cycle

duration, burned much of the leaves and significantly impacted production. The increase in temperature resulted in a humidity buildup that was between 60.5% and 87.8%. While damage was almost total in the traditional greenhouses, they were limited to 24% of the crop in the hydroponic system, as can be seen in the pictures below (Figure 6).

In addition, the intervention is energy-neutral through off-grid photovoltaic (PV) systems. Specifically, the PV panels produced an energy surplus of more than 1 KW/day in all cycles. The emphasis on cultivating cash crops and the integration of gender-friendly technology further enhance its socio-economic and environmental sustainability. The operation of the project by Community-Based Organisation (CBO), involving 13 male and 10 female youth, reflects the project's focus on inclusivity and local capacity building. Additionally, the project's efforts in capacity building and its engagement with the WEFE4MED Knowledge Hub demonstrate its dedication to knowledge exchange and fostering connections with stakeholders. The BONEX intervention is proving to be a model for sustainable and inclusive agricultural practices in Jordan.



Figure 6 – August 2024 heat wave effects in System 1 and System 2. (Left) System 1: hydroponic greenhouses; (Right) System 2: traditional greenhouses.

Barriers and facilitating factors

While the advantages of the BONEX demonstration site in Jordan are undeniable, it is important to insert the intervention into the regional context and discuss barriers and facilitating factors that may come into play for upscaling the intervention to achieve a significant impact on the WEF Nexus. Stakeholders from the local and regional community were asked during one of BONEX workshops to identify what could hinder or facilitate the intervention in terms of financial dimensions, physical implementation, and social, political and administrative aspects. The main findings from this session are shown below, together with some key recommendations, as agreed among the stakeholders.

Barriers

Physical Implementation

- Need for skilled labour and technical expertise
→ Training programs are essential.
- Access to water resources → Water scarcity remains a key constraint.
- Long-term planning requirements → Requires structured policy support.

Social, Administrative & Political Challenges

- Complex land rights and permit processes
→ Bureaucracy slows implementation
- Coordination difficulties among stakeholders
→ Strong leadership is needed
- Cultural resistance to new technologies
→ Awareness campaigns can help.
- Lack of a central coordination unit
→ A dedicated body would improve efficiency.

Financial Constraints

- High initial costs → Subsidies or grants could ease adoption.

- Underfunded agricultural sector → External funding is critical.
- Limited private funding for small farmers → Financial incentives are necessary.

Facilitating Factors

Physical & Technical Advantages

- Hydroponics requires less labour and space → Ideal for urban and arid regions.
- Significant water savings → Attractive for drought-prone areas.

Institutional & Political Support

- Collaboration with ministries & NGOs → Multi-stakeholder engagement boosts success.
- Media and advocacy → Public awareness drives acceptance.
- Off-grid interventions → Easier to deploy in remote areas.
- Regional cooperation → Ensures resource-sharing and sustainability.

Financial & Legal Support

- Funding from international organisations → Key for scaling up.
- Low-interest loans and risk funds → Reduce farmer vulnerability.
- Legal frameworks for approvals → Ensures compliance and stability.
- Support from JEDCO & training institutions → Enhances capacity-building

REWEF results

While the performance of the BONEX intervention in terms of improved productivity, water savings, capacity building, and community engagement was presented above, it is interesting to investigate the effect of different levels of upscaling on the WEFE Nexus. Four different scenarios were developed and their consequences explored using the REWEF Tool, which is an

Excel-based tool developed by FutureWater in the frame of BONEX to quantify the nexus implications of different scenarios and technological developments. While the Baseline explored the implications of traditional greenhouse agriculture within the nexus unit, Scenarios 1 to 4 investigate the effects of introducing BONEX hydroponic systems at different levels of upscaling (*Figure 7*).

It emerges that a small hydroponic system (S1) decreases energy consumption, requiring less irrigation and being more energy efficient compared to traditional greenhouses. However, in the upscaled scenario (S2), the expansion of hydroponic systems reflects higher energy demand, which would be, in the case of Jordan, a limiting factor. The ecosystem benefits increase with the development of a hydroponic system and the transition to solar energy (S3). This is because less water is used, leading to greater outflows from the nexus unit as well as a reduction in CO₂e emissions due to solar power generation. The deployment of a hydroponic system lowers water consumption by 5-7% due to the reduction in conventional irrigation requirements. Also, there is no blue water stress, as demand and supply are balanced. Furthermore, the deployment of hydroponic systems an increase in food production in all scenarios, ranging between 1% and 34%.

In general, it seems that the deployment and expansion of hydroponic systems in the nexus unit contribute to reducing water consumption while increasing food production. Also, the recirculation of water within the system reduces the need for fertilisers, and the soilless nature of cultivation reduces the stress on the soil. These factors contribute to healthier ecosystems. However, the higher energy consumption in the upscaled scenario (S4) highlights the need to expand renewable energy production in the nexus unit.



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Figure 7 – Results of the four REWEEF scenarios. Scenarios: **Baseline (B)** - Traditional greenhouse with no recirculation/reuse of water within the 'Madaba' governate (nexus unit); **Scenario 1 (S1)** – Development of a small hydroponic system; **Scenario 2 (S2)** – Expansion of hydroponic system; **Scenario 3 (S3)** – Hydroponic system powered by solar energy; and **Scenario 4 (S4)** – Upscaled scenario reflecting a higher adoption rate leading to a larger scale hydroponic system and increased solar power coverage.



Conclusion

The WEFE (Water-Energy-Food-Ecosystem) nexus in Jordan, particularly in the Wadi Mujib Basin, presents a complex interplay of challenges and opportunities.

At its core, the nexus revolves around ensuring food security for a growing population, managing water scarcity exacerbated by climate change, and addressing the energy needs of agricultural systems. The BONEX Demonstration Pilot in Jordan, located in the *Dhiban* area, offers a promising intervention through the adoption of soilless substrate culture (hydroponics using volcanic tuff) powered by solar energy. This innovative approach not only addresses water scarcity by significantly reducing water usage but also enhances agricultural productivity and resilience to climate extremes.

The participatory approach used in selecting and implementing the intervention ensured that the solution was context-specific, cost-effective, and aligned with the needs of local farmers. The project also introduced a social innovation by involving a youth cooperative, promoting gender inclusivity, and providing employment opportunities for young agricultural engineers. The hydroponic system demonstrated substantial water savings (25-38%) and increased productivity (25-106%) across multiple crop cycles, even under extreme climatic conditions. Additionally, the use of solar energy made the system energy-neutral, further contributing to its sustainability.

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In general, the deployment and expansion of hydroponic systems in the nexus unit contribute to reducing water consumption while increasing food production. The recirculation of water within the system reduces the need for fertilisers, and the soilless nature of cultivation minimises soil degradation, contributing to healthier ecosystems. However, the higher energy demand in upscaled scenarios highlights the need to expand renewable energy production within the nexus unit to maintain sustainability.

However, the success of the intervention and its potential for upscaling depend on addressing several barriers, including the need for skilled labour, access to water resources, and coordination among stakeholders. Financial constraints, particularly for small farmers, and the underfunded

agricultural sector in Jordan also pose significant challenges. Complementary measures such as capacity building, policy support, and collaboration with ministries, private sectors, and international organisations are essential to overcome these barriers.

The involvement of key stakeholders, including the Ministry of Agriculture, the Ministry of Water and Irrigation, and local cooperatives, will be critical in driving the adoption and scaling of this innovative solution.



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This project is part of the
PRIMA programme supported
by the European Union.