Science for resilient livelihoods in dry areas

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POLICY BRIEF

Potential of Water Harvesting as a Strategic Tool for Resilience, Sustainable Livelihoods, and Drought Mitigation in the Olive Farming System in Palestine

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Background

With only a small percentage of cultivated land irrigated, rain-fed agriculture is the backbone of Palestinian agricultural activities. Despite its scarcity, rainfall is generally poorly managed, and much is lost through runoff and evaporation. Capturing rainwater and efficiently using it is crucial for any economic and social development in this region, threatened by the systematic Israeli restrictions on access to agricultural land and water resources and climate change challenges.

Olive growers/farmers cannot obtain the water needed to irrigate their trees and make their products more sustainable and profitable. Thus, the only alternative is to abandon their land and find other income sources to secure their livelihood. Under these circumstances, Palestinian farmers rely on traditional rainfed agriculture that faces climatic change threats, including rainfall fluctuations and high temperatures; in addition, restricted water and land use rights exacerbate the threat and increase the instability of seasonal production. Such challenges have led to a vulnerable community relying on rainfed farming with a high risk of losing livelihoods. Within this context, providing a sustainable micro rainwater harvesting (MIRWH) technique is one option to ensure efficient use of scarce, fragile, and uncertain resources. The MIRWH technique restores degraded lands in drought-prone areas and expands and secures income generation opportunities and improved livelihoods for rural Palestinian communities. Such technology allows local development and improves smallholder olive growers' well-being without undermining ecosystem services and can make rainfed olive growers' communities resilient and the farming system sustainable. Among such opportunities, one can ask, "To what extent is the investment in the MIRWH systems profitable and what potential can rainwater harvesting offer to enable increased olive growers' livelihoods?" Because of the risk and uncertainties involved, Palestinian olive farmers may need to be convinced not only of the benefits of adopting appropriate water harvesting techniques but also of the potential to sustain their agricultural land. The most important benefit is enhancing olive production and, as such, olive farmers' incomes.

BOX 1. KEY FINDINGS

- The MIRWH technology is a lifeline for Palestinian well-being (improving production, productivity, and livelihoods for olive farmers).
- The MIRWH technology is a strategic tool for drought mitigation in the olive farming system in Palestine (reducing water shortage and stress in dry agriculture areas).
- The MIRWH systems create synergies by improving rainfed agriculture and enhancing sustainable agriculture in Palestine.
- Economic and financial indicators suggest that the MIRWH system is feasible and profitable for olive growers in high- and low-slope areas.

BOX 2. KEY ISSUES

- The MIRWH technique solves water shortages in areas with uncertain water supply (that is, low rainfall) and low irrigation water resources.
- The MIRWH technique is a potential development tool for managing dryland resources that shows promise for olive-based tree farming systems communities in Palestine.
- The cost of maintenance of rainwater harvesting technologies is affordable compared to other conventional/traditional technologies.
- The MIRWH technique enables the storage and collection of water in both high- and low-slope areas.
- Implementing the MIRWH technique is easy for smallholder farmers to learn and apply.
- The MIRWH technique design requires a precise decision.
- Adopting the MIRWH technique systems will encourage Palestinian olive-growing farmers to create a systematic engagement strategy resulting in sustainable use of water resources.

What this policy brief is about

This policy brief concerns the importance of adapting the MIRWH in the olive farming system in Palestine. It combines existing knowledge of the olive farming system in Palestine with the proven technology of the MIRWH. The policy brief builds on the analysis of the economic and financial viability of the MIRWH as an innovation system by deploying the enterprise budget tool to estimate the return, costs, and net returns associated with olive production under the MIRWH in the high (>16 degree) and low (<= 16 degrees) slope areas of Palestine. The policy considers the benefits of using MIRWH in the olive farming system that will support the farmers' livelihoods, especially vulnerable farmers and communities, through increasing olive and olive oil production, overall farm sustainability, decreasing agriculture input costs, overcoming challenges and difficulties to sustain olive productions (for example, the need for irrigation water during summer), and increasing farmer resilience to climate shocks. Additionally, the policy considers the benefits of the combined technique to enhance overall ecosystem services through soil stabilization, increasing soil moisture content, reducing runoff and erosion rates, and providing opportunities for enhancing farm soil biodiversity.

Enabling the benefits of rainwater harvesting in the Palestinian olive dry-farming system

Rainwater harvesting and ecosystems: a lifeline for Palestinian well-being

The olive tree is one of the oldest well-known planted trees in the world and originated in the Mediterranean region (Hanieh et al., 2020; Shadeed et al., 2022; Therios, 2008). In Palestine, the olive tree has "essential economic, cultural, social, religious, and national significance. It illustrates the Palestinian attachment to their land – olive trees resist the tough conditions of drought and poor soil conditions and remain attached to their place" (ReliefWeb, 2012).

Potential of water harvesting and conservation as a strategic tool

Farmers in the dry and semi-dry areas of Palestine are suffering from consecutive droughts, adding additional pressure to the existing political situation and accessibility of land and water, with the fact that around 50 percent of the West Bank receives rainfall of less than 450 mm annually (Figure 1), where olive tree production requires at least 500 mm of rainfall. Implementing the MIRWH technique in olive farms can improve farmer resilience, especially in areas with rainfall below 500 mm, increase olive productivity, and so their income, thus increasing land value and its greenness.

Rainwater harvesting: an old approach in landscape management

Rainwater harvesting concentrates surface runoff in well-defined target areas (pits, furrows, and ponds) to enhance local water storage and overcomes water shortages during dry spells (Ngigi, 2003). Water harvesting structures have been used traditionally in arid areas to capture runoff within pits and increase water availability for plant growth (Alshawahneh et al., 2011; Malagnoux, 2008; Oweis, 2017; Previati et al., 2010; Schiettecatte et al., 2005). These pits capture and store storm runoff, thus dissipating the erosive energy of flowing water, reducing concentrated flow erosion processes, and allowing the water to infiltrate into the soil (Founds et al., 2020). The water harvesting structure provides in-situ storage of water on hill slopes and provides the plant with enough soil moisture storage to survive and grow. Furthermore, the implementation of MIRWH along the terrain contours intersects the flow path of surface runoff and mitigates the effects of accumulated surface runoff, erosion, and sediment yield (Haddad et al., 2022; Strohmeier et al., 2021).

In areas where rainfall does not provide sufficient water for crop production and in areas with high and low slopes, the MIRWH technique can be a solution, which collects water from the upslope areas (Bruggeman et al., 2008; Oweis and Taimeh, 1996). Notwithstanding, the technique can be easily implemented by farmers using traditional farm tools such as a hoe or shovel, and it is a proven and reported success for fruit, forage, or forest tree production. However, a set of precise decisions about tree spacings and the shape and dimensions of MIRWH structures is necessary. In addition, the tree water requirements, and the expected amount of runoff at the site need a good understanding of the rainfall, runoff, and soil properties to determine the best MIRWH design for the site (Bruggeman et al., 2008; Critchley et al., 2013; ESCWA, 2022).

Economic and financial viability of the MIRWH systems for olive growers in Palestine

To analyze the economic and financial viability of the MIRWH innovation system, we deployed the enterprise budget tool (or partial budget analysis framework). This tool estimates returns, costs, and net returns associated with olive production using this technology and in both contexts: high- and low-slope areas.

For low-slope areas, the analyzed data revealed that the internal rate of return (IRR) of investing in the MIRWH system is 24 percent for a lifecycle of 5 years. The IRR indicator is a key element that determines the technology's validity by calculating when it exceeds the opportunity cost of capital. For a lifecycle period of 5 years, IRR exceeds the opportunity cost of capital (which is normally the interest rate on borrowed capital that is available in the economy – at the time of project implementation this was about 5.55 percent for Palestine). The analysis also determined that the net present value (NPV) of cultivating olives by adopting the MIRWH system at a 5.55 percent discount (or interest) rate is US$1256 per hectare per year. The overall benefit cost ratio (BCR) of using this system is 1.35, indicating that the costs could rise by 35 percent before the BCR would decline to 1. Therefore, the result also shows that the performance of the MIRWH system, given the return on investment (ROI) indicator used to measure the amount of return on a particular investment relative to the investment's costs, is acceptable (+35 percent), suggesting a gain from this investment in this technology relative to its costs. The profitability index (PI), also known as profit investment ratio, is greater than one (1.41). A PI below 1 indicates that the investment in this technology should be abandoned. The last measured indicator is the payback period (PBP). The PBP refers to the amount of time it takes to recover the cost of an investment and is defined as the length of time at which an investment reaches a break-even point. Thus, the desirability of an investment in this technology is directly related to its PBP. In our case, therefore, shorter paybacks mean more attractive investments. **Overall, all economic and financial indicators support investment in this technology for olive-growing farming systems in low-slope areas**.

BOX 3. RAINWATER HARVESTING TECHNOLOGY PERFORMANCE INDICATORS – ENTERPRISE BUDGET INDICATORS PER HECTARE OF OLIVE TREES

- Case 1: Olive trees in high-slope areas
  BCR = 1.50
  IRR = 8%
  ROI = 51%
  PI = 1.47
  PBP = 8 years
  NPV = US$3336

- Case 2: Olive trees in low-slope areas
  BCR = 1.35
  IRR = 24%
  ROI = 35.4%
  PI = 1.41
  PBP = 3 years
  NPV = US$1256

The assessment of the financial and economic indicators of the MIRWH system in high-slope areas also reveals the profitability of investment for a discount rate of 5.55 percent. The group of economic factors outlined in Box 3 suggests that NPV is US$3336 per hectare per year. The PI is greater than 1 (that is, 1.47). This confirms the profitability of adopting this technology in high-slope areas. The PBP is 8 years. In the MIRWH case, shorter paybacks mean more attractive investments. The ROI is reasonable (+50 percent), suggesting a gain from this investment in MIRWH technology relative to its costs, and consequently the profitability of this investment. This statement is also confirmed by the discounted profitability indicators (BCR = 1.50 and IRR = 8 percent). **Overall, the MIRWH technology in the rainfed-olive-grower community could save money for the next 10 years, proving its profitability and self-sustainability.**

Suitability maps – out-scaling

Suitability assessment using a geographic information system (GIS) aims to select suitable areas for specific land use and estimate the suitability level of certain land for a certain use (Shadeed et al., 2022). Suitability mapping was used to identify potential areas for out-scaling the MIRWH technique in olive farming systems. The mapping procedure adapted from the olive land suitability resulted from the most recent research findings (Adham et al., 2022; Shadeed et al., 2020, 2022) and focused on prioritized low-rainfall areas (250–350 and 350–450 mm) and in high-slope (>16°) and low-slope (<16°) areas. In Palestine, particularly the West Bank, around 32 percent of the country area receives annually an average of 250–350 mm of rainfall over 928.25 km^2 and 350–450 mm over 860.39 km^2. Most of this rain falls on areas with low slopes (around 1565.7 km^2). The total area of existing olive farms in Palestine is around 836 km^2, of which 12 percent is in the target rainfall zones, with the majority (around 94.36 km^2) in the low slopes (Figure 1).

Based on the Palestinian–Israel peace process agreement (Oslo Accord) (Shadeed et al., 2022) for land classification and the existing olive farm distribution map, around 34 percent of olive farms are located in Area A, 22 percent in Area B, and 44 percent in Area C. Existing olive farms in the 350–450 mm rainfall zone are distributed to 36, 32, and 31 percent in Areas A, B, and C, respectively. In the same target rainfall zones, existing olive farms with low slopes are distributed to 36, 31, and 33 percent in Areas A, B, and C, respectively. In comparison, the existing olive farms with high slopes are distributed to 41, 26, and 33 percent in Areas A, B, and C, respectively (Figure 2).

The suitability mapping criteria used in the olive land suitability mapping (Table 1) from Shadeed et al. (2022) were adapted to extract the estimates of the olive land suitable areas for the target rainfall zones (250–450 mm) and were distinguished between the two slope criteria [Note: each criterion was categorized into several scores assigned a value from 1 (low suitability) to 9 (high suitability) (Table 2 and Figure 3)].

The results show that 95 percent of the areas in the 250–350 mm rainfall zones have low (44 percent) and moderate (51 percent) suitability classes. In the higher targeted rainfall zones (350–450 mm), 59 percent of the area is moderate suitability, 25 percent is high suitability, and the rest is low suitability.

Figure 1: Average annual rainfall distribution and existing olive farms (left) and target rainfall zones and existing olive farms (right) in Palestine.

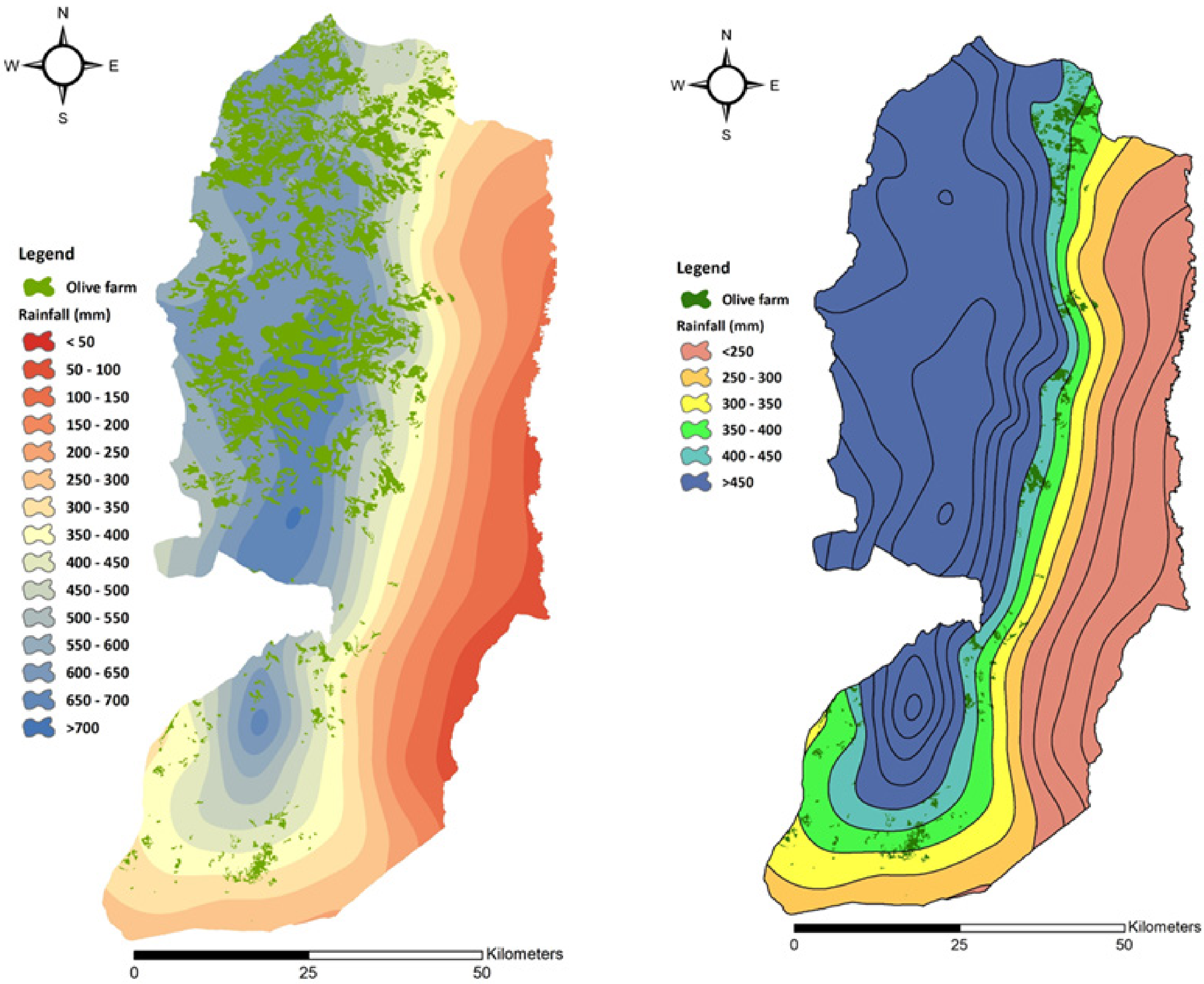


Figure 2: Existing olive farm distribution in the target rainfall zones and Oslo areas.

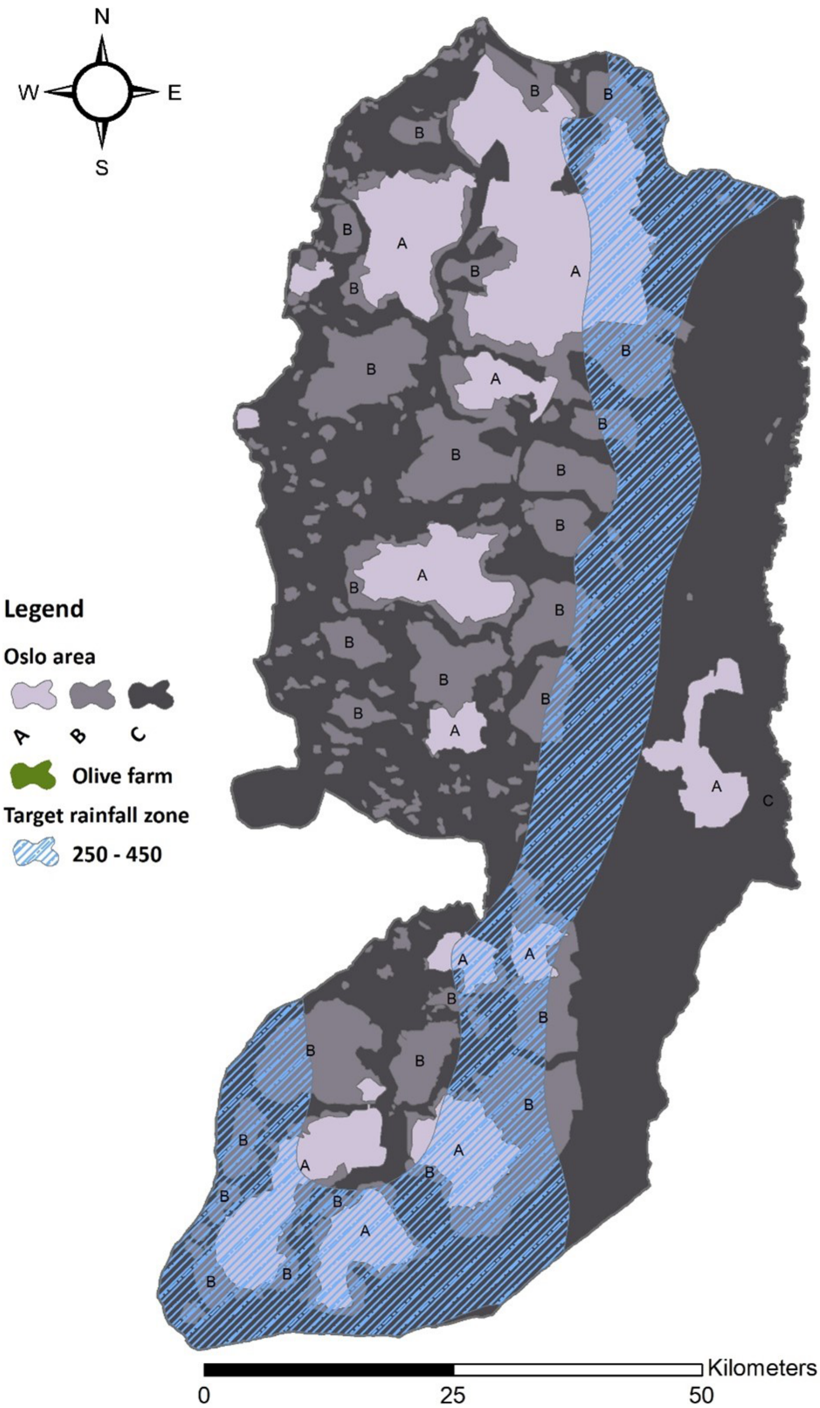


Table 1: The olive land suitability mapping criteria, ranges, and assigned values.

#	Criteria	Sub-criteria	Suitability value
1	Elevation (meters)	−375 to 0 0–250 250–500 500–750 >750	1 4 6 5 3
2	Aspect (degrees)	−1 (flat) 0–67.5 (north, northeast) 67.5–157.5 (east, southeast) 157.5–247.5 (south, southwest) 247.5–360 (west, northwest, north)	1 2 3 4 5
3	Slope (degrees)	0–8 8–16 16–30 >30	7 5 3 1
4	T_{max} (°C)	16–20 20–26 26–30	5 7 3
5	T_{min} (°C)	10–14 14–16	7 5
6	Rainfall (mm/year)	<150 150–300 300–400 400–500 >500	1 2 3 5 7
7	Land use	Built-up areas/Israeli settlements Woodland/Forest Rough grazing/Subsistence farming Irrigated farming (supporting vegetables) Permanent crops (grapes, citrus, etc.) Olive groves Arable land (supporting grains)	1 2 6 3 5 7 4
8	Soil Texture	Clay Clay loam Loamy Sandy loam	2 6 7 4
9	Agricultural Rainwater Harvesting Suitability	Very low Low Medium High Very high	2 3 5 6 7

Note: Each criterion was categorized into several scores assigned a value from 1 (low suitability) to 9 (high suitability)

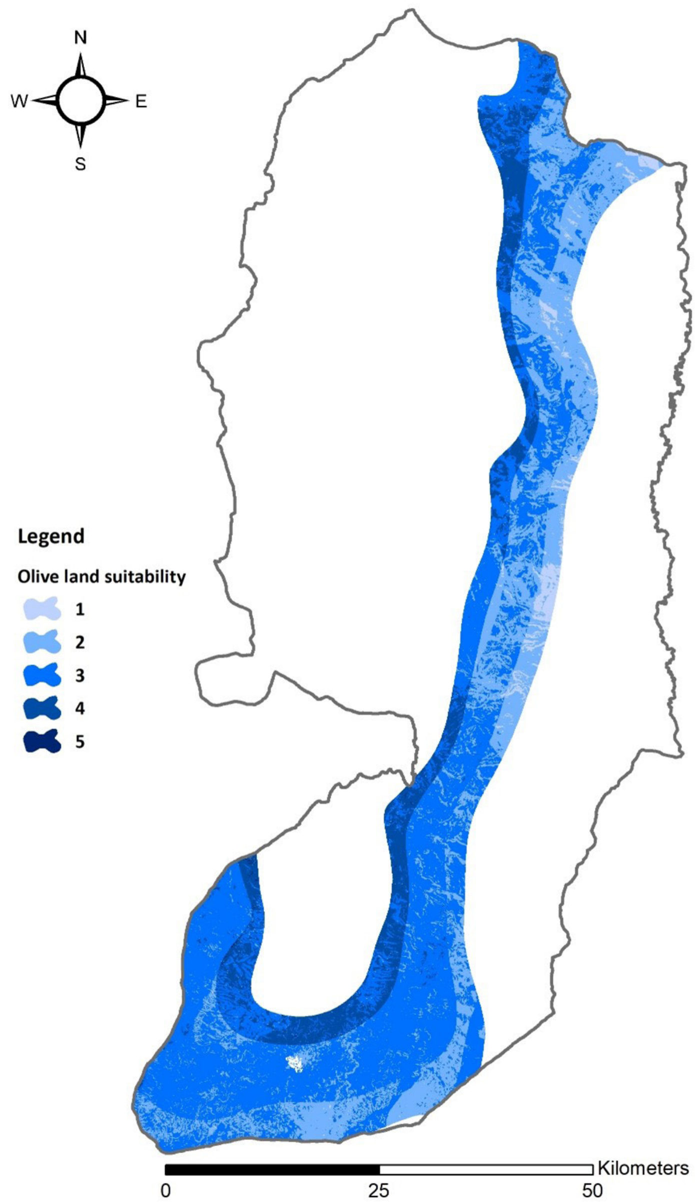
Source: Adapted from Shadeed et al. (2022).

Table 2: Olive land suitability areas (km²) in the target rainfall zone and disaggregated into two slope areas.

Class	Rainfall zone (mm)		Slope (degree)	
	250–350	**350–450**	**0–16**	**>16**
Very low	40.26	1.29	22.29	19.28
Low	410.47	134.31	413.49	131.29
Moderate	469.81	503.98	908.37	65.41
High	2.26	216.64	212.52	6.38
Very high	0	1.04	1.04	0

Source: Own elaboration (2022).

Figure 3: Olive land suitability map ranging from low (1) to high (5) suitability.



Source: Adapted from Shadeed et al. (2022).

BOX 4. AN ENABLING POLICY ENVIRONMENT

- Palestinian olive growers represent an enormous untapped potential for climate mitigation and adaptation.
- Combining local knowledge with proven technologies (such as MIRWH), the olive farming systems can become productive, sustainable, and resilient to climate shocks – but only with policy support.
- The FAO-SIDA-ICARDA project addresses the above challenges by sharing knowledge, facilitating learning, and generating dialog among researchers, civil society organizations, vulnerable communities, and policymakers in a participatory way, who can help adopt MIRWH systems and enhance their resilience to drought and climate change threats.
- Including the MIRWH systems within the government's development agenda will enhance the integrated land and water management and climate action plans.

Concluding remarks

- The Palestinian Authority, national research and development organizations, and various NGOs have recognized the need to adopt MIRWH technologies to fill the gap in water-supply-stressed areas in Palestine and as a strategic tool for drought mitigation.
- Several participatory approaches, such as training communities in constructing the MIRWH technologies, farmers' field schools, economic and financial analysis of the technology, and modeling techniques, have been used to validate and promote the MIRWH technology for olive growers. These approaches show that the MIRWH system is affordable, profitable, scalable, and sustainable.
- The MIRWH technologies can be scaled to similar agro-ecological contexts not only in Palestine but also in the Middle East and North Africa region.
- Some challenges have been outlined, such as the limited public funding to support adoption of these technologies.

BOX 5. TECHNICAL RECOMMENDATIONS

- About 10 olive trees per dunum[1] is suggested in the semi-dry areas.
- If possible, a cistern should be included (capacity 70–100 cm^3) for 10 dunums for supplementary irrigation during summer.
- Soil depth should be more than 80 cm.
- Compost should be provided for olive trees, or 250 mL per tree of humic acid, during winter.
- The soil just around the tree should be plowed once per season.
- Pruning, weed control, disease control, composting, and all other best practices should be implemented for olive integration with water harvesting techniques.

BOX 6. POLICY RECOMMENDATIONS AND STRATEGIC ACTIONS

- Enhancing the adoption of water harvesting techniques by the Ministry of Agriculture (MoA) as an improvement tool for the dry and semi-dry areas in Palestine.
- Dissemination of knowledge of water harvesting techniques for farmers, NGOs, relevant ministries, and universities through demonstrations, field days, and extension.
- Promote the MIRWH systems and include them within national water strategies to ensure that the MIRWH systems are scaled up.
- The development organization in Palestine should collaborate with all concerned stakeholders to scale up MIRWH beyond the pilot phase.
- Sensitization of the local communities and governments to embrace the MIRWH technology.
- Create revolving loan fund management to support investment in this system by smallholder olive growers (mainly in high-slope areas).
- Implementing public (funding)–private (construction of systems) partnerships enhances implementation and adoption.
- Involve rural communities and increase their knowledge and perception of the merits of this innovation through better access to technical information, know-how, effective extension delivery system, credit services, and training.
- Finally, to increase olive-farming system productivity in Palestine, policies are required to guarantee financial support from government institutions to farmers and technical training for the construction and sustainability of these systems.

1 dunum = 0.1 ha.

Further reading

https://www.researchgate.net/publication/228347939_Potential_of_water_harvesting_as_a_strategic_tool_for_drought_mitigation.

https://www.researchgate.net/publication/337689862_Long-term_effectiveness_of_sustainable_land_management_practices_to_control_runoff_soil_erosion_and_nutrient_loss_and_the_role_of_rainfall_intensity_in_Mediterranean_rainfed_agroecosystems.

https://www.sciencedirect.com/science/article/pii/S0341816219304941.

http://sro.sussex.ac.uk/id/eprint/78201/1/Dallimer_et_al-2017-Land_Degradation_%26_Development.pdf

Key References

https://link.springer.com/article/10.1007/s11269-015-1091-y.

https://cordis.europa.eu/project/id/266360/reporting.

https://www.researchgate.net/publication/222830443_What_is_the_limit_of_up-scaling_rainwater_harvesting_in_a_river_basin.

https://www.sciencedirect.com/science/article/pii/S0959378020307044.

https://www.ide.go.jp/library/English/Publish/Reports/Vrf/pdf/488.pdf.

https://iwaponline.com/hr/article/46/4/591/1058/Delineation-of-potential-sites-for-rainwater.

https://www.sciencedirect.com/science/article/pii/S2095633915301118.

https://www.semanticscholar.org/paper/The-potential-of-in-situ-rainwater-harvesting-in-a-Mahmoud-Alazba/f081ae660408cdb95bb5231107bf7acbf6904ac3.

Adham, A., M. Riksen, R. Abed, S. Shadeed, and C. Ritsema. 2022. "Assessing suitable techniques for rainwater harvesting using analytical hierarchy process (AHP) methods and GIS techniques." *Water* 14 (13): 2110. https://doi.org/10.3390/W14132110.

Alshawahneh, N., H. Saoub, T. Oweis, and N. Haddad. 2011. "Impact of micro-catchment water harvesting on plant diversity in Jordan Badia rangelands." In *Meeting the Challenge of Sustainable Development in Drylands under Changing Climate - Moving from Global to Local, Proceedings of the Tenth International Conference on Development of Drylands, 12–15 December 2010, Cairo, Egypt*, 273–283.

Bruggeman, A., A. Tubeileh, and F. Turkelboom. 2008. "Microcatchment water harvesting for olive production in water-scarce environments." *Acta Horticulturae* 791 (1): 265–270. https://doi.org/10.17660/ACTAHORTIC.2008.791.37.

Critchley, W., K. Siegert, C. Chapman, and M. Finkel. 2013. *Water Harvesting: A Manual for the Design and Construction of Water Harvesting Schemes for Plant Production*, 1st ed.; FAO: Rome, Italy, 1991; ISBN 978-3-905835-35-9.

ReliefWeb. 2012. *Olive Trees – More Than Just a Tree in Palestine - occupied Palestinian territory. Fact Sheet*, November 21. https://reliefweb.int/report/occupied-palestinian-territory/fact-sheet-olive-trees-%E2%80%93-more-just-tree-palestine.

Founds, M. J., K. C. McGwire, M. A. Weltz, S. K. Nouwakpo, and P. S. J. Verburg. 2020. "Predicting micro-catchment infiltration dynamics." *Catena* 190: 104524. https://doi.org/10.1016/j.catena.2020.104524.

Haddad, M., S. M. Strohmeier, K. Nouwakpo, O. Rimawi, M. Weltz, and G. Sterk 2022. "Rangeland restoration in Jordan: Restoring vegetation cover by water harvesting measures." *International Soil and Water Conservation Research* 10 (4): 610–622. https://doi.org/10.1016/J.ISWCR.2022.03.001.

Hanieh, A. A., M. Karaeen, and A. Hasan. 2020. "Towards a sustainability model for olive sector in Palestine." *Procedia Manufacturing* 43: 269–276. https://doi.org/10.1016/J.PROMFG.2020.02.153.

Malagnoux, M. 2008. Degraded Arid Land Restoration for Afforestation and Agro-Silvo-Pastoral Production through New Water Harvesting Mechanized Technology. In *The Future of Drylands* edited by C. Lee, and T. Schaaf, 269–282. Springer, Dordrecht. https://doi.org/10.1007/978-1-4020-6970-3_30.

ESCWA. 2022. Training Manual: Micro-catchment rainwater harvesting: planning, design and implementation: https://www.unescwa.org/publications/micro-catchment-rainwater-harvesting-training-manual.

Ngigi, S. N. 2003. “What is the limit of up-scaling rainwater harvesting in a river basin?” *Physics and Chemistry of the Earth* 28 (20–27): 943–956. https://doi.org/10.1016/j.pce.2003.08.015.

Oweis, T. 2017. “Rainwater harvesting for restoring degraded dry agro-pastoral ecosystems: a conceptual review of opportunities and constraints in a changing climate.” *Environmental Reviews* 25 (2): 135–149. https://doi.org/10.1139/er-2016-0069.

Oweis, T. Y., and A. Y. Taimeh. 1996. Evaluation of a small basin water-harvesting system in the arid region of Jordan. *Water Resources Management* 10: 21–34. https://doi.org/10.1007/BF00698809.

Previati, M., I. Bevilacqua, D. Canone, S. Ferraris, and R. Haverkamp. 2010. “Evaluation of soil water storage efficiency for rainfall harvesting on hill-slope micro-basins built using time domain reflectometry measurements.” *Agricultural Water Management* 97 (3): 449–456. https://doi.org/10.1016/J.AGWAT.2009.11.004.

Schiettecatte, W., M. Ouessar, D. Gabriels, S. Tanghe, S. Heirman, and F. Abdelli. 2005. “Impact of water harvesting techniques on soil and water conservation: a case study on a micro catchment in southeastern Tunisia.” *Journal of Arid Environments* 61 (2): 297–313. https://doi.org/10.1016/J.JARIDENV.2004.09.022

Shadeed, S., S. Alawna, M. Riksen, and L. Fleskens. 2022. “Land suitability mapping for rainfed olive tree plantation in the West Bank, Palestine.” *Desalination and Water Treatment* 268: 194–204. https://doi.org/10.5004/dwt.2022.28716.

Shadeed, S., T. Judeh, and M. Riksen. 2020. “Rainwater harvesting for sustainable agriculture in high water-poor areas in the West Bank, Palestine.” *Water* 12 (2): 380. https://doi.org/10.3390/W12020380.

Strohmeier, S., S. Fukai, M. Haddad, M. AlNsour, M. Mudabber, K. Akimoto, S. Yamamoto, S. Evett, and T. Oweis. 2021. “Rehabilitation of degraded rangelands in Jordan: the effects of mechanized micro water harvesting on hill-slope scale soil water and vegetation dynamics.” *Journal of Arid Environments* 185: 104338. https://doi.org/10.1016/J.JARIDENV.2020.104338.

Therios, I. 2008. Olives. In *Olives*. 398 pp. CABI Publishing (https://www.cabdirect.org/cabdirect/abstract/20093020235). https://doi.org/10.1079/9781845934583.0000.

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