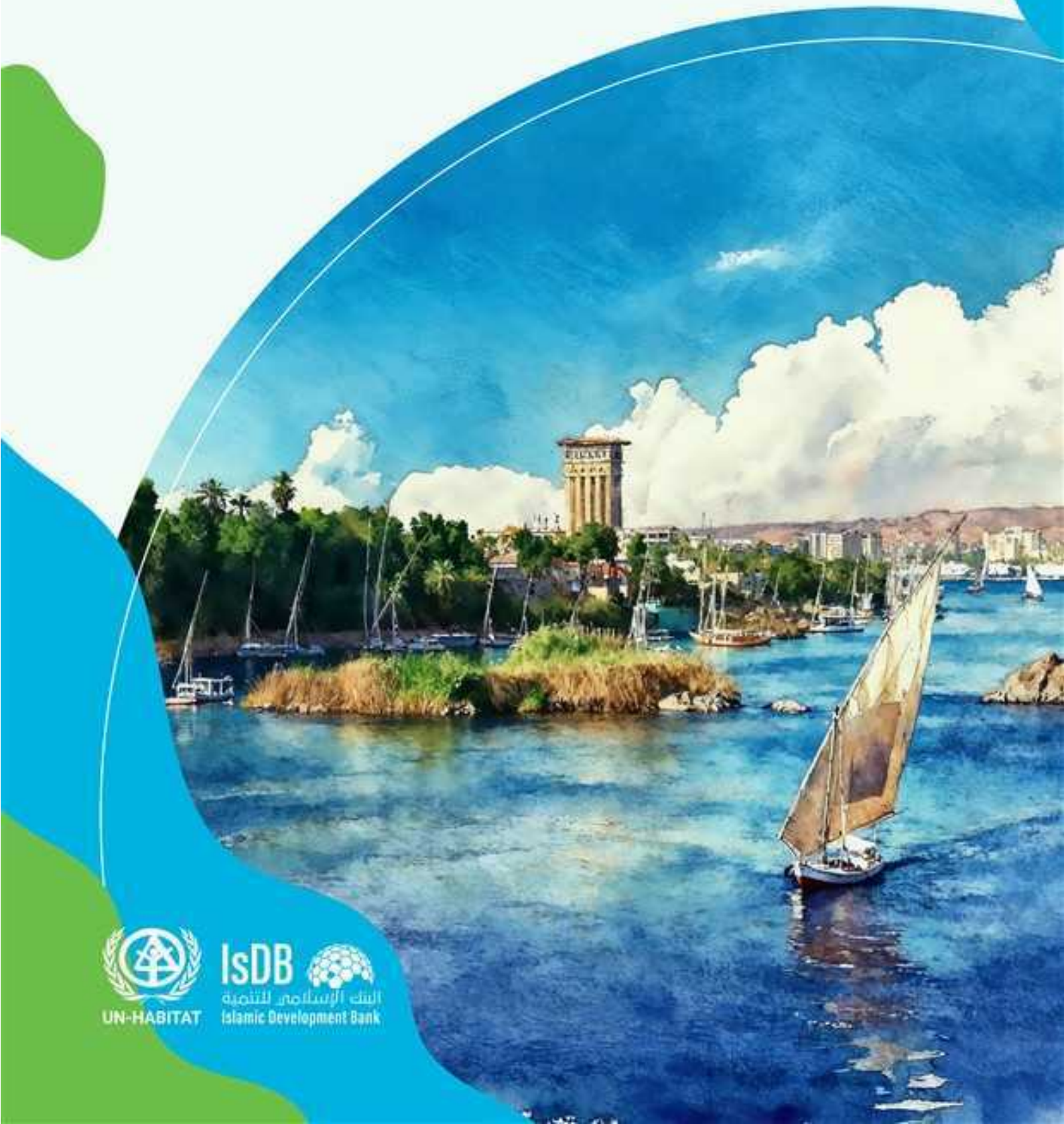
NATURE-BASED SOLUTIONS IN THE ARAB REGION

A Collection of Case Studies



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NATURE-BASED SOLUTIONS IN THE ARAB REGION:
A Collection of Case Studies

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Disclaimer:

This publication is a compilation of case studies on Nature-based Solutions (NbS) in the Arab region, jointly produced by UN-Habitat and the Islamic Development Bank (IsDB). The content was developed based on desk research and publicly available information, supplemented with visual materials sourced from original project documentation or publicly accessible platforms. All efforts were made to ensure accuracy; however, data and images remain the property of their respective owners, and any inadvertent omissions or errors are unintentional.

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Front Cover: **Egyptian Broadcast Systems**
Design and Layout: **Egyptian Broadcast Systems**

Foreword

In recent years, the Arab region has faced a convergence of complex and interrelated challenges – including water scarcity, conflict, economic instability, climate change, and environmental degradation – all of which have placed increasing pressure on governments to meet the basic needs of their populations. Looking ahead, the intensification of climate-related shocks such as droughts, flash floods, and rising sea levels is expected to disproportionately impact vulnerable communities. At the same time, rapid urbanization is straining infrastructure, livelihoods, and public health systems, while biodiversity loss and declining land productivity further threaten the region's ecological balance.

These interconnected challenges underscore the urgent need to strengthen resilience, scale up climate adaptation, and restore ecosystems in urban settings. Nature-based Solutions (NbS) offer an effective approach to addressing social, economic, and environmental issues by harnessing the power of nature. Green infrastructure – including urban forests, mangroves, wetlands, green roofs, and permeable surfaces – can reduce flooding, improve air and water quality, support biodiversity and carbon sequestration, and help cool urban environments. NbS also promote human well-being by creating healthier public spaces and micro-environments, while generating green jobs and economic opportunities.

As climate change and urbanization accelerate, integrating NbS with traditional grey infrastructure presents a flexible, effective, and cost-efficient pathway toward sustainable urban development. The implementation of NbS in urban areas directly advances multiple Sustainable Development Goals (SDGs), including SDG 11 on Sustainable Cities and Communities and SDG 13 on Climate Action.

Recognizing their potential, NbS are increasingly being mainstreamed into institutional strategies. UN-Habitat's Strategic Plan for 2026-2029 identifies NbS as a key element of integrated urban planning and management under its Environment and Climate Action impact area. Similarly, the Islamic Development Bank's (IsDB) 2026–2035 Group Strategic Framework highlights environmental stewardship, resilience, urbanization, and human development as core development priorities.

Cities are at the forefront of climate action, and re-establishing the connection between urban areas and nature is a vital step in the global effort to achieve prosperity and restore our planet. This report presents leading examples of NbS implementation across the Arab region, demonstrating that meaningful progress is already underway. These localized initiatives offer valuable lessons and models that can be scaled up with the right support and investment.

We hope this publication will inspire broader adoption, replication, and upscaling of NbS in the Arab region, while contributing to the growing global body of knowledge and practice. We are also proud that this report reflects the enduring partnership between UN-Habitat and IsDB and we remain committed to supporting a greener, more inclusive, and climate-resilient Arab region.

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Acronyms and Abbreviations

APAL	The Tunisian Coastal Protection Authority
AREC	Advancing Research Enabling Communities Center
ARR	Afforestation, Reforestation, and Revegetation
AWWR	Al Wathba Wetland Reserve
BMZ	German Federal Ministry for Economic Cooperation and Development
BOD	Biochemical Oxygen Demand
CBD	Convention on Biological Diversity
CDPWH	Comprehensive Development Plan for Wadi Hanifah
CIF	Climate Investment Funds
CityRAP	City Resilience Action Planning
COD	Chemical Oxygen Demand
COP	Conference of Parties
CWs	Constructed Wetlands
DEWATS	Decentralized Wastewater Treatment Systems
ECCADP	Enhancing Climate Change Adaptation in the North Coast and Nile Delta Regions in Egypt Project
EEG	Emirates Environmental Group
FAO	Food and Agriculture Organization of the United Nations
GAM	Greater Amman Municipality
GBF	Kunming-Montreal Global Biodiversity Framework
GCF	Green Climate Fund
GI	Green Infrastructure
HFCW	Horizontal Subsurface-Flow Constructed Wetland
ICARDA	International Center of Agricultural Research in Dry Areas
CDPWH	Comprehensive Development Plan for Wadi Hanifah
ICZM	Integrated Coastal Zone Management
IDPs	Internally Displaced Persons
IFAD	International Fund for Agricultural Development
IsDB	Islamic Development Bank
ITS	Informal Tented Settlements
IUCN	International Union for Conservation of Nature
IWMI	International Water Management Institute
IWRM	Integrated Water Resource Management Approach
KISR	Kuwait Institute for Scientific Research
KOC	Kuwait Oil Company

MDBs	Multilateral Development Banks
MERS	MERS Mangrove Ecosystem Restoration Solution
MGI	Middle East Green Initiative
MPA	Marine Protected Area
NAP	National Action Plan
NbS	Nature-based Solutions
NBSAP	National Biodiversity Strategies and Action Plan
NDCs	Nationally Determined Contributions
NPC	Nature, People, Climate
PES	Payment for Ecosystem Services
QF	Qatar Foundation
RBF	Riverbank Filtration
RNBWS	Resilient Nature-Based Water Solutions
SDG	Sustainable Development Goal
SDS	Sand and Dust Storms
SGI	Saudi Green Initiative
SLR	Sea-level Rise
SUDS	Sustainable Urban Drainage Systems
UAE	United Arab Emirates
UNCC	United Nations Compensation Commission
UNCCD	United Nations Convention to Combat Desertification
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNHCR	United Nations High Commissioner for Refugees
WWTP	Wastewater Treatment Plant

Introduction

Cityscape . Visual by Egyptian Broadcast Systems

Regional Context

The Arab region is undergoing a period of rapid transformation. With over 450 million people across 22 countries—and over 60% of the population already living in urban areas[1] —cities are becoming the primary engines of growth, innovation, and opportunity. By 2050, urbanization is projected to reach nearly 70%, which will pressure governments to ensure sustainable, inclusive, and resilient urban expansion[3]. Rapid demographic growth, economic transitions, and migration are accelerating urban change, often outpacing infrastructure, planning, and service delivery. In many areas, these pressures are compounded by protracted conflicts, forced displacement, and political instability, which have severely undermined urban systems, disrupted livelihoods, and weakened institutional capacity. This growing imbalance is placing unprecedented strain on natural resources, degrading ecosystems, and increasing vulnerability to climate risks.

The Arab region is among the most water-scarce in the world. Climate change is projected to decrease renewable water resources by 20% by 2050, and over 60% of the population lives in areas with high or very high water stress[4] . At the same time, desertification, land degradation, and coastal erosion threaten livelihoods, biodiversity, and food security. The region is also warming at nearly twice the global average[5], making urban areas particularly susceptible to extreme heat, flooding, and resource scarcity. These environmental pressures disproportionately affect vulnerable populations and undermine inclusive, sustainable urban development.

In this context, Nature-based Solutions (NbS) have emerged as a promising pathway to enhance resilience, protect ecosystems, and deliver socio-economic co-benefits. The International Union for Conservation of Nature (IUCN) defines NbS as ***"actions to protect, sustainably manage and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits"***[6]. NbS offer cost-effective, adaptable approaches that can be integrated into urban planning, water management, coastal restoration, and land use strategies.

Policy Environment for NbS

NbS align with and are strongly supported by several globally policies and agreements. At the 1992 Earth Summit in Rio de Janeiro, Brasil, three major international agreements were launched, namely the Convention on Biological Diversity (CBD), the United Nations Framework Convention on Climate Change (UNFCCC), and the United Nations Convention to Combat Desertification (UNCCD). These conventions, collectively referred to as the Rio Conventions, address interconnected environmental challenges: climate change, biodiversity loss, and desertification. Arguably, the greatest intersection of the Conventions is in the

[1]UN-Habitat. (2022). State of Arab Cities Report.
[2]United Nations Department of Economic and Social Affairs (UN DESA). (2022). World Urbanization Prospects 2022: Highlights.
[3]UN-Habitat. (2020). Cities in Crisis: UN-Habitat's Response to Urban Crises in the Arab States Region.
[4]World Bank. (2021). Water Security in the Middle East and North Africa.
[5]ESCWA. (2022). Arab Climate Change Assessment Report.
[6]IUCN. (2016). Defining Nature-based Solutions.

NbS space. The CBD focuses on the conservation of biodiversity, the sustainable use of its components, and the fair and equitable sharing of benefits arising from genetic resources. It recognizes that biodiversity is fundamental to human well-being and sustainable development. In December 2022, the CBD adopted the Kunming-Montreal Global Biodiversity Framework (GBF) to halt and reverse biodiversity loss by 2030, with a long-term vision for 2050. The GBF includes a goal to conserve 30% of the Earth's land and seas by 2030 (a goal known as "30 by 30"). At national level, National Biodiversity Strategies and Action Plans (NBSAPs) are the primary instruments for countries to implement the CBD. NBSAPs outline a country's approach to conserving biodiversity, including identifying threats, setting national targets, and integrating biodiversity considerations into various sectors.

The main objective of the UNFCCC is to stabilize greenhouse gas concentrations in the atmosphere at a level that prevents dangerous human interference with the climate system, allowing ecosystems to adapt naturally and enabling sustainable development. The UNFCCC is the parent treaty of the Paris Agreement, which aims to limit global warming to well below 2 degrees Celsius, and ideally to 1.5 degrees Celsius, compared to pre-industrial levels. The agreement establishes a framework for all countries to commit to climate action through nationally determined contributions (NDCs) and to strengthen those commitments over time.

The UNCCD focuses on sustainable land management, particularly in dryland areas. It addresses desertification and drought, aiming to improve living conditions, restore land productivity, and mitigate the effects of drought. The convention emphasizes a participatory approach, involving local communities in combating these issues. National Action Plans (NAPs) are the key instruments for affected countries to outline practical steps and measures to combat desertification and land degradation.

The recently launched “Rio Conventions Joint Capacity-building Program” aims to strengthen individual, institutional, and systemic capacities to enhance synergies between climate action, biodiversity conservation and sustainable land management. It promotes cross-sector collaboration, integrated planning, policy development and resource mobilization, and the inclusion of indigenous and local knowledge, while fostering coordination and coherence in achieving the three Rio Conventions’ objectives and the Sustainable Development Goals (SDGs).

NbS play a vital role in advancing the SDGs and the broader 2030 Agenda by offering integrated, cost-effective, and locally adaptable approaches to global challenges. By restoring ecosystems, enhancing biodiversity, and promoting sustainable land and water management, NbS directly contribute to goals such as SDG 13 (Climate Action), SDG 15 (Life on Land), and SDG 6 (Clean Water and Sanitation). They also support social and economic objectives, including poverty reduction (SDG 1), health and well-being (SDG 3), and sustainable cities (SDG 11), by improving urban livability, reducing disaster risks, and creating green jobs. The 2030 Agenda’s emphasis on interconnectedness and inclusivity aligns with the holistic nature of NbS, positioning them as essential tools for achieving resilient, equitable, and sustainable development across sectors and scales.

On the urban scale, the New Urban Agenda, which was adopted at Habitat III in 2016, provides a transformative framework for sustainable urban development that actively supports and promotes the use of NbS. It emphasizes the integration of ecological principles into urban planning to enhance resilience, mitigate climate change, and improve the quality of life for urban residents. By advocating for green infrastructure, sustainable land use, and ecosystem-based approaches, the New Urban Agenda encourages cities to harness the power of nature to address urban challenges such as flooding, heat stress, and biodiversity loss.

Furthermore, it calls for inclusive and participatory governance, ensuring that NbS are co-designed with communities and tailored to local contexts. This alignment positions nature not only as a tool for sustainability but also as a central pillar in shaping equitable, livable, and climate-resilient cities.

NbS Case Studies in the Arab Region

This publication—jointly developed by UN-Habitat's Regional Office for Arab States and the Islamic Development Bank—documents NbS case studies from across the Arab region that contribute to urban sustainability, climate adaptation, and ecological restoration. The objective is to highlight scalable, context-appropriate practices that can inform urban planning and climate strategies across the region while raising awareness of the multiple co-benefits of NbS for water security, public health, social inclusion, and disaster risk reduction. Many of these approaches are inspired by or build upon indigenous knowledge and traditional practices that have supported resilience and sustainable resource management in the region for generations.

Given the region's ecological diversity and varied development patterns, identifying what qualifies as an urban NbS required a nuanced and context-sensitive approach. Some interventions are located outside city boundaries yet have a direct impact on urban systems, such as water supply, flood mitigation, or air quality regulation. To guide the selection process, key criteria included whether the initiative contributes essential ecosystem services to urban areas, is integrated into spatial planning or governance frameworks, or addresses challenges primarily affecting urban environments.

To structure the analysis, the case studies are organized into four thematic areas aligned with both regional priorities and international frameworks:

Urban Nature. Visual by Egyptian Broadcast Systems

Water Management and Resilience
Explores nature-based approaches to water harvesting, treatment, and watershed protection. **1**

Coastal and Marine Ecosystem Restoration
Focuses on addressing degradation and climate resilience in coastal and marine zones. **2**

Urban Greening and Climate Adaptation
Highlights green infrastructure, biodiversity, and climate-responsive urban design. **3**

Agroecology and Sustainable Land Management
presents regenerative agriculture and land restoration strategies relevant to both urban and peri-urban settings. **4**

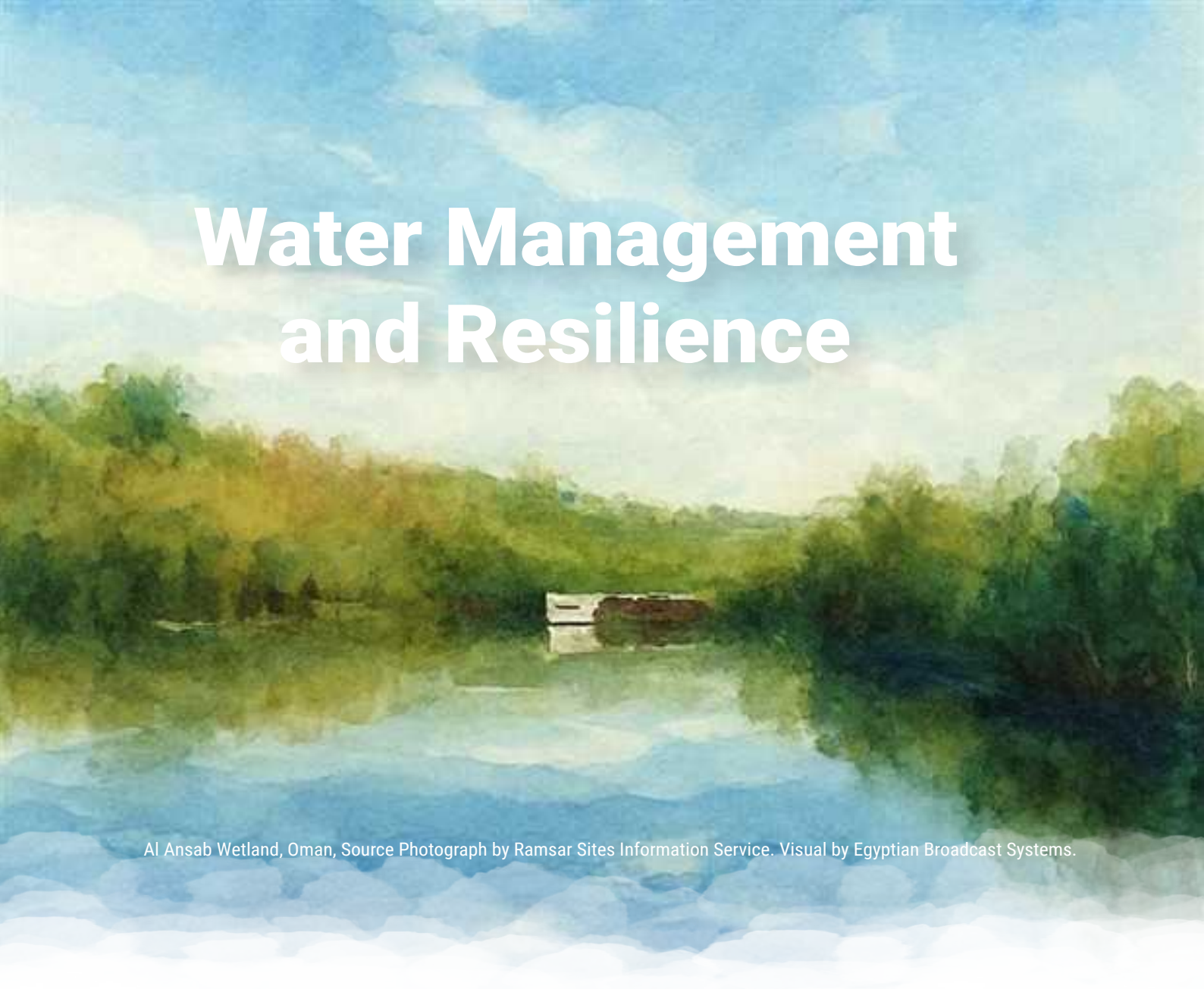
Water-related NbS are especially critical in light of the region's chronic water stress. Interventions such as wetland restoration, aquifer recharge, and stormwater management illustrate how ecosystems can help alleviate scarcity and reduce flood risks. Along coastlines, mangrove planting, coral reef rehabilitation, and natural shoreline protection strengthen resilience to storm surges and sea level rise. In city centers, initiatives like green roofs, urban forests, and nature-based cooling enhance adaptation to extreme heat, improve air quality, and expand green public spaces. Meanwhile, sustainable agricultural practices and land management strategies are combating desertification, enhancing food security, and restoring degraded lands.

The methodology used to compile this publication combined desk-based research with consultations and interviews involving multiple partners. Practitioners, institutions, and project stakeholders provided valuable insights that helped identify and validate case studies. Each example was assessed for its environmental and social impacts, degree of innovation, potential for replication, and alignment with broader development goals.

The case studies are divided among four chapters, each dedicated to one of the thematic areas. Each chapter begins with regional case studies, if available, followed by single-country case studies ordered geographically starting with North Africa and moving on to West Asia. Since some of the solutions presented are applicable in other contexts, this structure brings together geographically compatible examples, enabling related approaches to be considered side by side.

This collection serves as a regional knowledge resource supporting learning, exchange, and innovation. It demonstrates how NbS can be tailored to diverse urban and ecological settings across the Arab region, offering concrete pathways to more resilient, livable, and sustainable cities. The case studies are envisioned to inspire action and reinforce the value of integrating nature into planning, policy, and investment—transforming ecosystem restoration into a strategic asset for inclusive urban transformation.

Water Management and Resilience



Al Ansab Wetland, Oman, Source Photograph by Ramsar Sites Information Service. Visual by Egyptian Broadcast Systems.

Water scarcity is one of the most pressing challenges facing the Arab region, affecting 19 of its 22 countries. This challenge is further exacerbated by climate change, with shifts in precipitation patterns and rising temperatures, alongside widespread desertification and land degradation which affect 17 countries. As the world's most water-scarce region, the Arab region is home to 14 of the 25 most water-stressed countries globally.[7] These compounding pressures underscore the urgent need for innovative, effective, and scalable responses to enhance water security and resilience.

Nature-based solutions (NbS) offer a low-cost, multi-benefit approach that is well suited to addressing these challenges. This chapter showcases 31 case studies from across the region that demonstrate how innovative NbS are being applied to improve water management and build resilience. Many of these initiatives draw inspiration from, or build upon, indigenous knowledge and traditional practices that have supported sustainable resource management for generations. The cases span a wide range of approaches, including constructed wetlands, traditional NbS methods, innovative techniques such as water harvesting from fog, wastewater treatment and reuse, ecosystem regeneration and restoration, and integrated water resource management.

[7] World Resources Institute (2023, August 16) Aqueduct National Water Stress Rankings. Available at: https://www.wri.org/insights/highest-water-stressed-countries (Accessed: 28/04/2026).

1. Al Murunah Project, Egypt, Jordan, Lebanon, Palestine

Location	Egypt (Abu Matamir, Beheira Governorate), Jordan (Wadi Seer, Greater Amman Municipality), Lebanon (Baalbek District, Baalbek-Hermel Governorate), and the Occupied Palestinian Territories: (Wadi Al-Fara'a, Tubas Governorate)
Existing Ecosystems	Semi-arid, riparian-agricultural, and mountainous-agricultural systems
Climate Change Challenges	Water scarcity, land degradation, increased frequency and intensity of extreme climatic conditions, and the vulnerability of rural communities (especially women and youth) to environmental and resource stresses
NbS Approach	Agroecological practices (Egypt), flood management and afforestation (Lebanon), spring rehabilitation and agrobiodiversity (Palestine) and Spring and irrigation system restoration (Jordan)

Context

The Middle East and North Africa (MENA) region is the world's most water-scarce. Surface and groundwater resources, shared across borders, are under pressure due to increasing demand and climate change. Agriculture is the primary water user, accounting for around 65% or more of total water demand. Unsustainable land management practices, such as mechanized mono-agriculture and overgrazing, have resulted in land degradation and reduced soil water retention. Climate change exacerbates these issues by increasing temperature and, therefore, water demand, the frequency of droughts and floods, and decreasing precipitation.

In response to this complex and escalating environmental crisis, the Al Murunah project, named after the Arabic word for "flexibility", is an initiative led by the International Water Management Institute (IWMI) in partnership with the International Union for Conservation of Nature (IUCN). It was launched in response to escalating challenges in the MENA region, including water scarcity, land degradation, and climate vulnerability, which critically affect agricultural productivity and rural livelihoods. The project focuses on enhancing water and food security in agricultural areas by promoting Resilient Nature-Based Water Solutions (RNBWS) - an integrated approach that combines ecological restoration, sustainable water management, and community-led action.

These RNBWS are designed to improve water availability and quality, reduce demand, and boost productivity by working with natural processes. However, their widespread adoption faces several barriers, including knowledge gaps about their effectiveness, technical, social, and economic constraints, and limited institutional and community capacity to implement and scale them. The project focuses on overcoming these barriers through a combination of participatory implementation of pilot projects, capability building and awareness, and strategic planning for up-scaling of RNBWS.

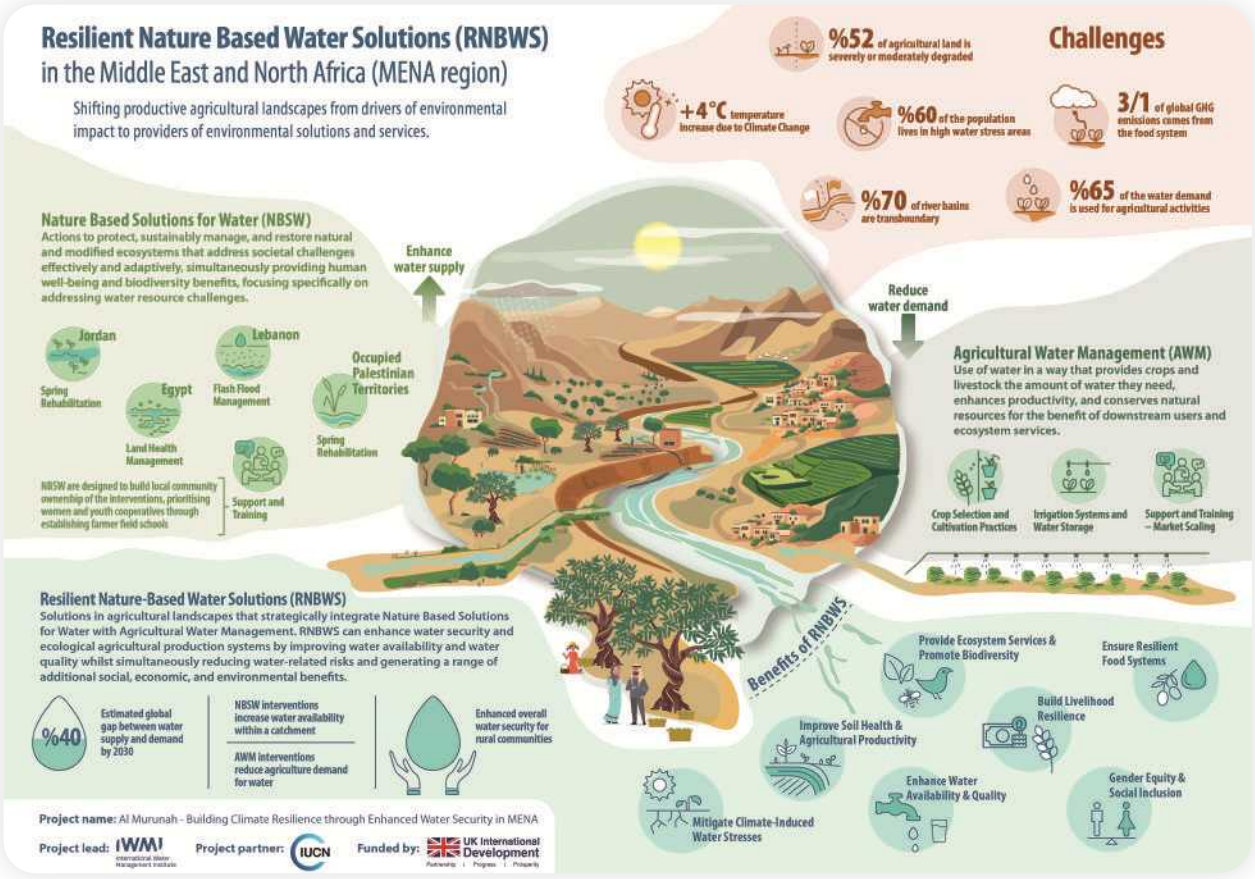
Applied NbS Methods

The Al Murunah project implements several NbS approaches to tackle water scarcity, agricultural challenges, and climate resilience across the MENA region. These interventions, also referred to as RNBWS, combine ecological restoration and community-driven approaches.

Key NbS implemented by the project include

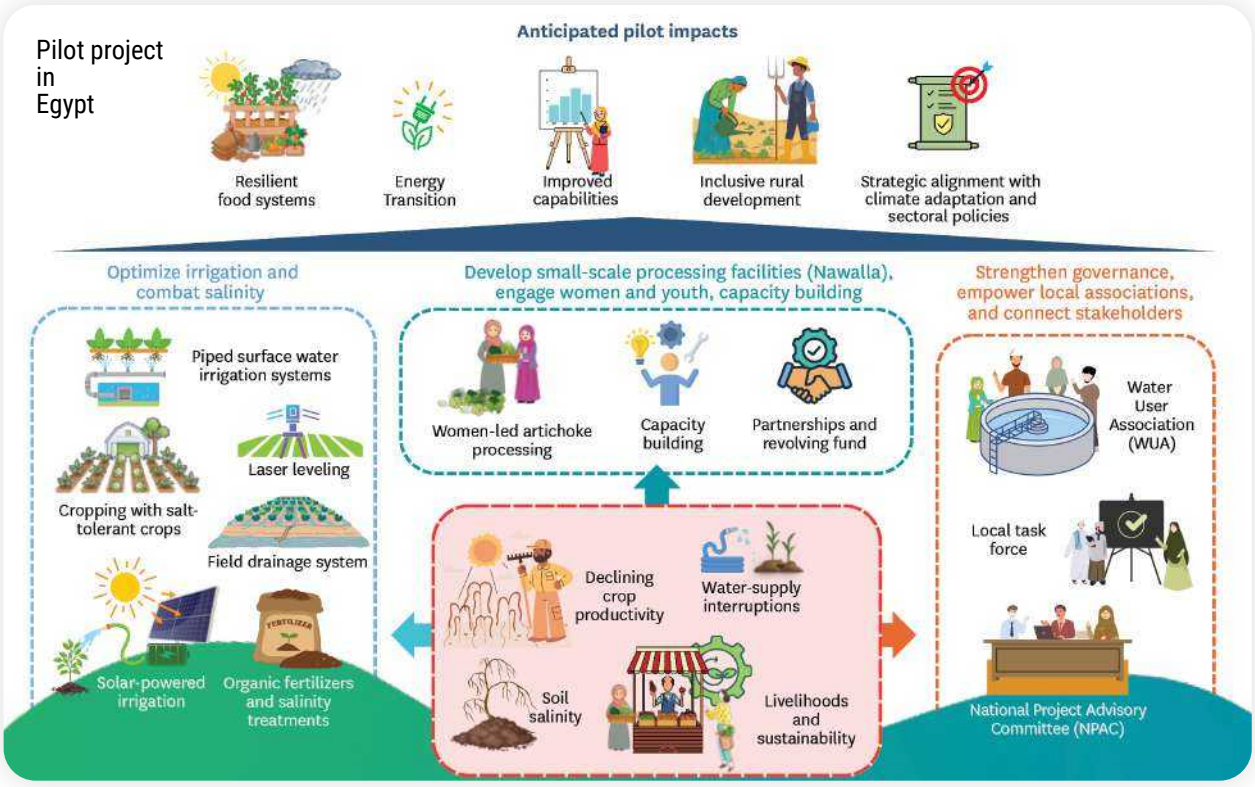
1. **Drought- and salinity-resistant crop varieties:** Used to improve agricultural sustainability in regions affected by water scarcity and soil salinity.
2. **Agroecological practices:** Including crop rotation and diversity, to enhance soil health and reduce dependency on chemical fertilizers.
3. **Solar-powered irrigation systems:** These systems help optimize water usage, especially in water-scarce areas.
4. **Afforestation and conservation agriculture:** Promotes the planting of trees and the use of techniques like soil conservation, which prevent erosion and improve soil quality.
5. **Rehabilitation of flood control structures:** Such as gabions and check dams, to manage flash floods and support groundwater recharge.
6. **Diversion canals for groundwater recharge:** Helps restore water sources and improve agricultural productivity.
7. **Agrobiodiversity gardens:** Promote the cultivation of indigenous and traditional crops to enhance food security and biodiversity conservation.

Figure 1 Illustration of Resilient Nature-based Water Solutions (RBNWS)



Note. From International Union for Conservation of Nature (IUCN). (2024). Resilient Nature Based Water Solutions .Al Murunah Initiative. Water & Nature Initiative. An infographic. https://waterandnature.org/all-initiatives/al-murunah/

Figure 2 Illustration of Pilot Projects in Egypt, Jordan, and the State of Palestine



Note. From International Water Management Institute (IWMI). (2024). Al Murunah – Egypt Pilot Brief
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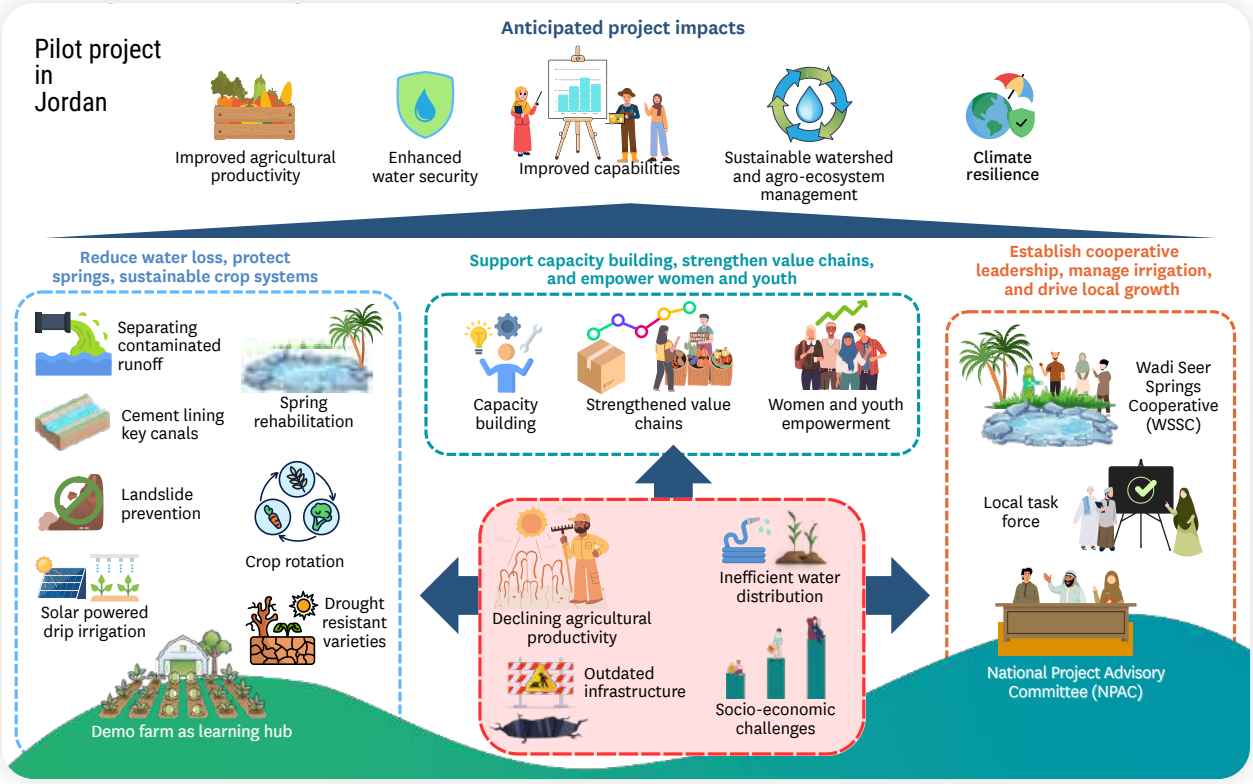
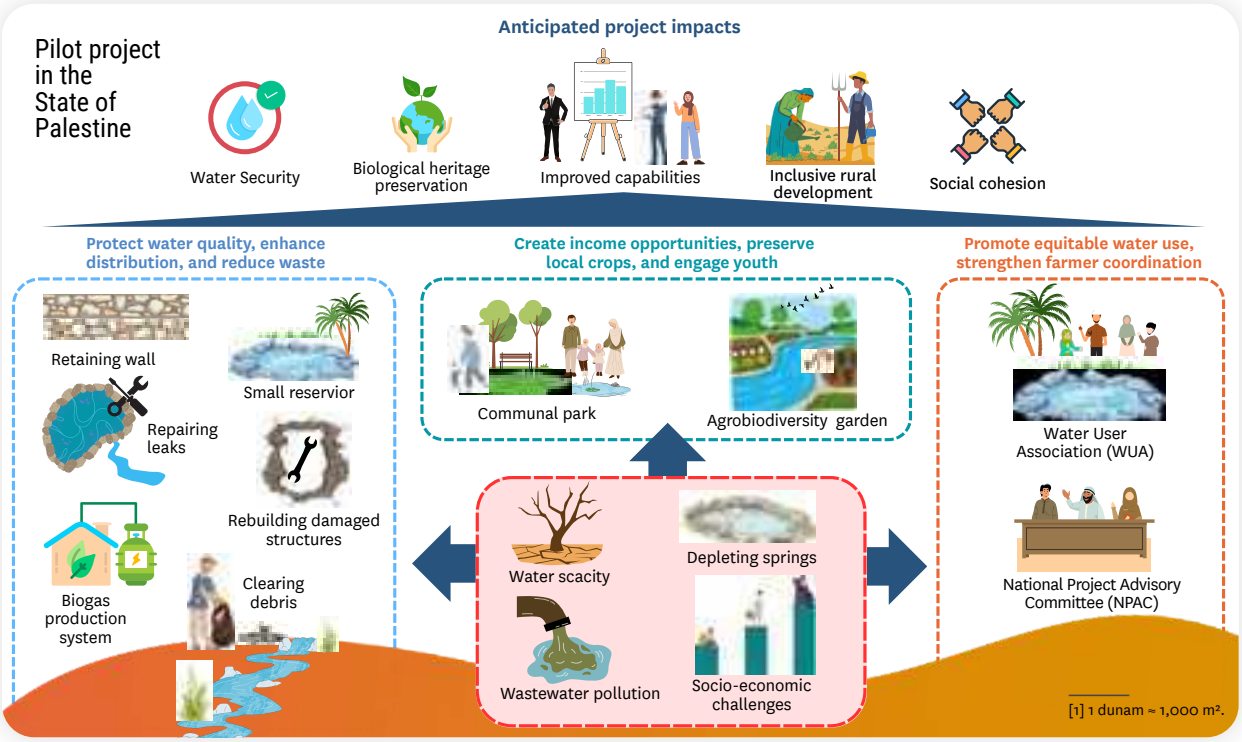


Note. From International Water Management Institute (IWMI). (2024). Al Murunah – Jordan Pilot Brief
https://almurunah.iwmi.org/wp-content/uploads/sites/52/2025/06/Al-Murunah-Jordan-Pilot-Eng-250611s.pdf



Note. From International Water Management Institute (IWMI). (2024). Al Murunah – Palestine Pilot Brief https://almurunah.iwmi.org/wp-content/uploads/sites/52/2025/06/Al-Murunah-OPT-Pilot-Brief-Eng-250621s.pdf

Figure 3 Photos from Project Target Areas

Egypt - mixed cultivation farm in the Nile Delta

Jordan, Wadi Seer - spring flow, diversion channels, and valley background
(Photo credit: IUCN ROWA)

Lebanon, Qaa - groundwater irrigated farm on slopes

State of Palestine, Ras Fara'a - groundwater irrigated cucumber farm with rangelands in the background

Note. From International Water Management Institute (IWMI). (2024). Al-Murunah: A Model for Resilient Livelihoods in the Arab Region. Al Murunah. https://almurunah.iwmi.org/wp-content/uploads/sites/52/2024/06/Al-Murunah-Brief-Eng.pdf

Sources

- International Union for Conservation of Nature (IUCN). (2024). Al-Murunah Initiative. Water & Nature Initiative. https://waterandnature.org/all-initiatives/al-murunah/
- International Water Management Institute (IWMI). (2024). Al-Murunah: A Model for Resilient Livelihoods in the Arab Region. Al Murunah. https://almurunah.iwmi.org/wp-content/uploads/sites/52/2024/06/Al-Murunah-Brief-Eng.pdf
- International Water Management Institute (IWMI). (2024). Building Climate Resilience through Enhanced Water Security in MENA (Al-Murunah). Al Murunah. https://almurunah.iwmi.org/
- Louise Sarant. (2024, April 9). Modern Tools and Ancient Smarts. International Water Management Institute (IWMI). https://www.iwmi.org/news/modern-tools-and-ancient-smarts/

2. Constructed Wetland Projects, Morocco

Location	Casablanca/Rabat/Marrakech/Meknes, Morocco
Type of Ecosystems	Inland water, urban and cultivated ecosystems
Climate Change Challenges	Water scarcity
NbS Approach	Constructed Wetlands

Context

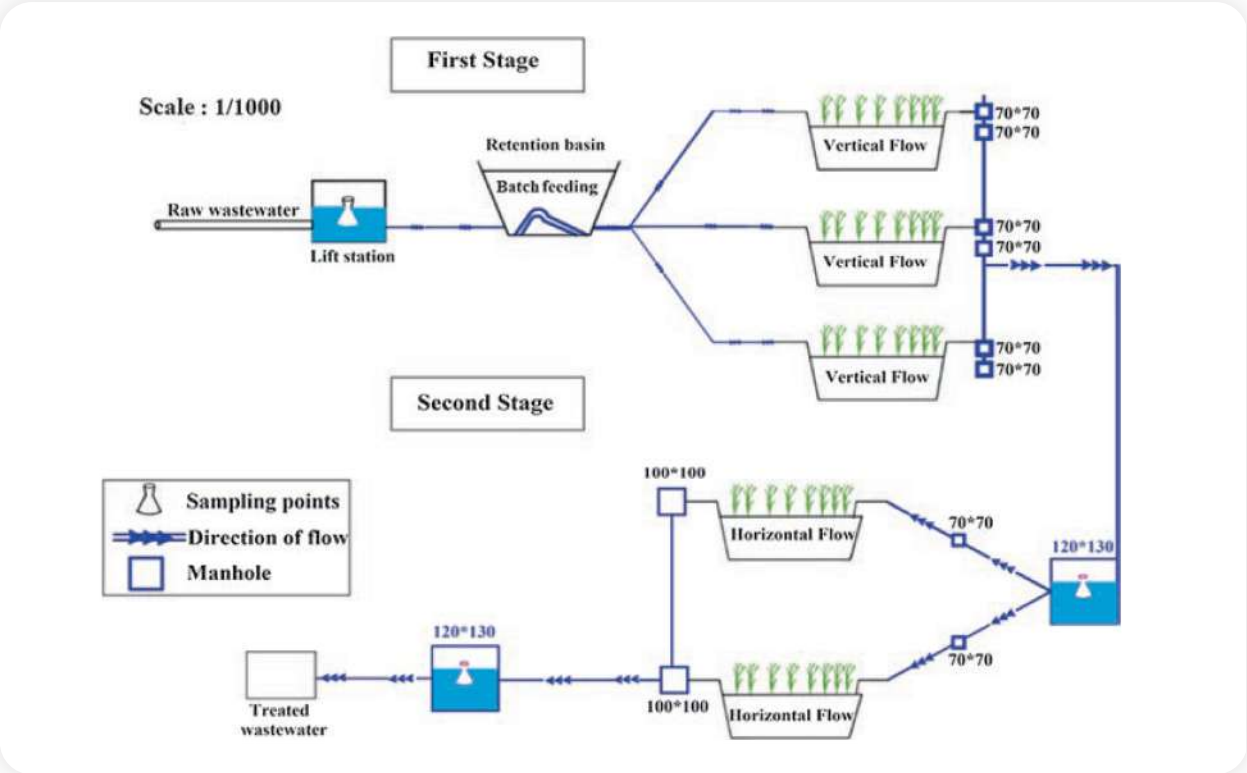
Morocco's predominantly arid to semi-arid climate results in significant water scarcity, which is projected to worsen in the coming decades. With per capita water availability expected to drop from 760,000 liters per year to 560,000 liters by 2030, sustainable wastewater treatment and reuse solutions are critical. Constructed wetlands (CWs) have emerged as a viable NbS to address these challenges, combining ecological benefits with cost-effective wastewater treatment and reuse for irrigation.

Applied NbS Methods

Across Morocco, CWs have proven adaptable to diverse settings—from urban neighborhoods to rural schools—while consistently delivering high-quality treated water suitable for agricultural reuse. These systems not only remove organic matter (COD, BOD) and nutrients but also reduce pathogens, supporting both public health and environmental sustainability.

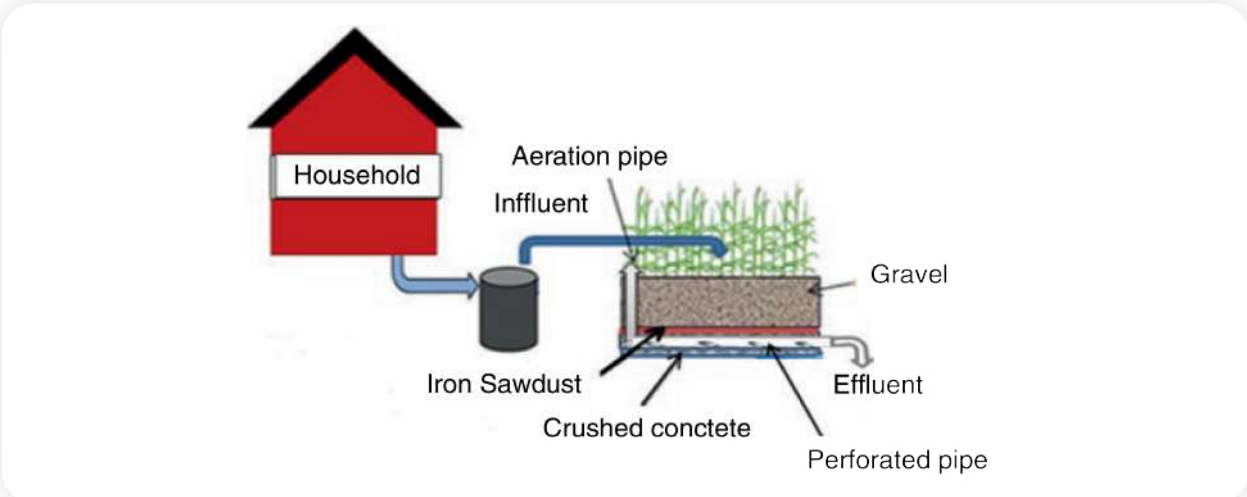
- **Urban Applications:** In Casablanca, a vertical flow CW treating 6–10 m^3/day of municipal bath wastewater used Phragmites australis and irrigated a 1,000 m^2 agricultural area. In Rabat, a hybrid system combining anaerobic pretreatment, high-rate algae ponds, and subsurface horizontal-flow CWs demonstrated high pollutant removal under seasonal temperature fluctuations (14–27°C), proving CWs' effectiveness in dense urban settings.
- **Rural Applications:** In Marrakech's mountainous rural areas, hybrid CWs with vertical and horizontal flow units achieved high removal of organic matter, nutrients, and pathogens. These systems provide a sustainable alternative to conventional wastewater treatment in areas with limited infrastructure.
- **Small-Scale and Pilot Systems:** In Meknes, school and household-scale vertical flow CWs treated wastewater efficiently with minimal maintenance, no pretreatment, and no daily sludge production. COD removal ranged from 74–92%, orthophosphate removal 68%, and ammonium removal 47%, making them ideal for educational facilities and rural households while supporting climate-resilient irrigation.

Figure 4 Schematic representation of the hybrid CW for the treatment of domestic wastewater in a rural area of Marrakech



Note. Adapted from El Ghadraoui, Ayoub, El Achaby, M., Mandi, L., Ouazzani, N., Zouhir, F., El Ghadraoui, Abdeljalil, Aziz, F. (2022, October 12). Constructed Wetland as an Efficient Technology for the Treatment of Urban/Industrial Wastewater in the Arid Regions: Morocco as a Model, in: Stefanakis, A. (Ed.), Constructed Wetlands for Wastewater Treatment in Hot and Arid Climates, Wetlands: Ecology, Conservation and Management. Springer International Publishing, Cham, pp. 101–122. https://doi.org/10.1007/978-3-031-03600-2_6

Figure 5 Schematic representation of the pilot CW for the treatment of wastewater from a school in Meknes.



Note. El Ghadraoui, Ayoub, El Achaby, M., Mandi, L., Ouazzani, N., Zouhir, F., El Ghadraoui, Abdeljalil, Aziz, F. (2022, October 12). Constructed Wetland as an Efficient Technology for the Treatment of Urban/Industrial Wastewater in the Arid Regions: Morocco as a Model, in: Stefanakis, A. (Ed.), Constructed Wetlands for Wastewater Treatment in Hot and Arid Climates, Wetlands: Ecology, Conservation and Management. Springer International Publishing, Cham, pp. 101–122. https://doi.org/10.1007/978-3-031-03600-2_6

Sources

- Taouraout, A., Chahlaoui, A., Belghyti, D., Najy, M., Sammoudi, R. (2019, October 2). Vertical flow constructed wetland a green technology to improve sanitation in future smart cities of Morocco, in: Proceedings of the 4th International Conference on Smart City Applications. Presented at the SCA2019: The Fourth International Conference on Smart City Applications, ACM, Casablanca Morocco, pp. 1–5. https://doi.org/10.1145/3368756.3368963
- El Ghadraoui, Ayoub, El Achaby, M., Mandi, L., Ouazzani, N., Zouhir, F., El Ghadraoui, Abdeljalil, Aziz, F. (2022, October 12). Constructed Wetland as an Efficient Technology for the Treatment of Urban/Industrial Wastewater in the Arid Regions: Morocco as a Model, in: Stefanakis, A. (Ed.), Constructed Wetlands for Wastewater Treatment in Hot and Arid Climates, Wetlands: Ecology, Conservation and Management. Springer International Publishing, Cham, pp. 101–122. https://-doi.org/10.1007/978-3-031-03600-2_6

Wetlands birds. Source photograph by Rachel C. Visual by Omnia Moussa

3. Harvesting Fresh Water from Fog, Morocco

Location	Agadir, Morocco
Type of Ecosystems	Inland water and dryland ecosystems
Climate Change Challenges	Water scarcity
NbS Approach	Fogwater catchment systems

Context

Dar Si Hmad's fogwater harvesting project is one of the largest in the world and the only system of its kind in North Africa. It provides a high-quality, context-appropriate water supply that combats scarcity while simultaneously addressing social challenges, including poverty, marginalization, lack of livelihoods, and limited educational opportunities. The project serves both as an integrated sustainable development initiative and a field-based research platform.

Despite being located in the arid and semi-arid foothills of the Anti-Atlas Mountains in Aït Baamrane, persistent fog occurs from September to June. Scientists note that "water generation from unconventional resources (e.g., dew or fog) can be a reasonable addition or even alternative to groundwater use in areas with scarce precipitation," highlighting the potential of fogwater harvesting in such regions.

Applied NbS Methods

Dar Si Hmad designed two pilot fogwater collection systems to capture and distribute water from seasonal fog. The fogwater harvesting process involves vertical nets that collect water droplets from fog; the captured water drips into gutters, passes through a hybrid solar and conventional UV filtration system, and flows seven kilometers downslope to reservoirs supplying around 500 residents across five villages and four schools.

- **Phase 1**, launched in 2006 and installed in 2013, consisted of 20 collection units covering 600 square meters of nets, connected by six kilometers of piping to a gravity-flow delivery system. Water passed through a hybrid filtration station with two storage cisterns, while a weather station monitored barometric pressure, temperature, humidity, rainfall, and wind conditions. This system produced an average of 6,300 liters of fresh water per day (2.3 million liters annually) and required only minimal maintenance, such as mending nets, changing filters, and monitoring infrastructure.

- **Phase 2** introduced experimental and portable fog collection units designed to improve water yield per square meter and enhance cost-effectiveness at scale. Field tests are ongoing, with the goal of refining the technology for broader application.

Impacts and Significance

The project has had transformative effects on marginalized rural Berber communities. By providing a sustainable alternative water supply, it ensures clean water for households and schools, reduces incidences of water-borne diseases, and supports agricultural and reforestation efforts. Women's roles have shifted from water gatherers to water guardians, while young girls are freed from water-fetching duties, increasing school attendance. Employment opportunities have expanded for local laborers, contributing to community stability and breaking cycles of poverty.

In addition, the project integrates innovative technologies, such as ICT-based water management, and promotes environmental education. Water-related programs for women and children, as well as a remedial school incorporating water science, have enhanced functional literacy and scientific understanding within the community.

This innovative project serves as a model for sustainable water solutions, demonstrating how technology and community-centered approaches can address environmental challenges while fostering social and economic development.

Figure 6 Dar Si Hmad's Phase 1 fogwater harvesting system includes 600 square meters of fog nets

Note. Photo by Leslie Dodson. From Dodson, L.L., Bargach, J. (2015, July 7). Harvesting Fresh Water from Fog in Rural Morocco: Research and Impact Dar Si Hmad's Fogwater Project in Aït Baamrane. Procedia Engineering 107, 186–193. https://doi.org/10.1016/j.proeng.2015.06.073

Sources

- Dodson, L.L., Bargach, J. (2015, July 7). Harvesting Fresh Water from Fog in Rural Morocco: Research and Impact Dar Si Hmad's Fogwater Project in Aït Baamrane. Procedia Engineering 107, 186–193. https://doi.org/10.1016/j.proeng.2015.06.073

4. MENAWET Project

Restoration of Dayet Aoua Lake, Morocco

Location	Middle Atlas Mountains, Fès-Meknès region, Morocco
Existing Ecosystems	Wetlands
Climate Change Challenges	Severe ecological degradation, prolonged droughts, increasing water scarcity, and decreasing annual precipitation levels
Type of NbS	MENAWET project proposes a transformative, science-driven approach to climate resilience and disaster preparedness in the MENA region by moving away from fragmented, reactive, and resource-intensive practices toward integrated, Nature-based, locally rooted, and technically informed interventions. At its core, MENAWET promotes the restoration and sustainable management of wetlands as essential climate buffers and water security assets in a region acutely vulnerable to heat extremes, water scarcity, and ecological degradation

Context

Dayet Aoua Lake, part of the Immouzer Kandar Lakes complex, is located in the Middle Atlas Mountains of Morocco, near the city of Ifrane, at an elevation of approximately 1,462 meters above sea level. It lies within the Sebou Basin and falls under the administrative territory of the Fès-Meknès region. The lake was designated as a Ramsar site in 2018 and classified as a site of biological and ecological interest in Morocco. Historically, the lake supported over 198 faunal species, including 60 rare or threatened species. The site served as a key stopover and breeding habitat for migratory waterbirds within the East Atlantic Flyway. Since 2018, the lake has experienced complete desiccation, resulting in the collapse of its wetland-dependent biodiversity, the loss of groundwater recharge functions, and the degradation of ecosystem services such as local cooling; flood regulation and recreational value.

Applied NbS Methods

Recognizing the critical ecological decline of the Dayet Aoua Lake, MENAWET project has prioritized the implementation of urgent restoration measures to stabilize its freshwater ecosystem, improve water retention, and restore key habitats. Under MENAWET, the Dayet Aoua site is undergoing science-based ecological engineering with the following components:

- **Hydrological reconnection:** Construction of a 2.8 km canal to reintroduce water from Oued El Kantra and Oued Tigzert, delivering up to 4 m^3/s to the lake's primary recharge zone (Zone Z1, ~40 ha).

Figure 7 On-site photos of Dayet Aoua Lake illustrating its condition in 2015 and 2019

Year 2015 Year 2019

Note. From Living Planet Morocco. (2020-2024). Technical field reports and restoration design notes from Sebou Water Fund. Internal documentation.

- **Water retention and sediment control:**

  Installation of a retention weir calibrated at 1,462 m a.s.l. to stabilize water levels between zones Z2 and Z3 (~100 ha), reduce evaporative losses, and regulate seasonal floodwaters.

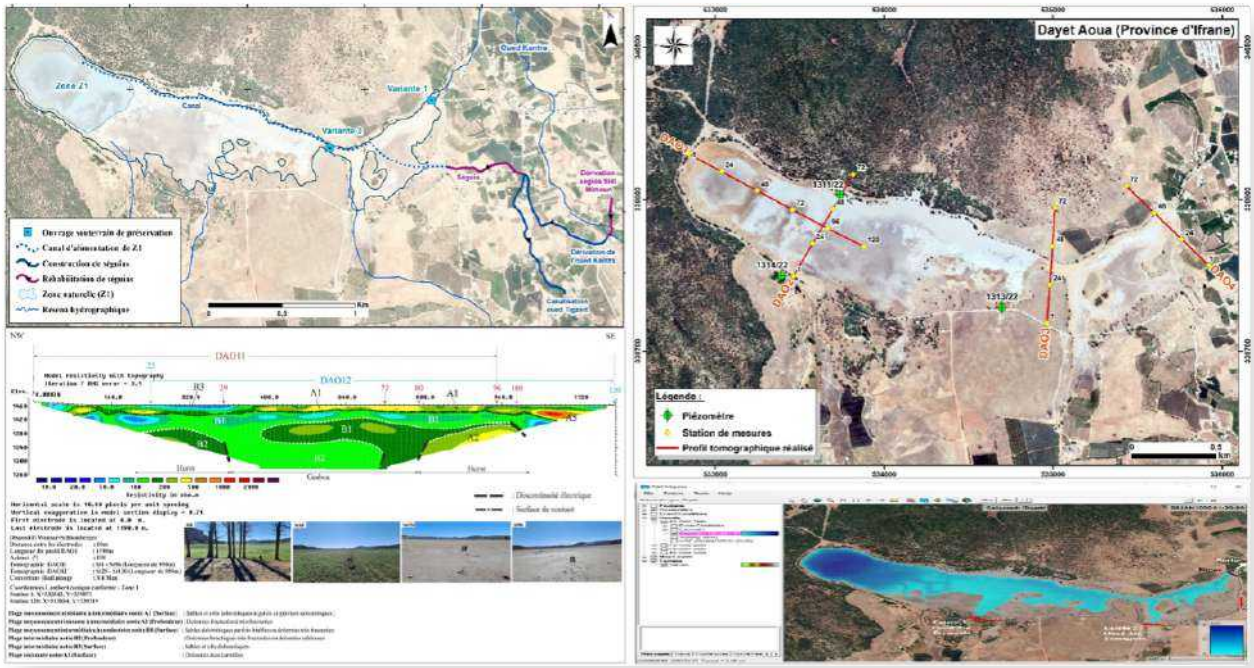
- **Diversion of Oued Ain Tamejjda:** Redirection of episodic floods using a 335 m diversion canal and a small weir, with protective road elevation to safeguard infrastructure.

- **Riparian vegetation restoration:** Mid-term actions include the planting of native riparian and aquatic speciesto stabilize banks, reduce sediment inflow, and support habitat restoration.

- **Water quantity impact:** Projected replenishment and water retention benefits total ~1,200,000 m^3/year at Dayet Aoua alone, based on hydrological models calibrated for local rainfall, soil infiltration, and evaporation data.

The restoration of lake Dayet Aoua is an illustrative example of how integrated, locally adapted NbS can contribute to regional water security, ecosystem resilience, and climate adaptation. The project uses a participatory model, involving local NGOs, engineers, authorities, and community stakeholders, to co-design and monitor interventions.

Figure 8 Maps of Dayet Aoua Lake showing the projected water supply regime



Note. From Living Planet Morocco. (2020-2024). Technical field reports and restoration design notes from Sebou Water Fund. Internal documentation.

Sources

- Living Planet Morocco. (2023). Field data and restoration design reports from the Dayet Aoua pilot project (2021–2023). Internal technical documentation.
- IUCN. (2022). Towards nature-based solutions in the Mediterranean: Lessons learned from implementation. Gland, Switzerland: International Union for Conservation of Nature.
- Ramsar Convention Secretariat. (2010). Wise use of wetlands: Concepts and approaches for the wise use of wetlands. Ramsar handbooks for the wise use of wetlands, 4th edition, vol. 1. Ramsar Convention Secretariat, Gland, Switzerland.

Source photograph by Jolien Quintyn. Visual by Omnia Moussa

5. Indigenous Foggaras Irrigation System, Algeria

An Indigenous and Traditional Water Management Technology

Location	Algeria
Existing Ecosystems	Arid ecosystems
Climate Change Challenges	Drought
Comple-mentary NbS Type	Agroecology and Sustainable Land Management
NbS Approach	**Foggara:** an indigenous underground hydraulic system used for irrigation, particularly in arid regions. It consists of a tunnel, slightly inclined to allow for natural water flow due to gravity and often extending up to 14,000 meters in length, with air shafts strategically placed along its course for ventilation and maintenance

Context

In arid and semi-arid landscapes, securing reliable water sources for agriculture is a persistent challenge. Algeria's Indigenous Foggaras System represents a highly efficient underground irrigation technique, adapted to low-rainfall environments. By harnessing gravity to transport water through long subterranean channels, this system has enabled the cultivation of palm groves and gardens, supporting food production and community livelihoods in desert areas.

Applied NbS Methods

A foggara consists of a slightly inclined underground tunnel, sometimes extending up to 14 kilometers, which collects and transports water to cultivated areas. Strategically placed air shafts along the tunnel ensure proper ventilation and allow for maintenance, helping farmers preserve the structure.

Foggaras have been implemented in over 30 countries, proving their effectiveness in transforming vast arid landscapes into fertile agricultural zones. In southwestern Algeria, foggaras have facilitated the expansion of extensive

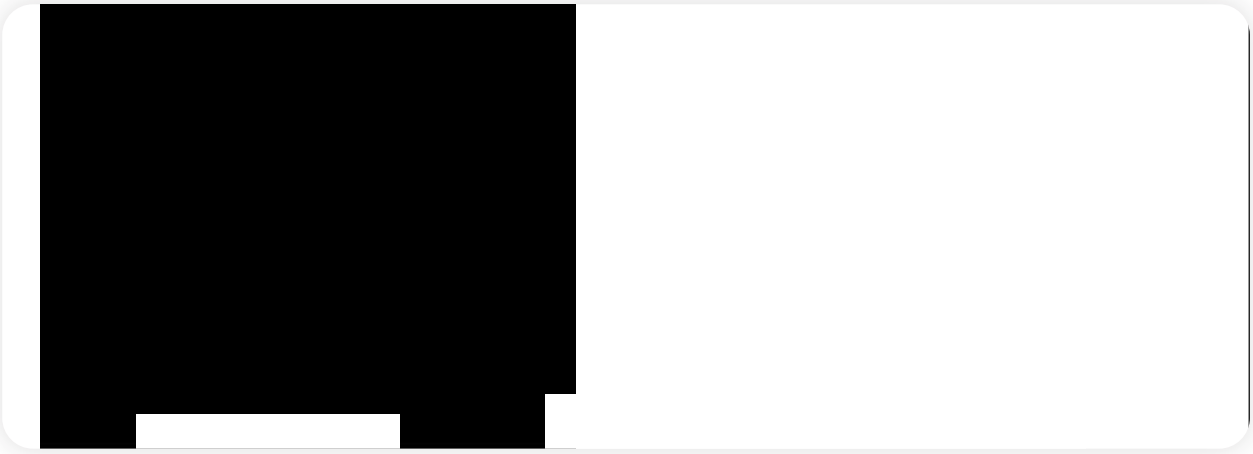
palm groves, contributing to the development of thriving oases. The foggara gallery collects water from underground sources and channels it to the surface, where it is distributed collectively among its owners.

At the foggara's outlet, a triangular pond known as the kasria serves as the main water distribution hub. Allocation of water is based on the individual contributions made by stakeholders toward the system's construction and upkeep. From the kasria, water flows into channels called seguia, eventually reaching storage basins known as madjen, which are gradually filled within a 24-hour cycle. Smaller channels, referred to as Guemoun, then deliver water from the madjen to irrigate palm trees and other vegetation in the gardens.

The distribution system is hierarchical. Water from the main kasria is routed through primary irrigation channels, which lead to secondary kasrias. These subsequently distribute the water into smaller seguias and tertiary kasrias, ensuring that each stakeholder receives their rightful share of water proportionate to their investment. This structured system ensures the efficient irrigation of palm groves and gardens, with the extent of the irrigated area dependent on the foggara's water flow rate.

As irrigation needs evolve, stakeholders can increase foggara flow rates or construct new systems, demonstrating the adaptability of this traditional water harvesting technique. The structured collective management model ensures fair water distribution, fostering long-term agricultural sustainability in challenging arid environments.

Figure 9 Schematic diagram of the foggara



A) An overveiw of the foggara

B) A Logitudinal Cup of the foggara

Note. From Boualem, R., Bachir, A., & Rabah, K. (2014, June 1). The Foggara: A Traditional System of Irrigation in Arid Regions. GeoScience Engineering, 60(2). https://geoscience.cz/ojs/index.php/GSE/article/view/28

Sources

- Boualem, R., Bachir, A., & Rabah, K. (2014, June 1). The Foggara: A Traditional System of Irrigation in Arid Regions. GeoScience Engineering, 60(2). https://geoscience.cz/ojs/index.php/GSE/article/view/28

6. Traditional Nature-Based Solutions for Water and Soil Conservation, Tunisia

A Mapping of Traditional and Indigenous NbS for Arid Landscapes

Location in Tunisia	Jessour (Matmata, Mountains of southeastern Tunisia), Individual Dry-Stone Basins (Kairouan), Gabion check dams (Bhayra, Beni Kedhache and Medenine), Tabia (Jeffara and Medenine), Cisterns (Medenine), Meskats (Sousse), Recharge wells (Medenine), Stone lines (Bouzgam, Kasserine), Dry stone walls (Bargou, Siliana), Mechanical benches (Testour and Mjez El Bab, Béja), Mechanical stabilization (Southern Tunisia – Kébili, Tozeur, Rjim Maatoug, Nefzaoua and Djerid)
Existing Ecosystems	Dryland Systems (Arid and semi-arid, arid foothills and piedmonts, arid slopes and valleys), Mountain Systems (within drylands), Cultivated Systems (Agroecosystems), and Oases and arid deserts.
Climate Change Challenges	Drought, floods and flashfloods, irregular rainfall patterns, soil erosion, land degradation and water scarcity

Context

In Tunisia's arid and semi-arid regions, water scarcity, irregular rainfall, and soil erosion pose persistent challenges to agriculture and local livelihoods. Annual rainfall in mountainous and foothill areas often falls below 200 mm, while steep slopes and rocky terrains limit the soil's ability to retain moisture. These conditions not only reduce soil fertility but also increase runoff and accelerate land degradation.

To address these issues, local communities developed traditional water harvesting and soil conservation methods that align with the principles of NbS. In the Matmata Mountains of southeastern Tunisia, the Jessour system captures rainwater in terraced basins to sustain agriculture. The Tabia technique, commonly used in foothill and piedmont regions, improves soil water retention, reduces erosion, and contributes to groundwater recharge.

In ephemeral wadi systems, gabion check dams are built to slow down runoff, allowing infiltration into deeper soil layers. Similarly, stone lines, dry stone walls, and mechanical benches are used in hilly/mountainous regions and slopy hilltops to stabilize the soil, increase water infiltration, collect sediments and create favourable areas for cultivation. To secure water supply for households and livestock, communities have also relied on cisterns, which store harvested rainwater and runoff

for use during periods of scarcity. Meanwhile, the Meskat system, developed in semi-arid areas, channels rainfall directly to cultivated plots, ensuring soil moisture retention and supporting tree cultivation. In Oases, arid deserts of southern Tunisia, mechanical stabilization techniques are used to control sand movement and protect infrastructure and agricultural fields from prevailing winds.

These indigenous practices illustrate how communities in Tunisia have long adapted to water scarcity and land degradation, using locally rooted techniques to conserve resources and sustain rural livelihoods.

The following subsections describe each of these practices in detail, explaining their design and the ways in which they facilitate water collection and use in arid contexts. The NbS included in this case study are:

- Jessour
- Individual Dry-Stone Basins
- Gabion check dams
- Tabia
- Cisterns
- Meskats
- Recharge wells
- Stone lines
- Dry stone walls
- Mechanical benches
- Mechanical stabilization

A. Jessour

Jessour (plural of Jessr) are traditional rainwater harvesting systems practiced in the Matmata Mountains of southeastern Tunisia, where annual rainfall is often below 200 mm. They enable agriculture and water management in arid, mountainous regions with steep slopes and scarce natural water resources.

Each Jessr is a hydraulic unit composed of:

- Impluvium – a runoff catchment area that channels water toward an outlet.
- Terrace – the cultivated zone formed by deposited sediments, used for fruit trees (olives, figs, almonds, date palms), legumes, and cereals. Terraces can accumulate soil layers up to 5 m deep.
- Dyke (tabia/sed/katra) – trapezoidal barriers (2–5 m high, 15–50 m long) that retain runoff and sediment. They include spillways (masref, manfas) to release excess water safely and are stabilized with abutments (ktef). Older systems often use dry stone reinforcements.

The Jessour systems enabled rainfed agriculture in arid landscapes, supporting local communities in achieving self-sufficiency and providing them with surplus crops to use in trade. Beyond supporting agriculture, these systems provide additional critical benefits, **as follows:**

- Support rainfed farming and local livelihoods.
- Recharge aquifers by enhancing infiltration.
- Control floods by slowing runoff.
- Prevent wind erosion by trapping sediment.

However, despite their effectiveness, Jessour systems face significant challenges. The construction and maintenance of Jessour is a labor-intensive process and requires meticulous planning. Rural-to-urban migration in Tunisia has reduced the labor force available to maintain these structures, leading to their gradual deterioration. Without consistent upkeep, the long-term sustainability of these invaluable systems is unfortunately at risk.

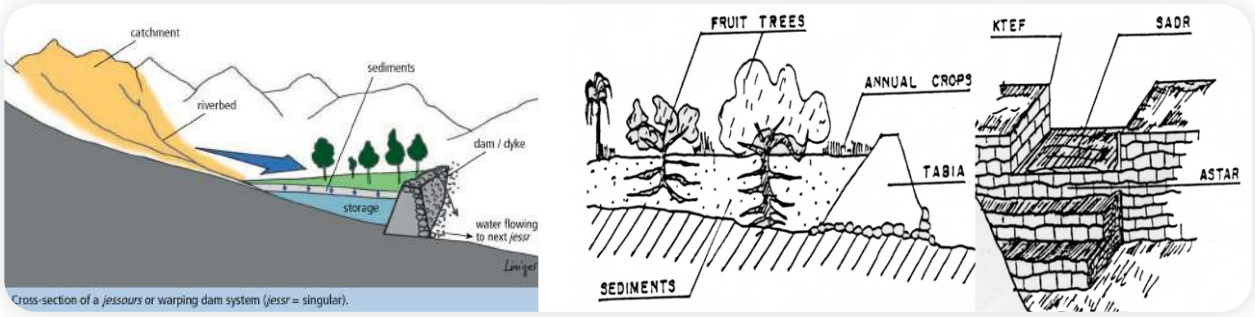
Figure 10 Jessour System

Note. View of an area with a number of jessours in El Athmane, Beni Khedache, Tunisia. Photo taken by Ben Zaied M. on 01/03/2008. From WOCAT. (2019, August 21). Jessour [Tunisia]. WOCAT Global SLM Database.
https://qcat.wocat.net/en/wocat/technologies/view/technologies_1013/

Figure 11 Jessour System during the dry season

Note. Jessour is the plural of a Jessr which is the hydraulic unit comprising a dyke, spillway, terrace (cropping area: fruit trees and annuals), and impluvium (runoff catchment area)
Photo by: van Delden H. From Mekdaschi Studer, R. and Liniger, H. 2013. Water Harvesting: Guidelines to Good Practice. Centre for Development and Environment (CDE), Bern; Rainwater Harvesting Implementation Network (RAIN), Amsterdam; MetaMeta, Wageningen; The International Fund for Agricultural Development (IFAD), Rome. .
https://www.researchgate.net/publication/259190040_Water_Harvesting_Guidelines_to_Good_Practice

Figure 12 Cross-section of a jessours or warping dam system



Note. (left) (jessr = singular of Jessour). (center) Cross-section of dyke (locally called tabia) and terrace (cropping area). The Jessour ensure the collection of both runoff water and sediments allowing creating very deep 'artificial' soils (terrace) which form a very good reservoir for water and nutrients to be used by fruit trees and annual crops. (right) The spillway allows the overflow to the other Jessour downstream. It also represents the symbol of water sharing equity between different farmers in the same watershed. Both drawings (center and right) adapted from El Amami (1984) by Mohamed Ouessar.
From Mekdaschi Studer, R. and Liniger, H. 2013. Water Harvesting: Guidelines to Good Practice. Centre for Development and Environment (CDE), Bern; Rainwater Harvesting Implementation Network (RAIN), Amsterdam; MetaMeta, Wageningen; The International Fund for Agricultural Development (IFAD), Rome.
https://www.researchgate.net/publication/259190040_Water_Harvesting_Guidelines_to_Good_Practice

Figure 13 Jessour in the wet season

Note. The different components of 1 unit of the Jessour system. From Gasmi, I., Eslamian, S. and Moussa, M. (2021). Evaluation of Traditional Rainwater Harvesting Technique of "Jessour" in Southern Tunisia, a Case Study on El-Jouabit Catchment. In Handbook of Water Harvesting and Conservation (eds S. Eslamian and F. Eslamian). https://doi.org/10.1002/9781119776017.ch13

Sources

- Gasmi, I., Eslamian, S., Moussa, M. (2021, April 30). Evaluation of Traditional Rainwater Harvesting Technique of "Jessour" in Southern Tunisia, a Case Study on El-J ouabit Catchment, in: Eslamian, S., Eslamian, F. (Eds.), Handbook of Water Harvesting and Conservation. Wiley, pp. 199–212. https://doi.org/10.1002/9781119776017.ch13
- WOCAT. (2019, August 21). Jessour [Tunisia]. WOCAT Global SLM Database. https://qcat.wocat.net/en/wocat/technologies/view/technologies_1013/

B. Individual Dry-Stone Basins

Individual dry-stone basins are a traditional rainwater harvesting method widely applied in Tunisia, particularly around olive trees in Oueslatia, Kairouan. Designed to collect and retain runoff water at the base of trees, they enhance soil moisture, reduce erosion, and improve tree health and productivity.

- **Construction:**
  Stones are arranged in a semi-circular basin on the upstream side of the tree. The process involves marking the tree's canopy, digging a shallow trench (10–20 cm), placing a foundation of large stones, and filling gaps with crushed stones. Two staggered rows and an additional layer of stones reinforce stability, with basin height ranging from 0.40 to 1 m, depending on slope conditions.
- **Functionality & Benefits:**
  The stone structure slows runoff, allowing rainwater to infiltrate the soil while filtering debris. Over successive rainfall events, sediment fills the gaps, improving water retention and stabilizing the basin. This promotes soil fertility, reduces erosion, and supports long-term tree growth and fruit production.
- **Maintenance & Challenges:**
  Regular upkeep—such as reshaping troughs, clearing weeds, and keeping outlets open—is necessary. While highly effective in conserving soil and water, the technique is labor-intensive and requires significant initial investment, which can limit adoption. Nonetheless, it remains a valuable practice for sustaining agriculture in drought-prone areas.

Figure 14 Dry-stone Basins

Note. (left) Olive trees arranged with individual dry-stone basins at the site in Oueslatia, Kairouan. Photo by Wafa SAIDI, 2023. (right) Individual dry-stone basins around olive trees Oueslatia, Kairouan. Photo by Wafa SAIDI, 2016. From WOCAT. (2024, March 22). Individual Dry-Stone Basins [Tunisia]. WOCAT Global SLM Database. **https://qcat.wocat.net/en/wocat/technologies/view/technologies_6601/**

Sources

- WOCAT. (2024, March 22). Individual Dry-Stone Basins [Tunisia]. WOCAT Global SLM Database. **https://qcat.wocat.net/en/wocat/technologies/view/technologies_6601/**

C. Gabion check dam

Gabion check dams are traditional water management structures widely used in Tunisia to regulate runoff in wadis (valleys). They are built by binding cubic metal cages ("gabions") filled with stones into stable units that form small dams, usually 1–4 meters high and adapted to the width of the wadi bed. Placed in series along wadis, typically 100–500 meters apart, they slow down floodwaters, promote infiltration, recharge groundwater, and mitigate erosion. In some cases, they also help divert water to nearby agricultural fields.

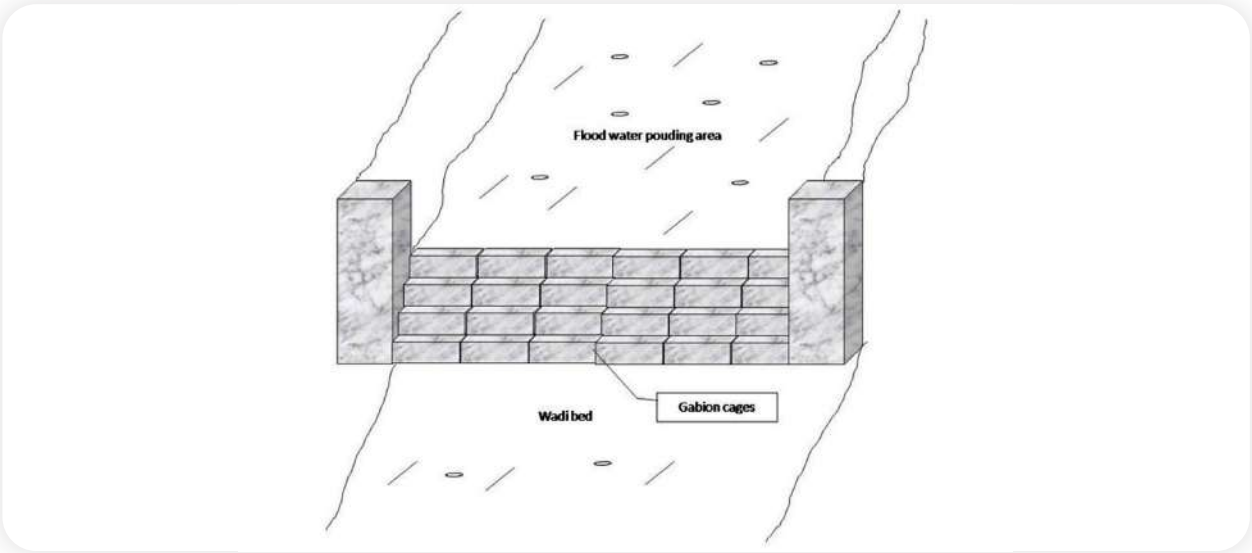
Although gabion technology was first developed for civil engineering, it has long been adapted in Tunisia as a practical, nature-based solution for water conservation and landscape restoration. Its flexible stone-and-cage design withstands the pressure of intermittent floods while remaining effective in stabilizing surrounding terrain.

In regions such as the Jeffara plain and Beni Khedache–Medenine, gabion check dams have played a crucial role in restoring degraded land and managing scarce water resources. By capturing runoff and encouraging infiltration, they enhance ecosystem resilience and provide a sustainable response to the challenges of arid environments.

Figure 15 Gabion Check Dams

Note. Gabion check dams are used to slow down the runoff flow, enhance infiltration, and in some cases to divert partly to neighbouring fields. (left) Bhayra, Beni Khedache – Medenine, Tunisia. Photo by Ouessar M. 01/03/2008. (right) Gabion check dam in the Jeffara plain. Photo shows the inspection of the dam after a flooding event, during which the dam was bypassed due to erosion and then lost its effectiveness. Bhayra, Medenine 04/05/2010 Photo by Cyprien Hauser (CDE, Bern) From WOCAT. (2019, August 21). Gabion check dam (Tunisia). WOCAT Global SLM Database. **https://qcat.wocat.net/en/wocat/technologies/view/technologies_1400/**

Figure 16 Technical Drawing of a Gabion Check Dam



Note. From WOCAT. (2019, August 21). Gabion check dam (Tunisia). WOCAT Global SLM Database. https://qcat.wocat.net/en/wocat/technologies/view/technologies_1400/

Sources

- WOCAT. (2019, August 21). Gabion check dam (Tunisia). WOCAT Global SLM Database. https://qcat.wocat.net/en/wocat/technologies/view/technologies_1400/

D. Tabia

Tabia is a traditional nature-based solution for water harvesting in Tunisia, widely practiced in foothill and piedmont areas with gentle slopes of less than 3%. Similar in concept to the Jessour system, tabias are specifically adapted to terrains where the gradient is lower. They consist of an earthen dyke, typically 50–150 meters in length and 1–2 meters high, constructed to intercept and store surface runoff. Each structure includes a central or lateral spillway and a designated collection area, ensuring that harvested water is directed efficiently to cultivated plots. The crop-to-catchment ratio usually falls between 1:6 and 1:20, which balances water supply with soil moisture needs.

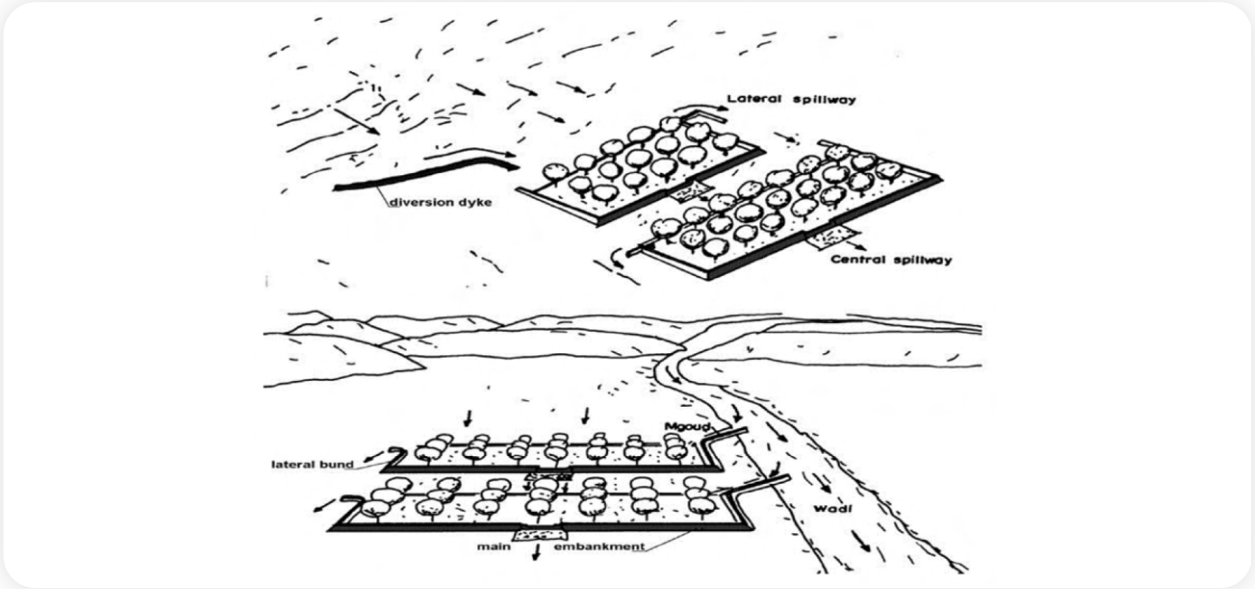
Distinct from Jessour, tabias incorporate two lateral bunds that can extend up to 30 meters, and occasionally a small diversion dyke (mgoud), allowing for improved control and distribution of water across fields. Their construction method depends on scale: smaller tabias are built manually using simple tools, while larger ones require machinery such as bulldozers or tractors.

Tabias have long been a cornerstone of Tunisian dryland agriculture. Ancient remnants remain in the Gafsa region, highlighting their deep historical roots. Today, they are still widely used in central and southeastern regions like Jeffara, where they have enabled the transformation of former pastoral land into productive farmland. Beyond providing water for tree crops and annual plants, tabias reduce soil erosion, enhance soil fertility, and contribute to groundwater recharge, making them a multifunctional and sustainable practice that continues to support rural livelihoods.

Figure 17 Tabias in Tunisia

Note. (left) Tabia on the piedmont area. Tree products (olive, almond, fig, palm) and annuals (barley) can be harvested. (Photo: Mongi Chniter). (right) View of a field improved through the implementation of semi-circular tabias in Tunisia. (H. Taamallah). From Mekdaschi Studer, R. and Liniger, H. 2013. Water Harvesting: Guidelines to Good Practice. Centre for Development and Environment (CDE), Bern; Rainwater Harvesting Implementation Network (RAIN), Amsterdam; MetaMeta, Wageningen; The International Fund for Agricultural Development (IFAD), Rome. **https://www.researchgate.net/publication/259190040_Water_Harvesting_Guidelines_to_Good_Practice**

Figure 18 Technical Drawing of a system of Tabias



Note. Tabia with natural water collection area (upper) and tabia on an expanded system with additional flood water diversions (lower). (Adapted from Alaya et al. 1993). Found in flatter areas, tabia can accommodate more trees on the terrace especially when it can receive additional water from floods. From Mekdaschi Studer, R. and Liniger, H. 2013. Water Harvesting: Guidelines to Good Practice. Centre for Development and Environment (CDE), Bern; Rainwater Harvesting Implementation Network (RAIN), Amsterdam; MetaMeta, Wageningen; The International Fund for Agricultural Development (IFAD), Rome.
https://www.researchgate.net/publication/259190040_Water_Harvesting_Guidelines_to_Good_Practice

Sources

- WOCAT. (2019, August 21). Tabia [Tunisia]. WOCAT Global SLM Database. **https://qcat.wocat.net/en/wocat/technologies/view/technologies_1420/**

E. Cistern

Cisterns are underground reservoirs designed to capture and store rainwater and runoff, ensuring reliable access to water in arid regions. Historically used for drinking water supply, cisterns have expanded to include irrigation and livestock watering applications. These reservoirs are categorized into two types: majel (private cisterns) and fesquia (communal cisterns), reflecting variations in ownership and scale. Constructed by excavating a hole and lining it with gypsum or concrete, cisterns prevent seepage, thereby optimizing water retention for sustainable long-term usability.

- **Each cistern consists of three main components:**
- Impluvium – a sloping catchment area that collects and directs runoff water, bordered by a diversion channel called a hammala.
- Sediment settlement basin – a pre-storage chamber designed to trap sediments and enhance water quality before storage.
- Storage reservoir – the main structure of the system, where water is stored for later use.

Cisterns are strategically located in flat areas, where floodwaters can be harnessed through diversion dykes. Artificially paved surfaces may also be used to enhance runoff collection efficiency. In larger systems, a dedicated pumping reservoir facilitates water extraction and improves accessibility. Cisterns vary considerably in size, from small private or communal units holding 5–200 cubic meters to large reservoirs with capacities of up to 70,000 cubic meters. A cistern with a capacity of 35 m^3 is estimated to meet the annual water needs of a family and its livestock (Ennabli, 1993). These structures have long supported water management in regions south of the 400-mm isohyet, where water scarcity is most acute. Many cisterns, some dating back to the Roman and Arab-Muslim periods, remain in use today—demonstrating the enduring value of traditional water conservation practices

Figure 19 Technical Drawing of a Cistern in Tunisia

Note. Drawing by M. Ouessar, 2012. From WOCAT. (2019, August 21). Cistern [Tunisia]. WOCAT Global SLM Database. https://qcat.wocat.net/en/wocat/technologies/view/technologies_1413/

Figure 20 Cisterns in Different Locations in the Arab Region

Cistern in Tunisia. (M. Ouessar) | Cistern in Jordan. (HP. Liniger) | A traditional cistern in Egypt. (T. Oweis)

Note. The cistern are used in Tunisia and other locations of the Arab region to store water for domestic and other uses. (left) Cistern in Tunisia. Photo by M. Ouessar. (center) Cistern in Jordan. Photo by HP. Liniger. (right) A traditional cistern in Egypt. Photo by T. Oweis.

From Mekdaschi Studer, R. and Liniger, H. 2013. Water Harvesting: Guidelines to Good Practice. Centre for Development and Environment (CDE), Bern; Rainwater Harvesting Implementation Network (RAIN), Amsterdam; MetaMeta, Wageningen; The International Fund for Agricultural Development (IFAD), Rome.
https://www.researchgate.net/publication/259190040_Water_Harvesting_Guidelines_to_Good_Practice

Sources

- WOCAT. (2019, August 21). Cistern [Tunisia]. WOCAT Global SLM Database. **https://qcat.wocat.net/en/wocat/technologies/view/technologies_1413/**

F. Meskats

The Meskat is a traditional rainwater harvesting system widely used in Tunisia since Roman times. Designed to address water scarcity and irregular rainfall, it has long supported soil moisture retention, tree cultivation, and sustainable farming. A Meskat typically ranges from 1.5 to 5 hectares and consists of two main parts:

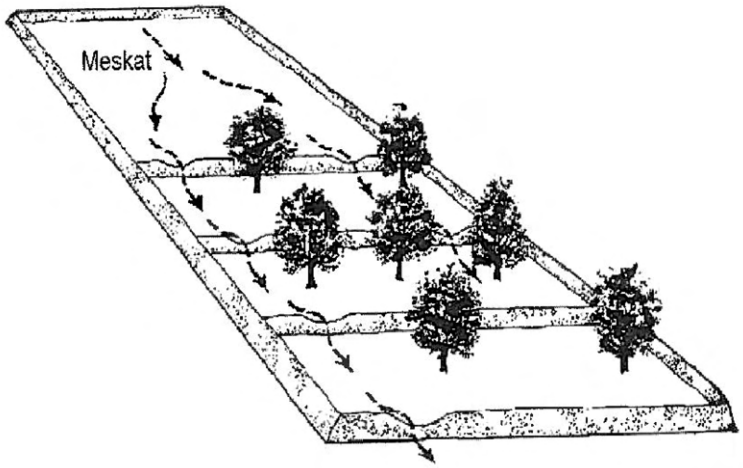
- Impluvium: a gently sloping catchment area (3–10% slope) that collects and channels rainwater.
- Mankaa: a smaller, downslope plot (1–2% slope) where crops such as olives, figs, and cereals are cultivated.

The system functions by directing runoff from the impluvium to the mankaa, regulated by earthen mounds (Tabias) and openings (Majref) that distribute water across plots. The optimal design follows a two-thirds impluvium to one-third mankaa ratio.

The limestone-rich impluvium often hosts natural vegetation such as rosemary, artemisia, and alfa grass, while mankaa zones are mainly planted with olive trees. In some cases, cisterns (Fesquias or Majels) are integrated for additional storage.

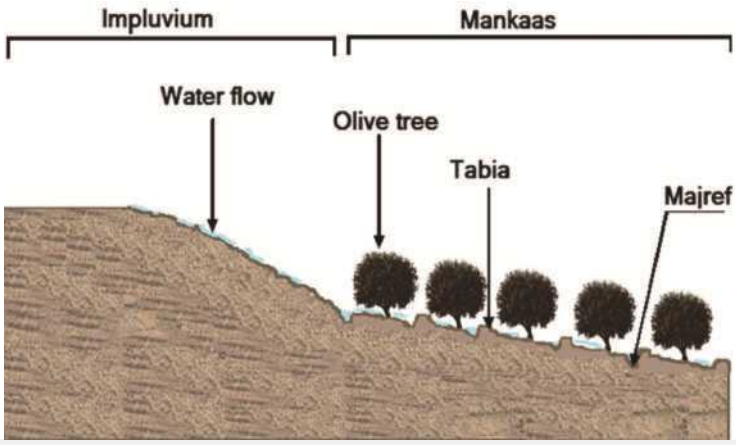
Although many Meskats have deteriorated due to agricultural expansion since the mid-20th century, revitalizing this practice offers a sustainable pathway for enhancing water efficiency and maintaining soil fertility in Tunisia's arid regions.

Figure 21 Meskat microcatchment in Tunisia



Note. From Prinz, D. 1996. (Adapted from El Amami 1983) Water harvesting: Past and Future. In Pereira L.S., (ed). Sustainability of Irrigated Agriculture. Proceedings, NATO Advanced Research Workshop, Vimeiro, 21: 26.03.1994. Balkema, Rotterdam. https://publikationen.bibliothek.kit.edu/158696/1132

Figure 22 Cross section of the Meskat system



Note. Adapted from Ben Salem, A., El Amri, A., M'nassri, S., Chokman, K., Majdoub, R. (2021, March 13). Spatio-Temporal Monitoring of the Meskat System Distribution in the Tunisian Sahel Region Using TM Landsat Images. In: Khebour Allouche, F., Negm, A.M. (eds) Environmental Remote Sensing and GIS in Tunisia. Springer Water. Springer, Cham. https://-doi.org/10.1007/978-3-030-63668-5_4

Sources

- Abdo, G. and Eldaw, A. (2004, January). Water-harvesting experience in the Arab region. Regional Workshop on Management of aquifer Recharge and Water Harvesting in Arid and Semiarid Regions of Asia: 27th November -1st December 2004, Yazd, Republic of Islamic Iran. https://www.researchgate.net/publication/292725885_Water-harvesting_experience_in_the_Arab_region
- Ben Salem, A., El Amri, A., M'nassri, S., Chokman, K., Majdoub, R. (2021, March 13). Spatio-Temporal Monitoring of the Meskat System Distribution in the Tunisian Sahel Region Using TM Landsat Images. In: Khebour Allouche, F., Negm, A.M. (eds) Environmental Remote Sensing and GIS in Tunisia. Springer Water. Springer, Cham. https://www.researchgate.https://-doi.org/10.1007/978-3-030-63668-5_4

G. Recharge Wells

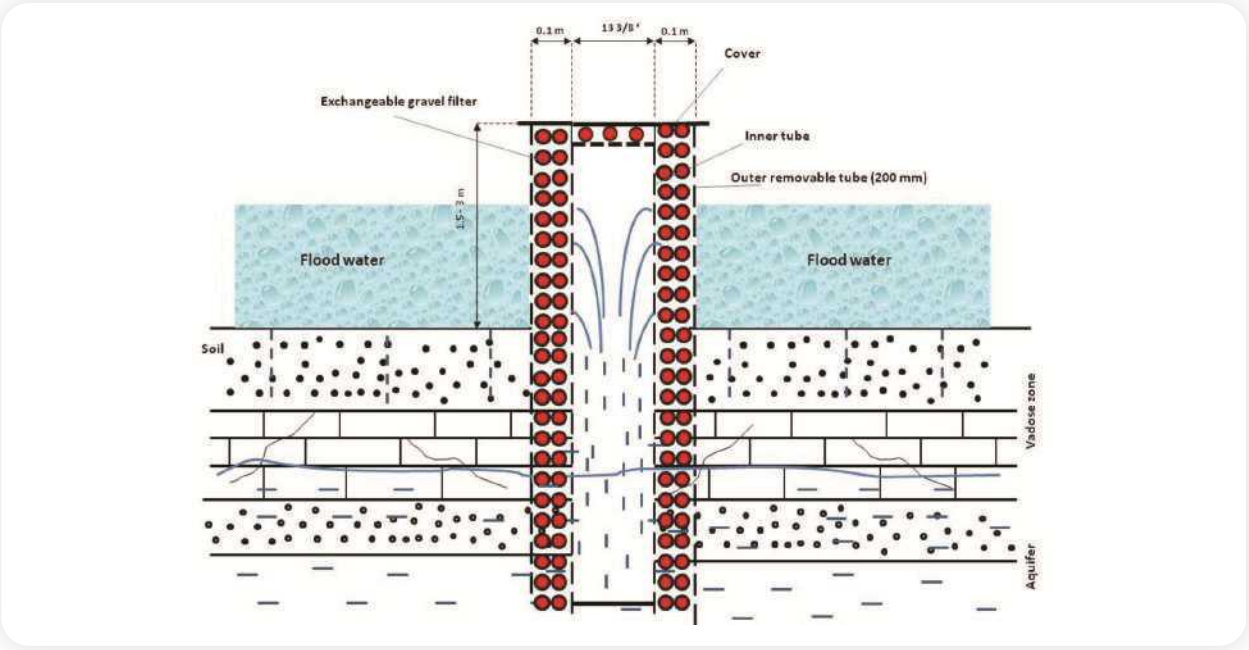
Recharge wells are a traditional nature-based solution in Tunisia used to replenish groundwater in arid and semi-arid regions. They consist of a drilled shaft, usually 30–40 m deep, fitted with a casing and gravel filter that allows floodwater to percolate directly into aquifers. Water enters through openings in the casing, is filtered through gravel, and flows into the inner shaft, ensuring controlled and efficient recharge. This design is particularly valuable where impermeable bedrock limits natural infiltration.

These wells are often integrated with gabion check dams built across ephemeral riverbeds (wadis). The dams slow down flash floods and create temporary ponds with a capacity of 500–3,000 m³, while the recharge wells accelerate infiltration when the soil beneath is unable to absorb water efficiently. In this way, floodwater that would otherwise run off is stored underground, reducing evaporation losses and replenishing deep aquifers.

The technology addresses multiple water management challenges, including declining groundwater from over-extraction, prolonged droughts, seawater intrusion in coastal aquifers, and rising irrigation demand. It provides a reliable means to store water during wet periods for use in dry seasons, strengthening both public water reserves and agricultural supply.

Successful implementation requires careful site selection and technical planning by hydrogeologists, as well as installation by specialized drilling firms. Although the investment is relatively high—typically USD 5,000 - 10,000 per well—the long-term benefits of increased water availability and resilience make it a strategic option for sustainable water management in Tunisia.

Figure 23 Technical drawing of a recharge well.



Note. By Technical drawing of a recharge well. Source: Ouessar M, 2011. From WOCAT. (2018, February 11). Recharge well [Tunisia]. WOCAT Global SLM Database. **https://qcat.wocat.net/en/wocat/technologies/view/technologies_1412/**

Figure 24 Recharge Well behind a Gabion Check Dam

Note. (left) A recharge well reduces the length of time of standing water, and thus evaporation, by injecting flood water rapidly into the aquifer, where it is stored and recovered later to be used for different purposes. This is an example of a recharge well behind a gabion check dam after rain. (Photo: M. Ouessar) (right) A recharge well needs to be always combined with a gabion check dam which prevents floodwater movement downstream and creates a temporary pond (Photo: S. Temmerman) From Mekdaschi Studer, R. and Liniger, H. 2013. Water Harvesting: Guidelines to Good Practice. Centre for Development and Environment (CDE), Bern; Rainwater Harvesting Implementation Network (RAIN), Amsterdam; MetaMeta, Wageningen; The International Fund for Agricultural Development (IFAD), Rome. **https://www.researchgate.net/publication/259190040_Water_Harvesting_Guidelines_to_Good_Practice**

Sources

- WOCAT. (2018, February 11). Recharge well [Tunisia]. WOCAT Global SLM Database. **https://qcat.wocat.net/en/wocat/technologies/view/technologies_1412/**

H. Stone Lines

Stone lines, also known as stone barriers, are a traditional method of placing stones in structures that range from 60 to 100 cm in height along the contour lines of rocky slopes. This method helps slow down run-off, collect sediments carried by the rain, and form terraces that are suitable for agriculture, as well as stabilize the hilltop soil. The technique entails placing stones on top of one another along the contour lines of the rocky slopes. Over time, stone lines enhance soil fertility, reduce erosion, and improve land productivity. They gradually accumulate sediments, enriching the soil and forming terraces that support the growth of olive trees, almond trees, fodder shrubs, and various forest species. This process not only stabilizes the sloping terrain and protects it against erosion but also promotes biodiversity by creating microhabitats for plant and animal species.

The design of stone lines follows specific guidelines to maximize their effectiveness. Each barrier is built under 500 meters in length to avoid structural weakness and with an upstream inclination of approximately 10%. The method of construction

involves arranging the stones on top of one another without using mortar or another binding material. The barriers are designed such that the downstream edge slopes forward to maximize runoff velocity reduction. Additionally, the barriers are spaced according to the slope gradient to ensure resilience against heavy rainfall. However, soil type plays a crucial role in their success—marly, clayey, or sandy soils lacking cohesion are not well-suited for this method.

To further enhance infiltration, subsoiling is often performed before the construction of stone lines. Maintenance is essential, as accumulated sediment necessitates periodic height adjustments of these barriers.

Beyond improving soil and water conservation, stone lines contribute to ecosystem services such as soil stabilization, water retention, and vegetation growth. By relying on local knowledge, materials, and craftsmanship, communities are actively engaged in their construction and upkeep, reinforcing principles of agroecology and sustainable land management. Farmers and land users value stone lines for their long-term benefits —enhanced soil fertility, improved agricultural productivity, and the promotion of a more resilient environment.

Figure 25 Stone lines in Kasserine, Tunisia

Note. (left and center) Stone lines, Bouzgam, Kasserine, Tunisia, Photo: Wafa SAIDI, 2023. (right) Terrain landscaped with stone lines, Bouzgam, Kasserine, Photo: Farhat MISSAOUI, 2023. From WOCAT. (2024, April 30). Stone Lines [Tunisia]. WOCAT SLM Database. **https://qcat.wocat.net/en/wocat/technologies/view/technologies_6610/**

Sources

- WOCAT. (2024, April 30). Stone Lines [Tunisia]. WOCAT SLM Database. **https://qcat.wocat.net/en/wocat/technologies/view/technologies_6610/**

I. Dry Stone Walls

Dry stone walls are a traditional rock placement technique that does not use mortar or any binder. Rocks are placed along the contour line or perpendicular to slopes to collect the sediment in run-off water and allow for the infiltration of water in the terrace created by the placement of the stone wall. This method is used for soil stabilization and the creation of terraces for sustainable agriculture in arid and semi-arid moderate slopes.

Dry stone walls are strategically constructed on slopes with moderate to steep gradients to address the challenges of erosion and runoff, particularly in rural areas where annual rainfall exceeds 400 mm. Their design involves selecting and stacking stones of various sizes, with larger stones forming a sturdy base and smaller stones fitted tightly on top. The foundation, made of partially buried stones, ensures additional stability, while drainage channels integrated within the walls prevent water accumulation that could weaken the structure.

These walls are instrumental in creating terraces, which convert sloped land into flat, arable plots suitable for farming. By holding soil in place and reducing runoff, they help retain moisture and nutrients, fostering improved soil fertility and agricultural productivity. Additionally, dry stone walls contribute to biodiversity, offering habitats for diverse plant and animal species.

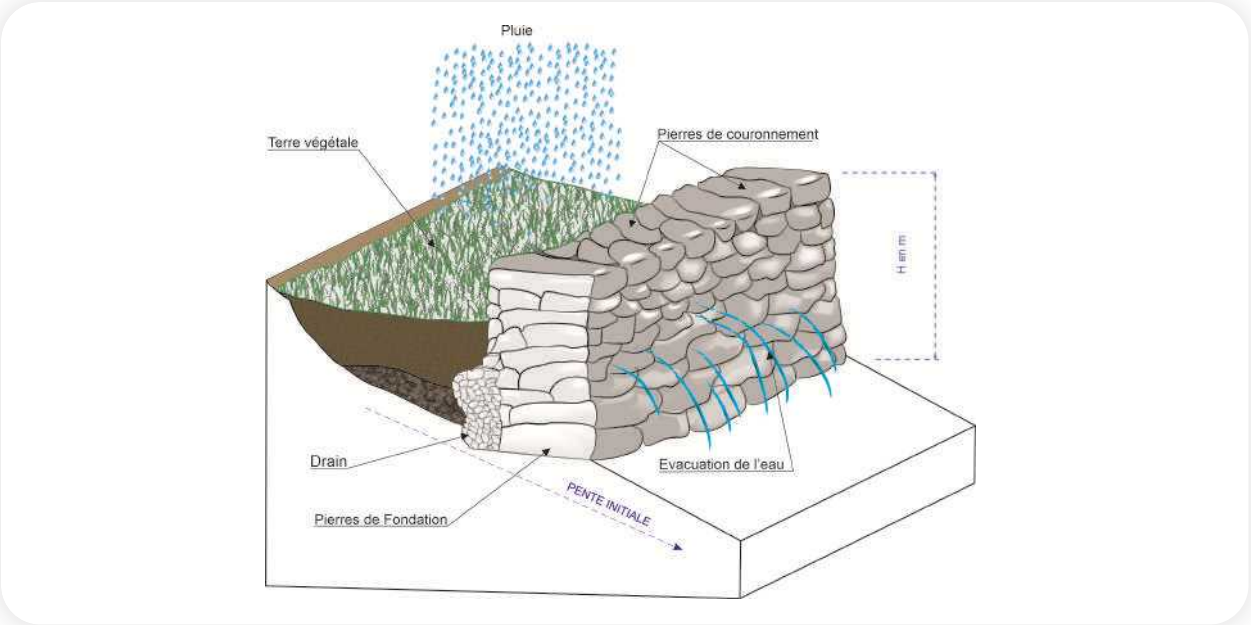
Construction follows a precise process, starting with site preparation to clear vegetation and debris. The foundation width ranges from 30 cm to 1 m and is slightly sloped inward to enhance durability. During assembly, larger stones are positioned at the base, while progressively smaller ones are stacked above to form a compact, interlocking structure. Though effective, this method requires skilled labor and access to suitable stones, making its implementation dependent on available resources and expertise.

Beyond their practical benefits, dry stone walls promote local economic growth by generating employment opportunities and preserving traditional building techniques. Despite requiring careful planning and maintenance, their long-term advantages, including erosion control, water retention, and enhanced farmland productivity, make them an essential component of sustainable land management.

Figure 26 Network of Dry Stone Walls in Bargou, Siliana, Tunisia

Note. Photo: Wafa SAIDI, 2023. From WOCAT. (2024, April 23). Dry Stone Walls [Tunisia]. WOCAT SLM Database. https://qcat.wocat.net/en/wocat/technologies/view/technologies_6666/

Figure 27 Technical Drawing of the Dry Stone Wall Technology.



Note. By Wafa Saidi, 2023. From WOCAT. (2024, April 23). Dry Stone Walls [Tunisia]. WOCAT SLM Database. https://qcat.wocat.net/en/wocat/technologies/view/technologies_6666/

Sources

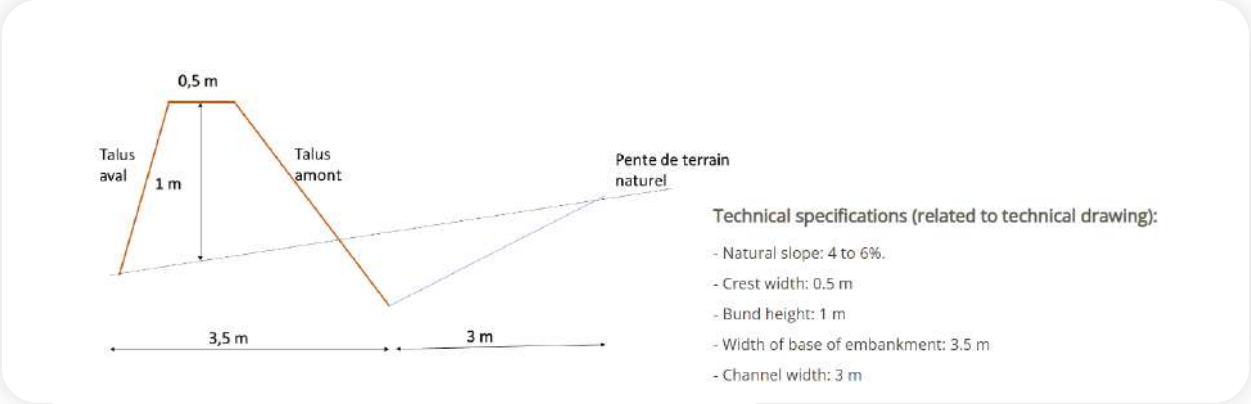
- WOCAT. (2024, April 23). Dry Stone Walls [Tunisia]. WOCAT SLM Database. https://qcat.wocat.net/en/wocat/technologies/view/technologies_6666/

J. Mechanical Benches

Mechanical benches - a method of earth working that involves the construction of benches or embankments along contour lines of sloping terrains - are an agricultural and land management practice designed to mitigate soil erosion, enhance soil stability and fertility, and optimize land productivity through reducing the velocity of run-off and collecting sediments. These structures are particularly beneficial in regions with high average annual rainfall but with low intensity, as they help ensure effective water infiltration and soil conservation. Strategically shaping the land into leveled embankments along contour lines, mechanical bench terraces not only enhance agricultural yield but also bring about broader environmental sustainability benefits, such as watershed protection and land restoration.

This nature-based technology consists of constructed earthen levees or embankments systematically placed along contour lines to minimize erosion and support land productivity. Suitable conditions for implementation require soil that is light to medium in texture with sufficient organic matter, a topsoil depth of at least 1.5 meters, and gentle slopes ranging from 4 to 6%. The figure below illustrates a typical mechanical bench and defines related technical specifications.

Figure 28 Technical drawing of the technology.



Note. By Wafa Saidi, 2023. From WOCAT. (2024, April 23). Mechanical Benches [Tunisia]. WOCAT SLM Database. https://qcat.wocat.net/en/wocat/technologies/view/technologies_6655/

Functioning as erosion-control structures, these terraces work by integrating bunds alongside drainage channels to regulate water flow and soil stability. By segmenting the slope into a series of cascading levels, they effectively reduce water velocity, prevent excessive sediment runoff, and improve water infiltration and soil moisture retention. The benches aid in surface water storage within agricultural fields, promoting soil fertility and reducing erosion in smaller watershed areas. Furthermore, mechanical benches offer additional advantages such as protecting cereal crops by minimizing soil erosion and establishing a favorable micro-climate for arboriculture. When coupled with these farming practices, these terraces can support increased productivity and enhance soil health:

- Farming along contour lines,
- And facilitating crop rotation strategies.

The specific design and spacing of these terraces are determined based on environmental conditions and conservation objectives. Their successful deployment requires thorough site assessment to ensure alignment with intended conservation goals. The construction and maintenance of these terraces involve several essential steps:

- Conducting detailed site evaluations for optimal layout,
- Utilizing heavy machinery for structural formation,
- Securing appropriate building materials,
- Continuous monitoring and upkeep to prevent degradation.

While mechanical bench terraces yield significant environmental and agricultural benefits, their implementation is not without challenges. Some land users welcome their contribution to water conservation and erosion control, while others raise concerns about potential constraints on land use due to the space occupied by embankments.

Nonetheless, their benefits remain valuable and primarily include enhancing agricultural productivity through improved soil and water management, preventing and reversing land degradation, safeguarding watersheds when integrated with broader conservation strategies, and generating economic benefits through sustainable land utilization.

Figure 29 A Site Featuring Mechanical Benches (Embankments) in Testour, Béja, Tunisi

Note. Photo: Wafa SAIDI, 2023. From WOCAT. (2024, April 23). Mechanical Benches [Tunisia]. WOCAT SLM Database. **https://qcat.wocat.net/en/wocat/technologies/view/technologies_6655/**

Sources

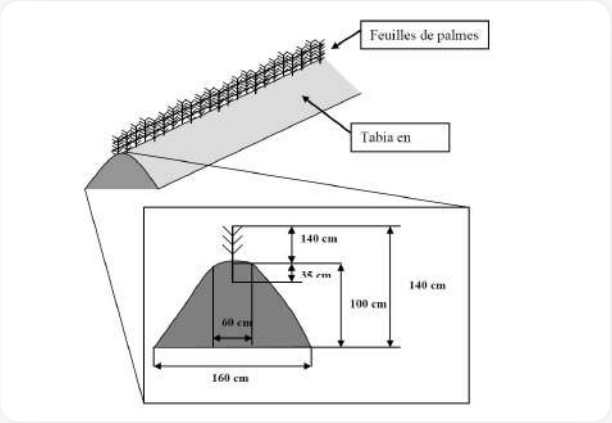
- WOCAT. (2024, April 23). Mechanical Benches [Tunisia]. WOCAT SLM Database. **https://qcat.wocat.net/en/wocat/technologies/view/technologies_6655/**

K. Mechanical Stabilization

Mechanical stabilization is a sand stabilization technique that employs the deployment of dunes and raised landforms reinforced by palm leaves or corrugated cement sheets to protect infrastructure and agricultural fields from prevailing winds.

Two primary mechanical stabilization techniques—counter dunes and grid systems—are commonly used to control sand movement. The counter dune is a linear barrier placed perpendicular to prevailing winds and serves as a blockade to prevent dunes from encroaching on critical infrastructure. Depending on terrain consistency, counter dunes can either be built directly in a 30 to 40 cm deep ditch or on an elevated earth embankment known as tabia, which is further reinforced with a palisade made of palm leaves or corrugated cement sheets. The tabia itself typically has a trapezoidal shape, with dimensions varying by

Figure 30 Technical Drawing of a counter dune.



Note. From Taamallah Houcine, WOCAT. (2018, November 22). Fixation des dunes de sables avec les feuilles de Palmes [Tunisia]. WOCAT SLM Database. **https://qcat.wocat.net/en/wocat/technologies/view/technologies_4168/SLM Database, 2018**

region, often measuring 60 cm at its small base, 160 cm at its large base, and standing 100 to 120 cm high.

For environments where winds shift in multiple directions, grid systems are used to stabilize mobile dunes. This approach involves constructing grids of varying dimensions composed of inert windbreak materials, such as palm leaves or fiber cement sheets, to fix dunes in place. The choice of materials depends on availability, with palm leaves exclusively utilized in Kébili, Tozeur, Rjim Maatoug, and parts of the South-East, sourced mainly from the oases of Nefzaoua and Djerid.

Both stabilization techniques play a crucial role in managing land erosion and sand dune movement, ensuring that shifting sand does not disrupt infrastructure or agricultural activities. By combining natural and manufactured materials, these methods offer sustainable solutions adapted to Tunisia's arid conditions.

Figure 31 Mechanical Stabilization

Note. (left) mechanical stabilization of sand dune by a dense palm leaf network of fences. (center) Protection of the new oasis against sand encroachment using palm leave fences. (right) Fixing works of the dunes using the dried palm leave fences fins. Photos: Houcine Taamallah. From WOCAT. (2018, November 22). Fixation des dunes de sables avec les feuilles de Palmes [Tunisia]. WOCAT SLM Database. https://qcat.wocat.net/en/wocat/technologies/view/technologies_4168/

Sources

- WOCAT. (2018, November 22). Fixation des dunes de sables avec les feuilles de Palmes [Tunisia]. WOCAT SLM Database. **https://qcat.wocat.net/en/wocat/technologies/view/technologies_4168/**

7. The Integrated Water Resource Management (IWRM) Program, Tunisia

Location	Tunisia
Existing Ecosystems	Coastal, rural, arid and semi-arid
Climate Change Challenges	Water scarcity, drought, coastal erosion, and SLR
NbS Approach	Integrated Water Resource Management (IWRM) Approach: combining NbS with traditional methods to address water scarcity. The IWRM approach in Tunisia consists of various applications that aim to enhance water security, curb losses, expand storage, and promote the sustainable management of water, soil, and coastal resources

Context: Water Scarcity and Environmental Challenges in Tunisia

Tunisia, one of the most arid countries in the world, is grappling with an escalating water crisis worsened by climate change. In the four years since 2020, annual rainfall has steadily declined, causing reservoir reserves to drop to critically low levels. Water scarcity is further exacerbated by the uneven distribution of rainfall over the nation, with northern regions receiving significantly higher levels of precipitation than the dry central and southern areas. Additionally, aging infrastructure, inefficient water management, and excessive groundwater extraction compounding the problem and place immense pressure on Tunisia's already strained resources. Besides, coastal erosion presents an additional challenge, threatening vital ecosystems and undermining the tourism sector along Tunisia's extensive shoreline.

Applied NbS Method within the Integrated Water Resource Management (IWRM) Program

In response to these pressing challenges, Tunisia launched the IWRM program with support from the German Federal Government, in collaboration with KfW Development Bank. The program integrates NbS and conventional measures and aims to improve water availability and enhance efficiency and resource protection. Through a broad range of interventions—amounting to approximately EUR 1.1 billion—, Tunisia aims to stabilize its water supply, minimize inefficiencies, expand storage capacity, and ensure the sustainable management of water, soil, and coastal ecosystems, safeguarding critical resources.

The IWRM program promotes the development of integrated planning tools for the sustainable use of water resources, tailored to diverse climatic, ecological, economic, and social contexts. The

program includes measures that focus on modernizing irrigation systems, rehabilitating water infrastructure, and promoting sustainable land and coastal management. Alongside efforts in coastal protection, desalination, sewage sludge treatment, and wastewater reuse, IWRM emerges as a cornerstone of Tunisia's sectoral water policy.

Nature-based solutions play a central role in the IWRM approach. Coastal stabilization efforts employ sand fences, dune restoration, and wave breakers to mitigate erosion while preserving biodiversity. To combat coastal erosion, APAL, the Tunisian Coastal Protection Authority, restored the beach at Hammam Sousse by constructing submarine breakwaters that trap sand and stabilize the shoreline. Furthermore, pinewood fences were installed along a four-kilometre coastal stretch to stabilize sand dunes which act as natural barriers against erosion. On the Kerkennah Islands near Sfax, rock reinforcements line the shore, backed by a paved esplanade with small public squares. These interventions not only shield the coastline but also enhance the livability and aesthetic value of the waterfront.

In agricultural areas, irrigation systems have been enhanced with droplet irrigation technology, significantly reducing water consumption and improving distribution efficiency. Efforts to expand and rehabilitate reservoirs help secure surface water supplies for future use, lessening reliance on overexploited groundwater reserves. Additionally, water transfer projects facilitate the redistribution of surplus water from the north to the water-scarce central and southern regions, addressing disparities in access to water.

The program has had a transformative impact on millions of Tunisians. Improved water infrastructure has enhanced living conditions for approximately 4.5 million people, while the development and rehabilitation of sewage treatment plants have reduced waterborne diseases for 3.6 million residents. Desalination plants in southern Tunisia now provide clean drinking water to 1.5 million people. In rural communities, modernized irrigation systems have boosted agricultural productivity, supporting smallholder farmers and strengthening local economies. Coastal stabilization projects have preserved 30 kilometers of Tunisia's coastline, safeguarding beaches for tourism while protecting marine ecosystems.

Beyond its environmental benefits, the IWRM program has delivered substantial economic gains. Infrastructure development has generated 35,000 temporary jobs during construction and 125,000 long-term employment opportunities, contributing to economic stability and growth. Meanwhile, water pricing reforms have encouraged more efficient water use while ensuring affordability for lower-income households.

By combining advanced water management strategies with NbS, Tunisia is taking critical steps toward securing its water future, protecting ecosystems, and sustaining livelihoods in the face of climate change.

Sources

- KfW Development Bank. (2024, April). Managing scarce water resources. KfW Development Bank. https://www.kfw-entwicklungsbank.de/s/enzBy8n-
- Christoph Albrecht-Heider. (2020, March 9). How Tunisia is protecting its 1,100-kilometre-long Mediterranean coastline from erosion. KfW Development Bank.https://www.kfw.de/stories/environment/climate-change/coastal-protection-tunisia/
- Christoph Albrecht-Heider. (2020, March 16). A seawater desalination plant in Tunisia produces drinking water. KfW Development Bank. https://www.kfw.de/stories/environment/natural-resources/tunisia-desalination-of-sea-water/
- KfW Development Bank. (2024, March 22). Tunisia - Water is rare and precious. KfW Development Bank. https://www.kfw-entwicklungsbank.de/About-us/News/News-Details_800128.html
- Christoph Albrecht-Heider. (2020, March 16). Modernising the Sidi Saad dam safeguards the future of the surrounding population. KfW Development Bank. https://www.kfw.de/stories/environment/natural-resources/tunisia-sidi-saad/

8. Integrated Agricultural Development Project in Kef and Kasserine, Tunisia

Location	Tunisia (Governorates of Kef and Kasserine)
Existing Ecosystems	Coastal and dryland ecosystems
Climate Change Challenges	Water scarcity due to climate change vulnerability and increase in desertification poses potential pressures on existing water capacity and infrastructure
NbS Approach	▪ Restoration of agricultural land within watersheds ▪ Portable water supply access in rural communities ▪ Deep boreholes construction

Context

The Arab region faces acute water scarcity, exacerbated by climate change. In Tunisia, water demand significantly exceeds supply, placing immense pressure on domestic resources. Beyond quantity, water quality and reserve sustainability are also under threat.

To address these challenges, the IsDB launched a project aimed at boosting agricultural productivity and food security while protecting natural resources, creating jobs, and improving rural livelihoods in the underserved governorates of Kef and Kasserine.

Key project components included the rehabilitation and development of irrigated areas, the installation of new water points to ensure safe drinking water, and the protection of the Sarrath Dam from siltation. The project targeted both governorates due to their shared location on the Sarrath River watershed, enabling synergy and efficiency. Following consultations with Tunisian authorities, a unified, integrated development approach was adopted.

Project outputs included:

i. Provision of potable water to 10,000 people across 22 villages;

ii. Expansion of arboriculture over 3,100 hectares;

iii. Implementation of soil and water conservation on 24,150 hectares;

iv. Rehabilitation of 95% of five irrigated perimeters; (v) Construction of 61 km of rural access roads to improve market connectivity.

Applied NbS Methods

The project employed NbS to tackle water scarcity, soil degradation, and climate vulnerability in an integrated way. Designed to restore ecosystem functionality and boost agricultural productivity, these interventions also aimed to ensure sustainable water access for local communities. Tailored to the semi-arid conditions of northwestern Tunisia, the NbS approaches addressed the region's fragile ecosystems, which are highly prone to erosion, drought, and land degradation.

Key NbS implemented by the project include:

1. The rehabilitation of hill lakes and water harvesting at El Behaouria and Wadi El Sharshara captured seasonal runoff, recharged groundwater, reduced flood risks, and supported irrigation, mimicking natural water retention to benefit smallholder farmers.

2. Contour bunding, terracing, and native reforestation of 24,000 hectares of land to stabilize slopes, reduce erosion, and restore catchments, which enhanced biodiversity and long-term resilience.

3. Eco-based Agroforestry Development, employing arboriculture across 3,100 hectares with drought-tolerant olive, almond, and fig trees. This diversified incomes, improved food security, and delivered ecosystem services like soil fertility and erosion control.

4. Community Water Infrastructure through implementing boreholes, pumping stations, and distribution systems to improve water access in 22 villages. This reduced pressure on natural springs and integrated engineered and ecological solutions for greater resilience.

Figure 32 Target Watersheds

Note. (Top) El Behaouriya Hill Lake in Kasserine Governorate. (Bottom) Wadi El Sharshara Hill Lake - Kef Governorate.
Source: IsDB

Sources

- IsDB. (2023). Integrated Agricultural Development Project in the Governorates of Kef and Kasserine. Project Completion Report (PCR).

9. Riverbank Filtration, Egypt

Location	Giza, Bani Suef, El Minya, Sohag, Qena, Qalyoubeya, Al Gharbeya, Ismailia and Port Said, Egypt
Existing Ecosystems	Freshwater Systems
Climate Change Challenges	Water scarcity and water quality degradation

Context

Egypt is facing critical water challenges driven by population growth, climate change, and pollution. The Nile River, which supplies over 95% of the country's freshwater, is under increasing pressure due to rising demand, inefficient use, and contamination from agricultural runoff and untreated wastewater. Many rural and underserved communities lack access to safe drinking water, often relying on unsafe surface sources that pose serious health risks. Traditional water treatment plants are costly to build and maintain, especially in remote or resource-limited areas.

To address these challenges, the Riverbank Filtration (RBF) project was launched by UN-Habitat in partnership with the Ministry of Housing and the Holding Company for Water and Wastewater. Piloted in Minya with seven filtration units serving over 150,000 people, the project has since expanded to governorates including Sohag, Qena, Luxor, and Assiut, benefiting millions of residents. By providing clean water through a sustainable, locally managed system, RBF supports Egypt's national water security goals and climate adaptation efforts in vulnerable communities.

Applied NbS Methods

The RBF project leverages the natural filtration properties of riverbank soils by extracting water from shallow wells near the Nile. As water flows through naturally occurring layers of sand and gravel, impurities such as bacteria and pollutants are filtered out, significantly reducing the need for costly and energy-intensive treatment. This low-cost, energy-efficient NbS is particularly suited for rural and peri-urban areas where access to advanced treatment facilities is limited.

The technology's simplicity and low operational costs enable scalability, while active community engagement in operating and managing the filtration units fosters local ownership and sustainability. Building on its success, the project plans to extend coverage to additional regions such as Qalyoubeya and Port Said and apply similar low-tech filtration methods to improve water quality in the Nile Delta discharge canals. These efforts contribute to enhancing Egypt's broader water security and climate resilience strategies.

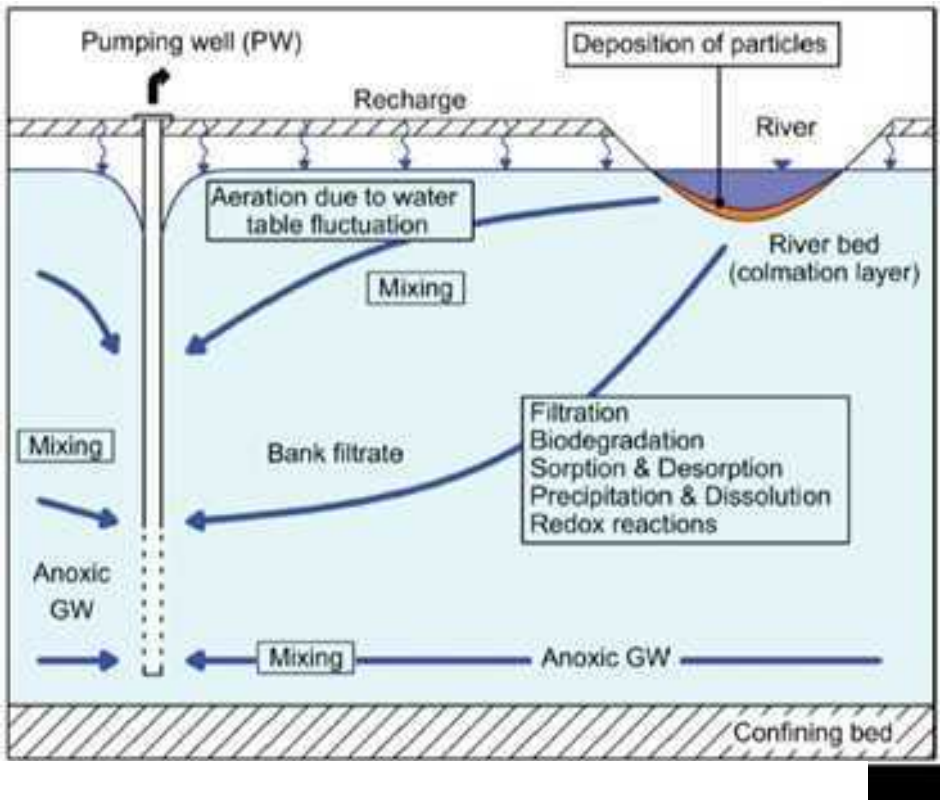
Figure 33 RBF Units

Note. The photos depict the preparation of RBF units before they are connected to filters, containers of filtration & storage tanks. Photos: UN-Habitat

Figure 34 Pumping Wells of RBF Units in Egypt

Note. (left) RBF unit connected to Connected to Iron & Manganese Removal tanks, water tank and filters, Qena, Egypt. (right) RBF unit, Luxor, Egypt. Photos: UN-Habitat

Figure 35 Processes of Riverbank Filtration



Note. Schematic diagram of processes affecting iron and manganese concentration during riverbank filtration. From Grischek, Thomas & Paufler, Sebastian. (2017). Prediction of Iron Release during Riverbank Filtration. Water. 9. 317. 10.3390/w9050317. https://www.researchgate.net/publication/316640779_Prediction_of_Iron_Release_during_Riverbank_Filtration

Sources

- UN-Habitat. (2020, August 12). UN-Habitat and partners bank on new technology for water provision to Egypt's vulnerable populations. https://unhabitat.org/news/07-jul-2020/un-habitat-and-partners-bank-on-new-technology-for-water-provision-to-egypts
- UN-Habitat. (2021). Riverbank Filtration Project for Clean Water Production in Minya, Egypt. https://unhabitat.org/riverbank-filtration-project-for-clean-water-production-in-minya-egypt
- UN-Habitat. (2021). Government of Egypt, UN-Habitat and partners celebrate riverbank filtration project in three Governorates. https://unhabitat.org/news/12-mar-2021/government-of-egypt-un-habitat-and-partners-celebrate-riverbank-filtration-project
- UN-Habitat. (2021). Guideline on Riverbank Filtration in Egypt. https://unhabitat.org/guideline-on-riverbank-filtration-in-egypt
- Ministry of International Cooperation, Egypt. (2022). Providing 240 Deprived Villages with Potable Water - Second Stage. https://moic.gov.eg/project/129

10. Sekem Constructed Wetland, Egypt

Location	El-Wahat El-Bahariya Oasis, Egypt
Existing Ecosystems	Dryland ecosystems
Climate Change Challenges	Severe aridity with extremely limited freshwater availability, as there are no productive aquifers and the nearest surface Nile water is approximately 450 km away. Local water resources are under high pressure from both irrigation and domestic use, while soil salinity and alkaline conditions further hinder agriculture and land reclamation efforts
NbS Approach	Nature-based Constructed Wetland Technology

Context and Applied NbS Method:

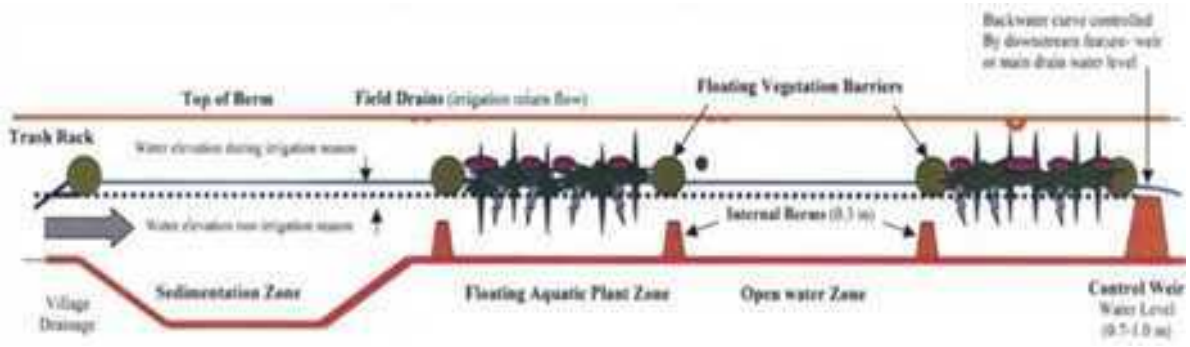
Sekem Farm is located in the El-Wahat El-Bahariya Oasis, about 450 kilometers southwest of Cairo in Egypt's Western Desert, an area with extreme water scarcity and soil degradation. The region relies on the Nubian Sandstone Aquifer, a non-renewable groundwater source, which has been declining due to over-extraction, while salinity and alkalinity increase, reducing agricultural productivity. These issues are compounded by severe aridity and rising temperatures, which intensify evaporation and water stress.

The REUSE project, developed under the MED-WET initiative and implemented by Heliopolis University for Sustainable Development, applies a nature-based constructed wetland system to treat wastewater from domestic and agricultural sources. The system mimics natural wetland processes using native plants, soil, microorganisms, and gravity-fed aeration, achieving over 90 percent removal of contaminants without energy-intensive infrastructure.

Treated water irrigates a green corridor approximately 12 kilometers long and 50 meters wide, planted with 70,000–80,000 drought- and salt-tolerant trees such as Acacia, Tamarisk, and Desert Willow, along with bamboo and cacti. This vegetation stabilizes soils, improves the microclimate, and supports carbon sequestration. Reuse is limited to non-edible plants, ensuring compliance with health and safety standards. The greenbelt also supports livelihoods through the use of bamboo for construction and other plants for composting, fodder, and agro-industrial purposes.

Economic analysis shows wastewater reuse to be significantly more efficient than groundwater extraction, with an 88 percent improvement in efficiency and substantial cost savings. The project has become a model for decentralized wastewater treatment in arid regions and is being replicated in other areas of the Western Desert. It demonstrates how NbS can improve water security, restore ecosystems, and create socio-economic benefits in water-stressed environments.

Figure 36 Profile view of an in-stream wetland treatment system.

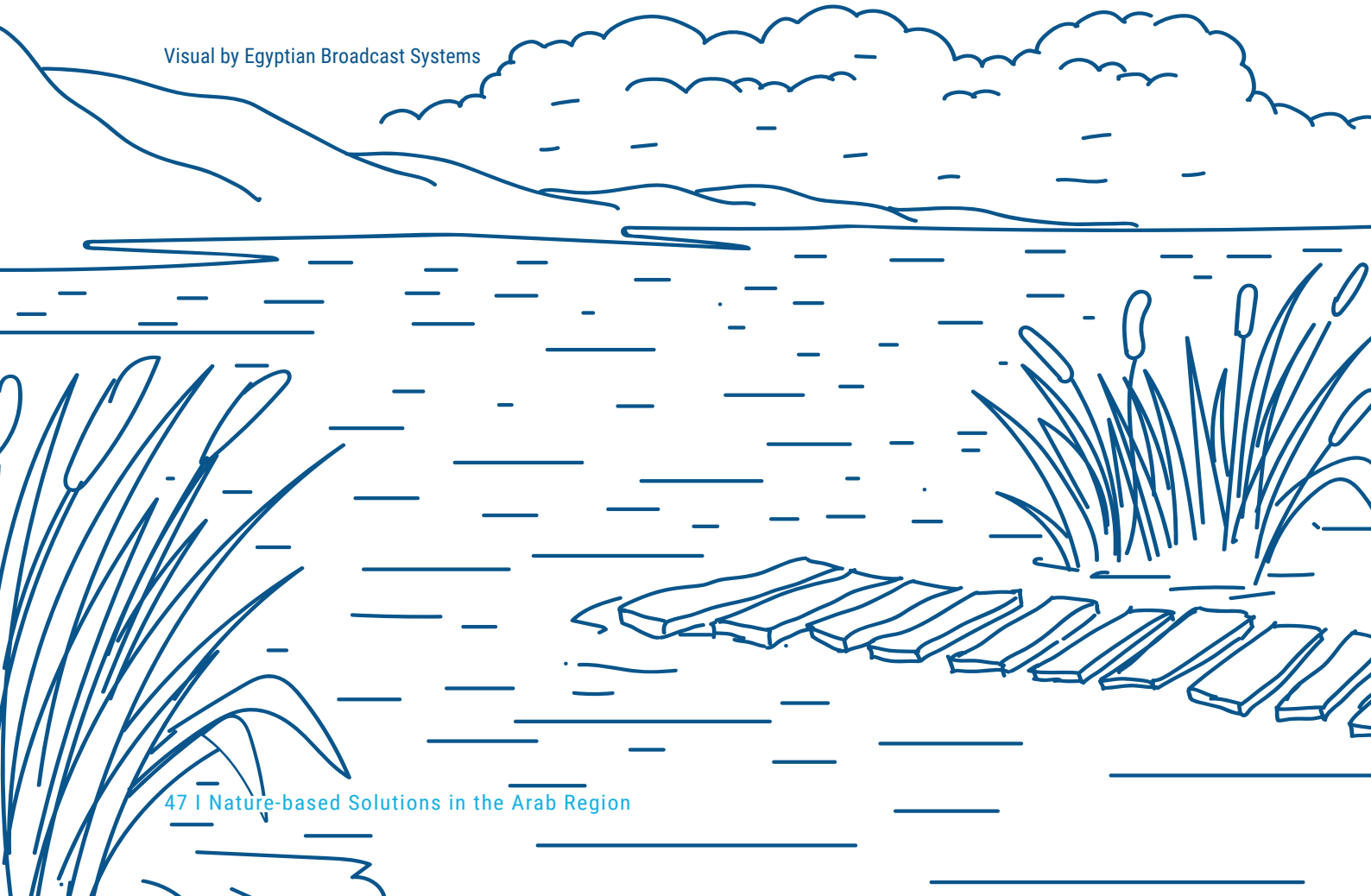


Note. Conceptual Design of an engineering constructed wetland treatment pilot. From Pereira, D., Leitao, J. C. C., Gaspar, P. D., Fael, C., Falorca, I., Khairy, W., Wahid, N., El Yousfi, H., Bouazzama, B., Siering, J., Hansmann, H., Zascerinska, J., Camilleri, S., Busuttil, F., Borg, M., Mizzi, J., Micallef, R., & Cutajar, J. (2023). Exploring Irrigation and Water Supply Technologies for Smallholder Farmers in the Mediterranean Region. Sustainability, 15(8), 6875. https://doi.org/10.3390/su15086875

Sources

- MED-WET Project. (2024). A success story: Wastewater reuse for desert reclamation in Egypt. https://www.medwet-eu.com/ar/post/a-success-story
- Sekem Initiative. (2025). Water reuse and desert regeneration projects. https://sekem.com/en/ecology/air-water/
- Wahid, N., Khairy, W., & Krause, R. (2024). Cost–benefit analysis on the implementation of nature-based treated wastewater reuse: Case of Sekem Farm El-Wahat, Egypt. Discover Water, 4, 63. https://doi.org/10.1007/s43832-024-00121-w

Visual by Egyptian Broadcast Systems



11. Wadi El Ku Catchment Management Project, Sudan

Location	North Darfur, Sudan
Existing Ecosystems	Wadi (River valley or dry riverbed that is filled with water only during episodes of heavy rain)
Climate Change Challenges	unreliable rainfall in terms of seasonality, intensity and overall levels and frequent droughts
NbS Approach	Integrated management of water resources (IWRM) and water harvesting infrastructure; agroforestry

Context and Applied NbS Method:

In Darfur's arid climate, Wadi El Ku (WEK) is a crucial water source for the region's growing population. Originating in the Jebel Mara highlands, the wadi flows southeast through North and East Darfur before reaching its delta. Rapid population growth and ongoing conflict have led to severe environmental degradation, causing many to migrate to urban centers and displacement camps. This shift has intensified deforestation, groundwater depletion, excessive land cultivation, and overgrazing, particularly around Wadi El Ku and El Fasher. Approximately 87,000 farmers and agro-pastoralists, along with 440,000 residents of El Fasher and 220,000 internally displaced persons (IDPs), rely on effective natural resource management within a 50-kilometer radius of the wadi.

The initiative focuses on IWRM, incorporating water-harvesting infrastructure to enhance water availability. Key interventions include constructing weirs, haffirs (circular earthen water basins), diversion channels, and water yards to harvest water-harvesting structures, while the second phase (WEK 2) expanded efforts by rehabilitating a dam and building two additional weirs in Wada'a, Eid Al Beida, Kosa, and Sarafaya.

The project integrates NbS with conventional infrastructure to restore degraded land within and beyond the fertile low-lying wadi areas. Earth dams and crescent-shaped terraces have been constructed to manage surface runoff, enhance water infiltration, and curb gully erosion. Rangeland rehabilitation involved planting high-quality native grass seeds and promoting afforestation to restore communal forests and support sustainable land use. Communities were encouraged to integrate trees into farming and grazing systems, such as cultivating gum arabic trees (Acacia senegal) to generate income while improving land management practices.

A community-led governance model was adopted to ensure inclusive natural resource management. Natural resource management

women—were formed to plan, manage, and oversee rangeland, farmland, and water resources. This participatory framework fosters equitable access to resources and mitigates conflicts arising from competing land and water needs.

The interventions in Wadi El Ku, such as earth dams and crescent terraces, have had substantial environmental benefits, including improved groundwater recharge, reduced land degradation, and enhanced stabilization of wadi banks. A positive feedback loop was created due to these measures, where recharged groundwater sustains plant growth, which in turn strengthens soil retention and reduces erosion. The United Nations Environment Programme (UNEP) and the North Darfur state government are now advancing the second phase of the Wadi El Ku Catchment Management Project, building upon these successes.

Beyond Wadi El Ku, similar efforts in Kabkabiya have significantly improved water access. Practical Action facilitated the rehabilitation of 29 hand pumps, enhancement of 12 wells, and the construction or upgrading of 17 boreholes, seven of which are powered by solar pumping systems. Farmers were trained in the operation and maintenance of these systems as well as the sustainable management of water resources for climate change adaptation. These interventions have boosted groundwater recharge, securing water for irrigation and livestock needs.

This integrated approach to water resource management coupled with specific infrastructure interventions has been instrumental in improving livelihoods and reducing conflicts. Given the region's arid conditions and dependence on rain-fed agriculture, the introduction of water-spreading weirs has significantly expanded cultivated land, boosting agricultural productivity. Beyond enhancing food security, these infrastructure projects have created employment opportunities for IDPs and local communities, fostering economic stability. By improving water efficiency and agricultural resilience, the project has addressed key challenges posed by climate change, contributing to sustainable development in North Darfur.

Sources

- United Nations Environment Programme. (2024, December 9). Lessons learned from the Implementation of the Wadi El Ku Catchment Management Project (Phase 2). https://www.unep.org/resources/report/lessons-learned-implementation-wadi-el-ku-catchment-management-project-phase-2
- United Nations Environment Programme. (2024, February). Wadi El Ku Catchment Management Project. https://wedocs.unep.org/handle/20.500.11822/44886
- Hou-Jones, X, Roe, D and Holland, E. (2021, July). Nature-based Solutions in Action: Lessons from the Frontline. London. Bond. https://www.bond.org.uk/wp-content/uploads/2022/03/bond_-_nbs_case_studies_-_v4.pdf

12. Decentralized Wastewater Treatment Systems (DEWATS), Lebanon

Location	Lebanon
Existing Ecosystems	Freshwater rivers and wetlands (e.g., Litani River, Aammiq Wetland), Coastal and marine ecosystems (e.g., Mediterranean coastline, estuaries, coastal wetlands). Mountain and forest ecosystems (e.g., Cedars of Lebanon, Mount Lebanon range), Karst aquifers and springs. Mediterranean shrublands and agricultural terraces
Climate Change Challenges	Chronic water scarcity
NbS Approach	Decentralized Wastewater Treatment System (DEWATS) which includes NbS interventions including constructed wetlands, reed-bed filters, and other low-energy, modular systems, and wastewater reuse

Context and Applied NbS Method:

Lebanon faces a critical wastewater management crisis that threatens both public health and the environment. The country generates over 300 million cubic meters of wastewater annually, much of which is either untreated or inadequately treated before being discharged into rivers, agricultural land, and the sea. Despite the existence of 96 wastewater treatment plants (WWTPs), only a fraction are fully operational—9 large-scale and 34 small-scale. Many facilities never reach functionality due to fragmented responsibilities between donors, municipalities, and households, alongside Lebanon's prolonged energy crisis, which makes operation costly and unreliable. Diesel dependence in particular undermines the viability of large-scale systems. The situation is further compounded by Lebanon's role as host to about 1.5 million refugees in addition to its resident population of 5.2 million. In the 3,562 informal tented settlements where many refugees live, permanent wastewater infrastructure is not permitted. Instead, UN agencies and NGOs provide water trucking and desludging services at an annual cost of around 35 million USD. In 2023, 400,000 m^3 of wastewater was safely removed from these sites. However, declining funding threatens the continuation of such services; only 4 million USD is currently available, raising the risk of unmanaged wastewater in highly vulnerable communities.

In this context, decentralized wastewater treatment systems (DEWATS), including nature-based solutions (NbS), provide a practical and sustainable alternative. Technologies such as constructed wetlands,

reed-bed systems, and soil-based treatment mimic natural processes to remove pathogens and nutrients. They require little energy, can operate off-grid, and offer co-benefits such as water reuse for agriculture, biodiversity enhancement, and groundwater recharge. Pilot projects in Lebanon, including the Bcharre reed-bed system and Mrüna's BiomWeb in Miziara, demonstrate the feasibility of NbS at both household and community levels.

Scaling such solutions requires regulatory adaptation, financing mechanisms, and greater coordination among stakeholders. Lebanon's experience shows that in fragmented and energy-scarce contexts, decentralized and nature-based systems can turn wastewater from an environmental hazard into a resource that contributes to resilience and sustainability.

This case study is extracted from the policy paper "Sustainable Wastewater Management in Lebanon: Decentralization is Key." This policy paper was developed under the program titled "From Innovation to Creation", which strengthens innovation through supporting cluster cooperation and start-up ecosystems in the South Neighborhood countries. Through a 4-year program financed by the European Commission, SPARK is strengthening innovation and startup ecosystems, together with implementing partners, in Palestine, Jordan, Lebanon and Tunisia.

Figure 37 Decentralized Wastewater Treatment Systems (DEWATS) in Lebanon

Note. (Left) Cewas. Reed-bed Filter in Harim, Bcharre, 2024 (Right) Mrüna, Biomweb system. Photos: IsDB

Sources

- CEWAS (n.d). Sustainable Wastewater Management in Lebanon: Decentralization is Key. https://www.cewas.org/articles/sustainable-wastewater-management-in-lebanon-decentralization-is-key
- UNHCR. (2024, April). Wash Sector Alert. Operational Data Portal. https://data.unhcr.org/en/documents/details/108581

13. NAWAMED Constructed Wetlands, Lebanon

Location	Bekaa Lebanon
Existing Ecosystems	Dryland, urban and inland water ecosystems
Climate Change Challenges	Water scarcity
NbS Approach	Constructed Wetlands

Context

In the heart of Bekaa Lebanon, an environmental project known as the NAWAMED - Constructed Wetlands has taken root. Developed in collaboration with the American University of Beirut, this project shows the innovative approach of using constructed wetlands for greywater treatment. With the installation complete, the Constructed Wetlands are now fully operational, efficiently treating greywater and demonstrating their capacity to provide a sustainable and eco-friendly solution for greywater treatment.

Applied NbS Methods

Constructed Wetlands are nature-inspired greywater treatment systems that mimic the processes of natural wetlands. By harnessing the power of wetland vegetation and microorganisms, these systems effectively purify greywater while minimizing negative environmental impacts. The two Constructed Wetlands serve as exemplary models for this approach, presenting an eco-friendly alternative to conventional treatment methods.

The primary objective of the Constructed Wetlands is to provide a cost-effective and sustainable solution for greywater treatment in Advancing Research Enabling Communities Center (AREC), addressing the pressing issue of water scarcity. The design and implementation process involved careful planning and expertise. The project includes two constructed wetlands for the treatment and reuse of greywater produced by three buildings at the AREC Campus in the Bekaa Valley. The first constructed wetland treats greywater collected from the women's dormitory and administration building, while the second constructed wetland treats greywater collected from the boys' dormitory. The 1st step of the construction process was the separation of the greywater from the blackwater in each of the three buildings. The greywater is primarily collected and treated in a degreaser, then circulated in a horizontal subsurface-flow constructed wetland (HFCW) as the secondary treatment. The HFCW is fed by a small submerged pumping station, and the treated greywater is collected in a tank to be reused for irrigation of the nearby planted area.

Looking ahead, the project envisions both expansion and long-term monitoring of the wetland system's performance. The data collected will support ongoing research in sustainable water management. Additionally, the team is exploring collaborations with organizations and communities to replicate and scale up similar wetland projects across other regions of Lebanon.

Figure 38 Constructed Wetland, Bekaa, Lebanon

Note. From ENI CBC Med. (2023, October 20). NAWAMED implements two constructed wetlands in Bekaa, Lebanon for sustainable treatment of greywater. ENI CBC Med. **https://enicbcmed.eu/nawamed-implements-two-constructed-wetlands-bekaa-lebanon-sustainable-treatment-greywater**

Figure 39 Water before and after treatment

Note. From ENI CBC Med. (2023, October 20). NAWAMED implements two constructed wetlands in Bekaa, Lebanon for sustainable treatment of greywater. ENI CBC Med. **https://enicbcmed.eu/nawamed-implements-two-constructed-wetlands-bekaa-lebanon-sustainable-treatment-greywater**

Sources

- ENI CBC Med. (2023, October 20). NAWAMED implements two constructed wetlands in Bekaa, Lebanon for sustainable treatment of greywater. ENI CBC Med. **https://enicbcmed.eu/nawamed-implements-two-constructed-wetlands-bekaa-lebanon-sustainable-treatment-greywater**

14. Olive Trees Cultivation in Arid Areas, Syria

Location	Aleppo, Syria
Existing Ecosystems	Rainfed agricultural land
Climate Change Challenges	Low and erratic rainfall, drought, land degradation
NbS Approach	Runoff water harvesting through traditional furrow-enhanced

Context and Applied NbS Method:

In arid climates where rainfall has become more unpredictable, efficient rainwater harvesting and runoff water collection are essential. In north-west Syria, where the climate is considered too dry to plant olive trees, traditional runoff collection has proven successful in overcoming this challenge. For example, in the Khanasser Valley, a marginal agricultural area where annual rainfall is around 220 mm/year and soil is shallow and poor in productivity, the degraded hills are typically used for grazing or barley cultivation. To reach self-sufficiency, the farmers started cultivating olive trees. To avoid weed growth, farmers till the land, which leads to runoff and soil erosion. To harvest the runoff and increase productivity, the farmers are using a traditional furrow-enhanced runoff harvesting technique.

The furrow-enhanced runoff harvesting method involves the manual construction of V-shaped micro-catchments around individual trees, which help capture runoff water. The catchment area around each tree is about 60 m², where the spacing between each tree is 8m. Consequently, the catchment-to-cultivated area ration is approximately 60:1. This system effectively harvests runoff water, enhancing soil moisture storage, conserving irrigation water during the dry season, and stimulating olive tree growth. This method also captures nutrient-rich fine particles of eroded soil, increasing the soil richness. However, these particles have the potential to clog the surface over time, thus the V-shaped earthen bunds must be rebuilt annually and maintained following heavy storms. Despite the required periodic maintenance, the technology is considered low-cost, easily maintained and minimal labour input is required. Moreover, local farmers are already skilled in operating, maintaining and expanding this system.

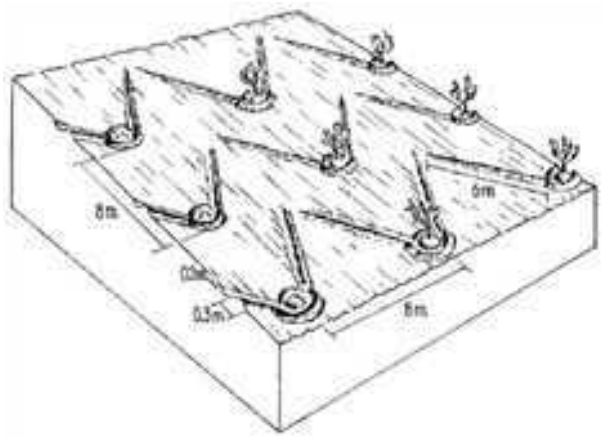
To further enhance the furrow enhanced runoff harvesting technique, mulching the area around each tree is employed using local stones, such as basalt and limestone. This helps lower soil temperature, enhance water infiltration and decrease surface evapouration. Moreover, annual winter crops that have a low water demand, such as barley, vetch and lentils, are sometimes planted in between the olive trees. This helps reduce surface erosion when the trees are young.

The furrow-enhance runoff water harvesting technique was adopted in 2002 and it has been gradually increasing ever since due to its benefits to the soil quality and crop production.

Figure 40 Water Harvesting through V-shaped micro-catchments, Aleppo, Syria

Note. (left) Runoff harvesting for olive trees by up-and-down tillage (by tractor) and V-shaped micro-catchments in a semi-arid area, Khanasser Valley, Aleppo, Syria. (right) Runoff is collected in micro-basins around each tree. The V-shaped bunds extend to the left. Stone mulching - as a supportive measure - further enhances moisture conservation by reducing evaporation. From WOCAT. (2019, August 14). Furrow-enhanced runoff harvesting for olives [Syrian Arab Republic]. WOCAT SLM Database. https://qcat.wocat.net/en/wocat/technologies/view/technologies_1005/

Figure 41 Technical Drawing of the Technology



Note. V-shaped micro-catchments harvest water for the olive trees; the furrows up-and-down slope help channel the runoff to the olives. The technology requires low technical knowledge required for field staff, advisors, and land users. The main technical functions of this technology is the control of dispersed runoff through retaining or trapping, increasing and maintaining water stored in soil, and harvesting water and increasing water supply. Secondary technical function include: reduction of slope length, sediment retention or trapping, sediment harvesting, reduction in wind speed.

Structural measure: V-shaped bunds and mulching with stones.
Construction material (stone): limestone, basalt (locally available)

By: Mats Gurtner. From WOCAT. (2019, August 14). Furrow-enhanced runoff harvesting for olives [Syrian Arab Republic]. WOCAT SLM Database. https://qcat.wocat.net/en/wocat/technologies/view/technologies_1005/

Sources

- WOCAT. (2019, August 14). Furrow-enhanced runoff harvesting for olives [Syrian Arab Republic]. WOCAT SLM Database. https://qcat.wocat.net/en/wocat/technologies/view/technologies_1005/

15. The Restoration of the Once Drained Marshlands of Southern Iraq

Location	Between the cities of Nasiriyah and Basrah, Southern Iraq
Existing Ecosystems	Wetlands
Climate Change Challenges	fluctuating precipitation and increasing water scarcity, temperature extremes
NbS Approach	Engineered reflooding and monitoring, Hydrology management/restoration

Context and Applied NbS Method:

The southern Iraq marshlands, often referred to as the Mesopotamian Marshes, are located at the convergence of the Tigris and Euphrates rivers. These wetlands, once covering an estimated area of 15,000 to 20,000 Km^2, are renowned for their rich biodiversity and cultural heritage. The Marsh Arabs, or Ma dān, have inhabited these marshes for millennia, developing a unique lifestyle strongly connected to the wetlands. They engaged in traditional agriculture, fishing, and raising water buffalos, and constructing communal buildings of woven reeds called mudhif. The marshlands served as a critical habitat for migratory birds and numerous fish species, contributing to the socio-economic and heritage value of the region. Moreover, the marshlands provide regionally important regulating services such as flood control, water storage and purification, and climate regulation.

In the mid-20th century, efforts to drain the marshlands began, initially aimed at making the land suitable for agriculture. However, under the Ba'athist regime, the drainage accelerated, diverting water from the Tigris and Euphrates for irrigation and oil exploration. By the 1990s, extensive drainage projects resulted in the near complete dryness of the marshlands, drastically reducing their area to less than 10% of their original size, causing a significant loss of biodiversity. The Marsh Arabs were forced to flee their homes, disrupting their cultural practices and livelihoods. The drainage not only destroyed the natural landscape but also harshly affected the socio-economic fabric of the region.

In 2003, efforts to restore the marshlands led by the Iraqi government with support from international organizations. Reflooding projects were initiated to revive the wetlands and their biodiversity, as well as bring back the Marsh Arabs' socio-economic and cultural practices. By 2014, around 40-60% of the marshlands were reflooded, bringing back water and some of the native species. Restoration projects included the construction of dams, levees, and pumping stations to manage water flow and maintain the marshlands. These efforts led to the return of around 300,000 Marsh Arabs to their ancestral lands, allowing them to resume traditional practices. The reflooded marshlands also saw a resurgence in biodiversity, with the reappearance of various bird and fish species. Despite ongoing

challenges such as water scarcity and pollution, the restoration of the southern Iraq marshlands represents a significant step towards preserving this unique ecosystem and its cultural heritage.

Sources

- Ramsar Sites Information Service. (2015, September 24). Hammar Marsh. Retrieved April 16, 2025 https://rsis.ramsar.org/ris/2242?language=en
- Ramsar Sites Information Service. (2015). Ramsar Information Sheet: Hammar Marsh. Retrieved April 16, 2025. https://rsis.ramsar.org/RISapp/files/RISrep/IQ2242RIS_1509_en.pdf?language=en
- United Nations Environment Programme. (2004, July 23). Restoring Iraqi Marshlands Project Launched by UN Environment Programme. Retrieved April 16, 2025. https://press.un.org/en/2004/ik449.doc.htm
- Powers, K. (2004, June 15). The Iraq Marshes: Restoration Activities. Congressional Research Service. Retrieved April 16, 2025. https://www.everycrsreport.com/files/20040615_RL32433_7e4f6dd2e80375e06cddbcdfab1dae4d8acc853f.pdf
- ReliefWeb. (2004, April 27). Iraq: Special Efforts to Restore Marshlands. Retrieved April 16, 2025. https://reliefweb.int/report/iraq/iraq-special-efforts-restore-marshlands
- Human Rights Watch. (2003, January). The Iraqi Government Assault on the Marsh Arabs: A Human Rights Watch Breifing Paper. Retrieved April 16, 2025. https://www.hrw.org/legacy/backgrounder/mena/marsharabs1.htm

Marshlands, Southern Iraq. Source photograph by Hasan Majed. Visual by Omnia Moussa

16. The Eden in Iraq Water Remediation Project, Iraq

Location	El-Chibaish, Southern Iraq
Existing Ecosystems	Wetlands
Climate Change Challenges	Droughts, fluctuating precipitation and increasing water scarcity, temperature extremes
NbS Approach	Wastewater gardens for water remediation and reuse

Context and Applied NbS Method:

The Eden in Iraq Wastewater Garden Project is a humanitarian initiative aimed at providing effective sewage treatment and fostering environmental and cultural regeneration in southern Iraq through water remediation. It addresses the needs of the Marsh Arab community, a group deeply connected to the Mesopotamian marshes, one of the world's oldest cultural regions. These wetlands, once the third largest globally, were partially drained in the 1990s, displacing thousands of Marsh Arabs. Since 2003, approximately 300,000 displaced Marsh Arabs have returned, working to restore their marshes with support from Nature Iraq – a local Non-Governmental Organisation (NGO). However, this rapid return has led to severe sewage and health issues.

The Eden in Iraq project employs sustainable wastewater recycling technology to transform sewage into clean water and nutrients for plants, using a subsurface flow wetland system. This process not only improves health outcomes but also celebrates the Marsh Arabs' rich cultural heritage. The wastewater garden incorporates locally significant design elements, such as reed structures, earthen bricks, and Mesopotamian-inspired patterns for ceramic tiles, creating a space that is both functional and culturally symbolic. The garden's floral layout draws inspiration from traditional embroidered wedding blankets, reflecting the region's artistic traditions.

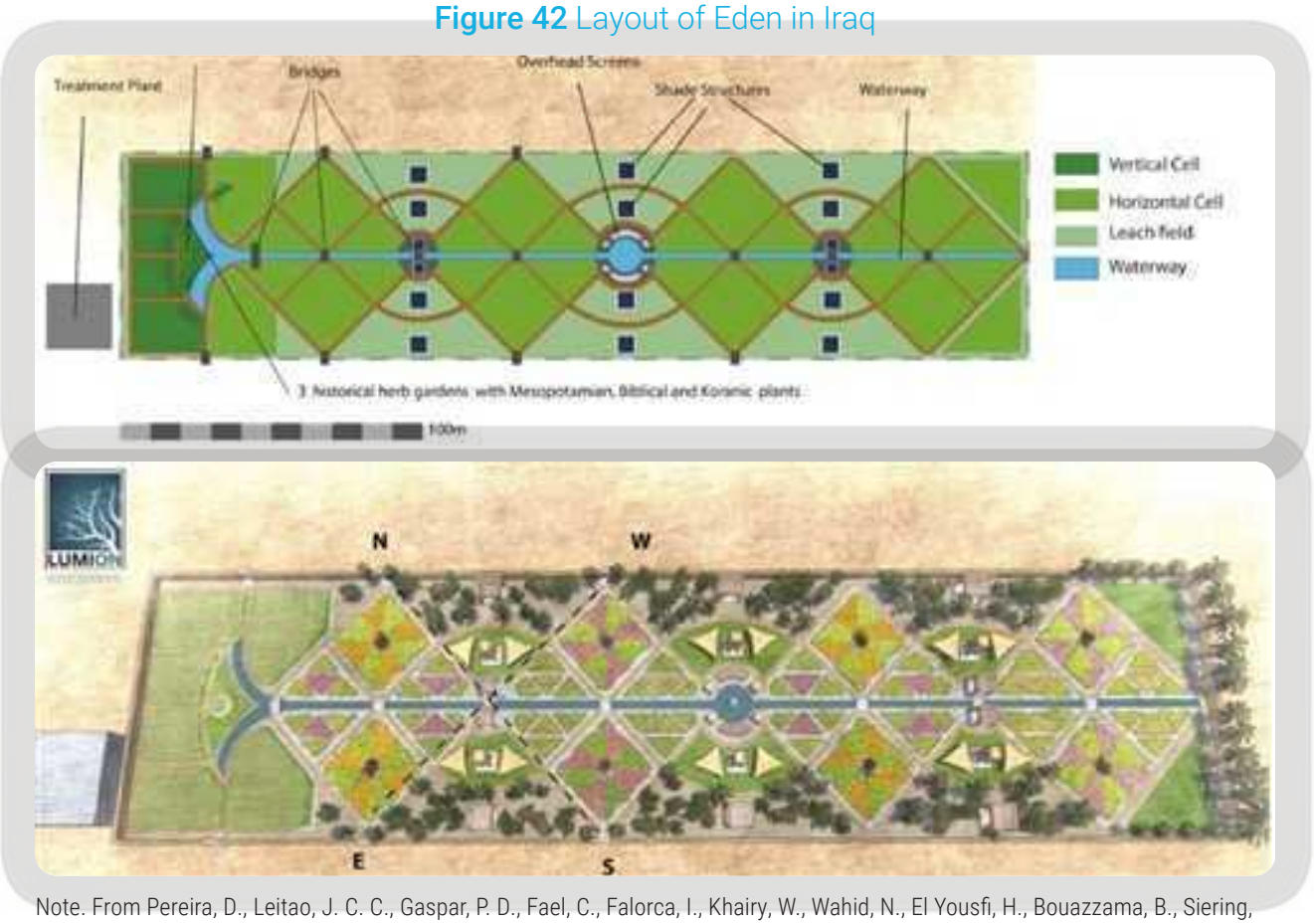
Since its inception in 2011, the project has received support from Iraqi municipalities, regional and state authorities, and international organizations. In 2021, it was recognized as one of UNESCO's 100 grassroots projects under the Green Citizens Initiative. The first phase of the garden, spanning 2.8 acres of a 10-acre site in El Chibaish, was completed in May 2023 with the support of the Iraq Ministry of Water Resources. This phase involved constructing a perimeter wall, installing pipe connections, and planting reeds and other native marsh plants to start the sewage treatment. These efforts have already reduced water contamination by 50%, with marsh vegetation flourishing and utilizing organic compounds that would otherwise pose health and environmental risks.

The second phase, expected to take 3–6 months, will include installing an underground pipe system, planting nursery-grown vegetation, and constructing cultural and shade structures. Local craftspeople will play a key role in the design and construction, ensuring the garden remains a vibrant cultural heritage site and ecological learning center. Treated water from the garden will be used to irrigate shrubs and fruit trees, transforming the site into a lush public park.

The Wastewater Garden is designed to be scalable, offering a model for sustainable sewage treatment across Iraq and the broader region. It also contributes to climate change mitigation by creating green spaces for carbon sequestration, providing shade, and protecting natural wetlands, which are among the most effective carbon-storing ecosystems. Unlike conventional sewage treatment plants, which consume large amounts of energy, this nature-based solution operates sustainably and promotes environmental stewardship.

The project also holds significant social and economic potential. By creating a community-centric hub, it supports local trade and cottage industries, bolstering the regional economy. The Eden in Iraq Wastewater Garden Project demonstrates the power of integrating sustainable technology, cultural heritage, and community engagement to address pressing environmental and social challenges.

Figure 42 Layout of Eden in Iraq



Note. From Pereira, D., Leitao, J. C. C., Gaspar, P. D., Fael, C., Falorca, I., Khairy, W., Wahid, N., El Yousfi, H., Bouazzama, B., Siering, J., Hansmann, H., Zascerinska, J., Camilleri, S., Busuttil, F., Borg, M., Mizzi, J., Micallef, R., & Cutajar, J. (2023). Exploring Irrigation and Water Supply Technologies for Smallholder Farmers in the Mediterranean Region. Sustainability, 15(8), 6875. https://-doi.org/10.3390/su15086875

Sources

- Eden in Iraq Project Team. (n.d.). Eden in Iraq. Retrieved May 11, 2025. https://edeniniraq.com/
- Eden in Iraq Project Team. (2023, August 17). Eden in Iraq: The Wastewater Garden Project [PDF]. Retrieved May 11, 2025. https://edeniniraq.com/wp-content/uploads/2023/08/Eden-in-Iraq-FINAL-8-17-2023-WEB.pdf
- Rubenstein, M., & Sathikh, P. (2021). Eden in Iraq: A wastewater design project as bio-art—a confluence of nature and culture, design and ecology, in Southern Iraq marshes. AI & Society, 36(4), 1377–1388. https://doi.org/10.1007/s00146-020-00967-3

17. Nature-based and Engineered Solutions at Sanur Meadow, Palestine

Location	Jenin, West Bank, Palestine
Existing Ecosystems	Mountainous agro-ecosystem; Meadow
Climate Change Challenges	Flooding, water scarcity and drought
NbS Approach	Traditional stone terraces; artificial groundwater recharge wells

Context and Applied NbS Method:

Located in the northern part of the West Bank in Palestine, the Sanur Meadow is a closed basin with no natural drainage system, where thick, muddy soil that has low permeability covers the meadow's grounds. Spanning approximately 59 km², the meadow's watershed receives rain from October to May, where annual precipitation averages 634 mm, ranging from 400 to 1200 mm.

Sanur Meadow is confronted with the dual challenge of flooding and water scarcity. In winter, rainwater flows down mountain slopes into the meadow, creating a natural reservoir. This happens when the rainwater quantity surpasses the land's storage capacity or the rates of evaporation, transpiration, and/or soil infiltration. This usually results in flooding that negatively impacts agricultural activities through spreading soil diseases that wipe out many common crops, damaging or completely destroys unharvested crops, and delaying summer planting when water does not dry up fast enough. Flooding also disrupts mobility through blocking the two roads leading to Sanur village, isolating its residents. These impacts reduce crop yields, cause significant economic losses for farmers, and increase fuel consumption as diesel pumps are used to remove floodwater.

On the other hand, water scarcity stems from prolonged droughts in the region coupled with increased groundwater extraction, primarily for agriculture. Between 1969 and 2013, groundwater levels dropped by approximately 70 meters. This decline in water levels has reduced the pumping capacity of wells that are drilled into the shallow aquifer. Moreover, unmanaged surface activities deteriorated the water quality. These conditions negatively affect agriculture and harm the ecosystem by destroying plants and animals, disrupting habitats, food chains, and biodiversity. The resulting loss of biodiversity destabilized ecosystem services, while invasive plant species have further degraded the area.

To enhance the Sanur Meadow ecosystem, reduce flooding vulnerability, and address water scarcity, both nature-based and engineered solutions have been implemented. One key approach is the use of retaining stone terraces to minimize soil erosion caused by heavy rainfall. These terraces are a

prominent agricultural feature in less arid regions of Palestine and Yemen and are commonly used for cultivating fruit trees, especially olive trees. Unlike modern mechanical terraces, which require leveling or slope cutting with heavy machinery, traditional terraces preserve the natural terrain as they are an ecosystem-based solution. These terraces are usually employed to boost agricultural productivity and in turn increase the farmers' income. Traditional terraces have multiple benefits including mitigating runoff, soil erosion, floods, droughts and landslides. Moreover, through safeguarding biodiversity, the mountainous agro-ecosystem resilience is enhanced, and climate change and natural hazard adaptability is increased.

Additionally, two artificial recharge wells have been constructed in Sanur Meadow to address the sharp decline in groundwater levels and reduce the extent of agricultural land affected by flooding. agricultural land affected by flooding. These wells are strategically located to avoid runoff water that contains high levels of suspended material. Groundwater recharge wells are considered an effective engineered solution to combat groundwater depletion in Sanur Meadow due to the availability of annual floodwater and the storage potential of the shallow aquifers in the meadow.

Sources

- UNESCO. (2021). Atlas on natural hazards in the Arab Region: a tool for socio-ecological systems resilience and adaptation. https://unesdoc.unesco.org/ark:/48223/pf0000378046.locale=en

18. Ramallah Wastewater Reuse to Combat Water Scarcity, Palestine

Location	Ramallah, Palestine
Existing Ecosystems	Urban ecosystem
Climate Change Challenges	Droughts and water scarcity
NbS Approach	Wastewater reuse

Context and Applied NbS Method:

Ramallah, located in Palestine's West Bank, faces significant water scarcity due to rapid urbanization and limited water resources. The city, with an official population of 39,000 that is likely three times higher, experiences frequent water cuts lasting three to four days weekly during the summer months. Freshwater is prioritized for human consumption, leaving minimal supply for irrigation, construction, or firefighting. Compounding the issue, untreated wastewater often flows into valleys, wasting valuable resources and contributing to environmental degradation.

To address these challenges, Anera - a nonprofit organization - worked on an innovative wastewater reuse project aimed at sustainable water management. A reservoir near Ramallah collects high-quality reclaimed water from the Tireh treatment plant. Positioned at an elevated location, the reservoir uses gravity-fed distribution to eliminate the need for energy-intensive transportation. This reclaimed water is utilized for non-potable purposes such as irrigating public parks, gardens, and olive groves, as well as for construction and firefighting. Additionally, ten demonstration gardens have been established to showcase the potential of reclaimed water for private irrigation, encouraging the adoption of sustainable practices. The project also captures water lost from valley streams and redirects it to the reservoir for reuse, maximizing resource efficiency.

The impact of the project has been transformative. It conserves water by providing 1,000m3 of reclaimed water daily, preserving potable water for essential needs. By reusing wastewater, the initiative reduces waste, mitigates desertification, and supports the expansion of green spaces, enhancing environmental sustainability. Gravity-fed distribution improves operational efficiency by cutting transportation costs and increasing access to reclaimed water. Furthermore, the demonstration gardens and public engagement efforts have fostered a culture of sustainable water use, raising community awareness about the importance of resource conservation.

Sources

- Anera. (2019, March). Construction is underway on the Ramallah wastewater reuse project. Anera. https://www.anera.org/stories/construction-ramallah-wastewater-reuse-palestine/

19. Green Infrastructure Pilot Projects in Amman, Jordan

Location	Amman, Jordan
Existing Ecosystems	Urban ecosystem
Climate Change Challenges	Flash Floods
NbS Approach	Stormwater Bioretention and bioswales and Stormwater Detention

Context

The Green Infrastructure Pilot Projects aim to strengthen the social stability and resilience of vulnerable Jordanian communities and Syrian refugees in Amman against the growing risk of flash floods. These risks have intensified due to rapid urbanization, insufficient drainage capacity, and climate change. Flash floods in Amman have caused significant damage, paralyzing the city, disrupting essential services, and disproportionately impacting vulnerable populations. In response, UN-Habitat Jordan, in collaboration with the Greater Amman Municipality (GAM), implemented this project from April 2020 to November 2022, funded by the Japan Supplementary Budget FY2019.

The project aimed to enhance resilience through integrated flood management solutions, including community consultations, capacity building, and infrastructure improvements. Its outcomes included:
The project aimed to enhance resilience through integrated flood management solutions, including community consultations, capacity building, and infrastructure improvements. **Its outcomes included:**

- Improved flood protection and resilience in targeted locations.
- Reduced vulnerabilities of local communities and refugees to flash floods.
- Strengthened government and community capacities for flood management in urban areas.

The project developed participatory pilot initiatives through two methods:

Water Harvesting Systems Installation and Green Pockets Initiative:
Developed through CityRAP (City Resilience Action Planning tool) consultation and prioritization sessions, water harvesting systems were installed at four sites: the University of Jordan, GAM's Basman building, and the Heart of Amman building in Ras El Ain. These systems collect rainwater through gutters and store it in tanks for future use, mitigating flood risks while raising awareness about water harvesting.
At Ras El Ain, a rain garden was also introduced. Designed with plants, mulch, and bioretention soil, it filters rainwater into underground storage while reducing stormwater runoff.

Figure 43 Rendered Images of Al Zohour Green Triangle Design

Note. From UN-Habitat. (2023, May). Al Zohour Green Triangle. UN-Habitat. https://unhabitat.org/sites/default/files/2023/05/230319_al_zohour_brochure_a5.pdf

Al-Zohour Green Triangle Pilot Project:
Aligned with the Flood Risk Assessment and Flood Hazard Mapping Study for Downtown Amman, this initiative focused on strategic green infrastructure interventions to reduce flood risks in one of the city's most vulnerable areas.

Applied NbS Methods

As part of a comprehensive flood risk mitigation initiative, UN-Habitat conducted a "Flood Risk Assessment and Flood Hazard Mapping" study for Downtown Amman. The study identified flood hotspots and proposed solutions, including green stormwater infrastructure to manage flood risks. The Al Zohour Green Triangle, located at the intersection of Al Quds Street and Bab Al Khalil Street in the Al Zohour District, was selected as a pilot project to demonstrate innovative stormwater retention and detention systems. This site was chosen due to its suitability in terms of runoff volume, ownership by the GAM, and minimal impact on neighboring land use.

The Al Zohour Green Triangle spans an area of 2,300 m² and incorporates two primary green stormwater management concepts:

- Stormwater Bioretention: Using bioretention and bioswale areas to allow water infiltration into the ground and absorption by vegetation. The bioretention and bioswale areas have a capacity of 750 m³, encouraging water infiltration and vegetation absorption.
- Stormwater Detention: Employing an underground concrete tank to temporarily detain floodwater for controlled release. The underground concrete tank holds up to 2,100 m³ of water, detaining it temporarily before controlled release.

Equipped with a pump, the detention tank facilitates water reuse for agricultural irrigation or external use via tankers, especially during the summer. Excess water is managed through drainage systems in the bioretention areas and overflow outlets from the detention tank, ensuring readiness for subsequent storms.

The project includes two water inlets: A 150 mm pipe connected to Bab Al Khalil Street for the bioretention system; and a 250 mm pipe connected to Al Quds Street for the underground detention tank.

The project's landscape design integrates all components into a visually appealing green

infrastructure. It enhances water absorption while creating an aesthetically pleasing "green window" in Amman, addressing the arid nature of the surrounding environment.

The Al Zohour Green Triangle serves as a model for sustainable urban flood management, showcasing practical and scalable solutions for green stormwater infrastructure in the region.

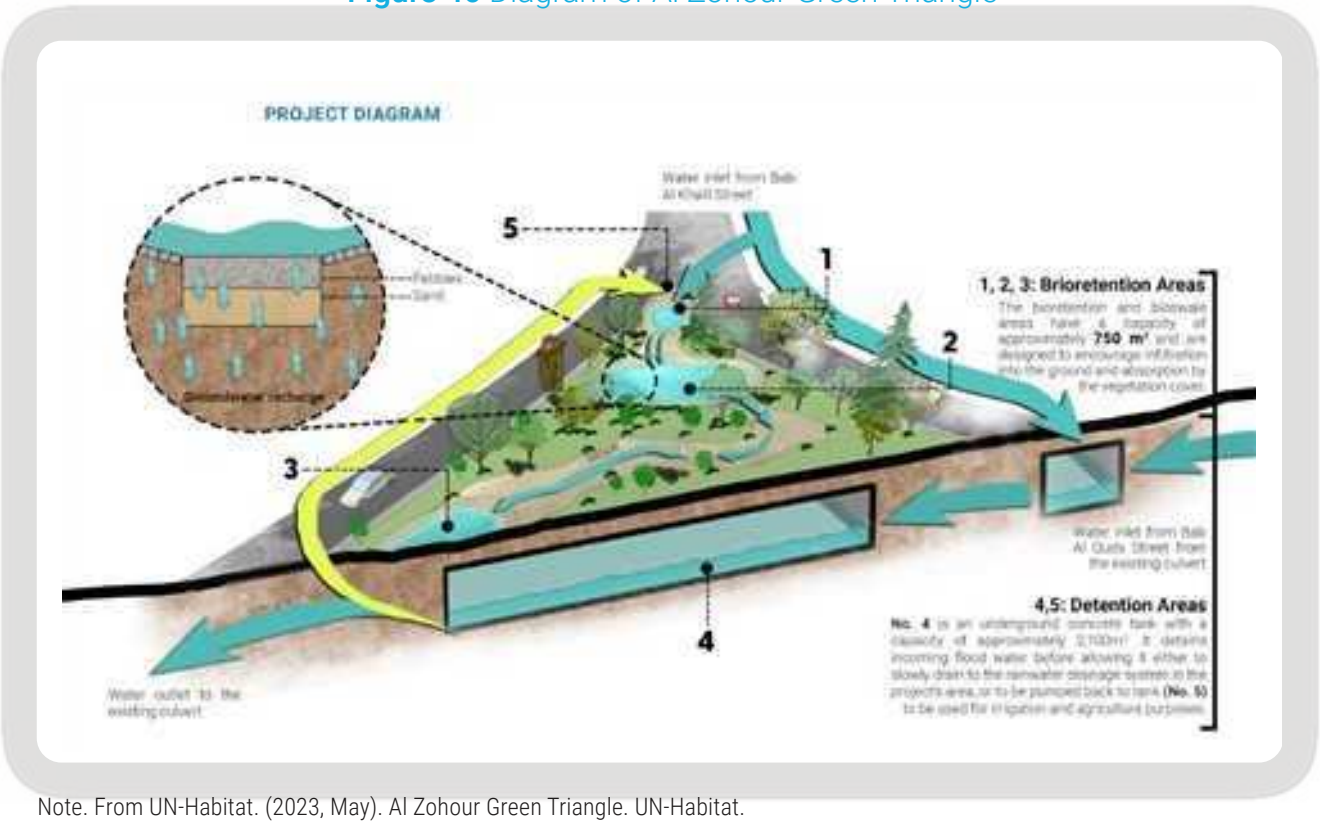
Figure 44 Construction Phases of the Al Zohour Green Triangle

Note. From UN-Habitat. (2023, May). Al Zohour Green Triangle. UN-Habitat. **https://unhabitat.org/sites/default/-files/2023/05/230319_al_zohour_brochure_a5.pdf**

Figure 45 Different Components of Al Zohour Triangle

Note. (left) Bioretention and Bioswales area, (right) underground storage tanks. From UN-Habitat. (2023, May). Al Zohour Green Triangle. UN-Habitat. **https://unhabitat.org/sites/default/files/2023/05/230319_al_zohour_brochure_a5.pdf**

Figure 46 Diagram of Al Zohour Green Triangle



Note. From UN-Habitat. (2023, May). Al Zohour Green Triangle. UN-Habitat. https://unhabitat.org/sites/default/files/2023/05/230319_al_zohour_brochure_a5.pdf

Sources

- UN-Habitat. (2023, May). Al Zohour Green Triangle. UN-Habitat. https://unhabitat.org/sites/default/files/2023/05/230319_al_zohour_brochure_a5.pdf

20. Wastewater Reuse in Wadi Mousa, Jordan

Location	Wadi Mousa, Jordan
Existing Ecosystems	Dryland and agroecosystems
Climate Change Challenges	Water scarcity
NbS Approach	Wastewater reuse, Permaculture, Irrigated Agriculture Optimization

Context

Jordan is among the world's five most water-scarce countries, with demand surpassing the limited available supply. Research indicates that climate change is expected to intensify aridity and deepen the country's water shortages. These pressures directly impact food security, given that nearly 67% of Jordan's total water use goes to agriculture.

Wastewater reuse in Wadi Mousa comes in response to these challenges and is part of the "Increasing the resilience of poor and vulnerable communities to climate change" project, implemented by the Ministry of Planning and International Cooperation with support from the Adaptation Fund.

Applied NbS Methods

The project aims to strengthen the agricultural sector's ability to cope with climate-related water scarcity and the resulting pressures on food security through piloting innovative technologies such as treated wastewater reuse, water harvesting systems, and permaculture practices.

Key components include

1. **Fodder Production**
   Reclaimed water is used to grow alfalfa and fodder for sheep feed.
2. **Endangered Plant Propagation**
   Cultivation of medicinal, herbal, and native plants, alongside beekeeping for honey production.
3. **Irrigated Agriculture Optimization**
   Soil salinity management, replacement of drip irrigation lines, and maximizing economic returns from reclaimed water.
4. **Permaculture Introduction**
   Farmers are trained to adopt integrated on-farm agriculture.
5. **Community Resilience**
   Improved household incomes and adaptation to climate change, benefiting nomadic Bedouin communities.

Sources

- Adaptation Fund. (n.d.). Increasing the resilience of poor and vulnerable communities to climate change. Adaptation Fund. https://www.adaptation-fund.org/project/increasing-the-resilience-of-poor-and-vulnerable-communities-to-climate-change-impacts-in-jordan-through-implementing-innovative-projects-in-water-and-agriculture-in-support-of-adaptation-to-climate-4/
- Al-Qinna, M., Daibes, W., & Albatsh, M. (2020, October). Mid-Term Evaluation Report for Jordan's Adaptation Fund Program: "Increasing the Resilience of Poor and Vulnerable Communities to Climate Change Impacts in Jordan through Implementing Innovation Projects in Water and Agriculture in Support of Adaptation to Climate Change". Retrieved from https://fifspubprd.azureedge.net/afdocuments/project/36/36_Mid_Term_Report_Jordan_MOPIC.pdf

Source photograph and visual by Omnia Moussa

21. Traditional Thadiq Pits for Water Harvesting, Saudi Arabia

An Indigenous and Traditional Water Management Technology

Location	Thadiq National Park, Riyadh, Saudi Arabia
Existing Ecosystems	Arid desert, wadi (valley) and high plateaux
Climate Change Challenges	Water scarcity, drought, land degradation, soil erosion, desertification
NbS Approach	Plantation pits are a water harvesting technique that utilizes rainwater collection to support the growth of trees and shrubs. While their dimensions may vary, a typical pit measures around 2 meters in length, 1 meter in width, and up to 1 meter in depth. They can also be supplemented with manual irrigation when needed

Context

Saudi Arabia's arid climate presents significant challenges for vegetation growth, particularly in areas with annual rainfall of less than 100 mm. Water scarcity and land degradation due to desertification have made traditional planting methods difficult to sustain. Additionally, overgrazing and soil erosion have worsened ecological conditions, further reducing opportunities for natural vegetation regeneration. Given these challenges, innovative water harvesting techniques are essential for restoring ecosystems and ensuring the long-term viability of tree and shrub planting in wadi landscapes and high plateaux.

Applied NbS Methods

Traditional Thadiq Pits for Rainwater Collection

Thadiq pits are innovative water harvesting structures designed to capture rainfall runoff for tree and shrub planting. These pits, which can also be manually watered, are rectangular in shape, measuring approximately 2 meters in length, 1 meter in width, and up to 1 meter in depth, depending on soil conditions. Excavated using mechanical diggers, these pits are typically located within wadis, sheyhib (small wadis), and high plateaux in national parks managed by the National Centre for Vegetation Cover Development and Combating Desertification (NCVC).

The pits are prepared up to two years before planting to collect runoff and the organic and mineral-rich matter it carries. Over time, many annual and perennial plants naturally colonize the pits, creating a fertile environment. Trees and shrubs, such as species from Acacia, Ziziphus, and Haxloylon, are planted in the center of the pit with minimal disturbance to the existing vegetation. These plantings not only combat desertification but

also support biodiversity by attracting bees, with beekeeping initiatives often introduced alongside tree planting.

This method is highly effective in arid regions with annual rainfall of less than 100 mm. While supplemental irrigation is required, each pit is watered around seven times over 18 months, using 20 to 100 liters of water per session, depending on availability. The watering strategy encourages deep root growth, enabling plants to reach the water table. Watering is usually discontinued after three to five years when the roots have fully developed. The interval between watering is carefully managed to ensure the plant survives while promoting downward root growth.

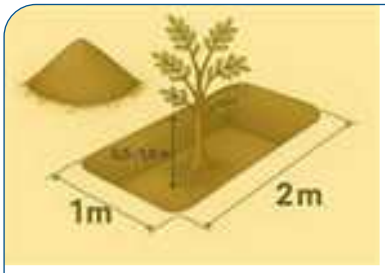
Although the initial costs are significant, the results are promising, with high survival rates and notable environmental impacts when at least 100 pits are constructed per hectare. Over the past five years, 1.5 million Thadiq pits have been created. This technique was designed by Abdulla Al Eissa, a park manager, with technical advice on planting operations provided by the Food and Agriculture Organization of the United Nations (FAO).

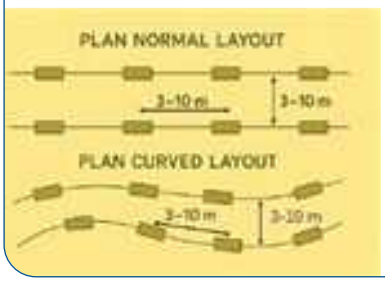
This activity is part of the FAO project, Strengthening MoEWA's Capacity to Implement its Sustainable Rural Agricultural Development (SRAD) Programme (2019–2025), funding by the NCVC, local donors, and volunteers, highlighting a collaborative effort to combat desertification and promote sustainable land use in Saudi Arabia.

Figure 47 Tree plantation pits in Thadiq National Park

Note. Plantation pits, Thadiq National Park, Saudi Arabia. Under Strengthening MoEWA's Capacity to implement its Sustainable Rural Agricultural Development (SRAD) Programme (2019-2025) Photos: Éric Lacroix, 2022. From WOCAT. (2025, July 17). Tree Plantation Pits in Arid Zones [Saudi Arabia]. WOCAT SLM Database. **https://qcat.wocat.net/en/wocat/technologies/view/technologies_7380/**

Figure 43 Technical Drawing of the Thadiq Pit Technology





Technical Specifications

Spacing Configuration:
- Curved lines: 3 to 10 m between pits
- Clusters: 3 m spacing between pits

Planting Capacity:
- 1–3 seedlings per pit (trees, shrubs, or other vegetation)

Watering Volume per Pit:
- 20–100 L, based on water availability, transportation cost, and local pricing

Watering Frequency:
- Approximately 7 times over 1.5 to 2 years (soil moisture-dependent)

Pit Density:
- Minimum: 100 pits per hectare
- Maximum: ~1100 pits per hectare (rare in this environment)

Note. From WOCAT's adaptation Éric Lacroix. WOCAT. (2025, July 17). Tree Plantation Pits in Arid Zones [Saudi Arabia]. WOCAT SLM Database.
https://qcat.wocat.net/en/wocat/technologies/view/technologies_7380/

Sources

- WOCAT. (2025, July 17). Tree Plantation Pits in Arid Zones [Saudi Arabia]. WOCAT SLM Database. https://qcat.wocat.net/en/wocat/technologies/view/technologies_7380/

Visual by Omnia Moussa

22. Al Baydha Regenerative Agriculture, Saudi Arabia

Location	40 km South of Makkah, Hijaz, Saudi Arabia
Existing Ecosystems	Arid desert
Climate Change Challenges	Flash floods, soil erosion, desertification
Comple-mentary NbS Type	Agroecology and Sustainable Land Management
NbS Approach	Ecosystem restoration and regenerative agriculture: the project included implementing food forests as self-sustaining ecosystems and managing flash floods through earthworks such as terraces and check dams

Context

Forty kilometers south of Makkah, in the arid Hejaz region of Saudi Arabia, Bedouin communities face severe ecological and economic challenges due to desertification, land degradation, overgrazing, and deforestation for firewood. These practices deplete natural resources, forcing reliance on imported animal feed and worsening soil erosion, flash floods, and environmental damage—threatening infrastructure, livelihoods, and lives.

The Baydha Project was launched to counter these issues through landscape restoration, regenerative agriculture, and water management. Initially, the area was extremely degraded with no soil, water, or biological capital- only mountains, stones, dust, and occasional floods.

Applied NbS Methods

The Al Baydha Project employs low-tech water management, using earthworks and check dams to slow flash floods, create seasonal streams, recharge aquifers, and support desert agriculture. This approach also mitigates flood risks, protecting infrastructure and communities. Spanning 700 km² and serving nearly 5,000 residents, the project was initiated in 2010 by Princess Haifa Al Faisal and Princess Nouf Bint Fahd with Neals Spackman and Mona Hamdi, supported by the Royal Magistrate and Governorate.

A 90-acre pilot site, including watershed, mountains, wadis, and floodplains, was developed with design input from the Permaculture Research Institute. The strategy: capture and infiltrate floodwater to restore underground reserves. Sixty-five check dams and 15 km of terraces were built by local workers trained by skilled Yemenis.

Unlike conventional farming, the project uses savannah-based agroecology, creating self-sustaining ecosystems that restore land and support economic sustainability. Food forests provide livestock forage, fruits, timber, honey, and medicinal plants. Plans include a dairy industry using crossbred goats adapted to local conditions, reducing dependency on imports. Biodiversity efforts include pigeon and bat houses.

Challenges included floods damaging structures, but these were treated as feedback for system improvements. The approach proved effective during a major 2011 storm, absorbing 10–14 million liters of water. The first trees were planted in 2012 with drip irrigation from a local well and desalination plant, requiring 20,000 m^3 of water. The system can direct and infiltrate up to 50,000 m^3 of rainwater. By 2016, the project engaged 120 tribesmen and eight trained teams in terrace and check dam construction, sustainable agriculture, and livestock management.

When funding ended in 2016, irrigation was cut to test self-sustainability. Despite 27 months without rain (2017–2018), the landscape revived after rains in late 2018 and 2019, demonstrating resilience.

Al Baydha Project promotes economic independence, employment, and traditional practices, while providing education and vocational training. It serves as a replicable model for western Saudi Arabia and other arid regions, showing how low-tech flood control and regenerative agriculture can reverse desertification, enhance biodiversity, sequester carbon, improve water resources, and enable food production. Benefits include job creation, reduced food imports, improved public health, and reduced pressure on urban centers.

Sources

- Permaculture Research Institute. (2015, October 7). Al Baydha Project. Permaculture Research Institute. **https://permaculturegloba l.org/projects/286-al-baydha-project**
- Miriam Kresh. (2020, August 10). Al Baydha Regenerative farming in Saudi Arabia. Green Prophet. **https://www.greenproph-et.com/2020/08/the-al-baydha-project-how-regenerative-agriculture-revived-green-life-in-a-saudi-arabian-desert/**
- Al Baydha. (2014, February 1). Reversing the Cycle of Desertification [Video]. YouTube. **https://www.you-tube.com/watch?v=C1_lmV8U6Lk**

Visual by Omnia Moussa

23. The Restoration of Wadi Hanifa, Saudi Arabia

Location	Najd Plateau, near Riyadh, Saudi Arabia
Existing Ecosystems	Valley, arid
Climate Change Challenges	Increased frequency and intensity of flash floods due to changing rainfall patterns in arid regions, prolonged droughts and higher evaporation rates reducing groundwater recharge and base flows in the wadi, water scarcity from rising demand combined with reduced natural replenishment, soil erosion and land degradation from extreme weather events and loss of vegetation cover and biodiversity stress due to altered hydrological regimes and habitat fragmentation
NbS Approach	Ecosystem Rehabilitation and Wastewater bioremediation

Context

Wadi Hanifa, situated in the Najd Plateau of Saudi Arabia, is the longest and most significant valley near Riyadh. It serves as a natural water drainage system, with an area of 4500 m2 and several tributaries and smaller valleys. Despite its ecological and geographical importance, between the 1960s and the 1990s, the valley's natural resources, including natural stones and ground water, were overexploited and polluted, and the valley was being used as a waste site. The aggressive exploitation over the years led to environmental degradation, affecting both natural resources and local communities. In response to the extreme deterioration, the Royal Commission for Riyadh City launched and implemented the Comprehensive Development Plan for Wadi Hanifah (CDPWH) between 2001 and 2010 to rehabilitate and restore the valley.

Applied NbS Methods

The CDPWH rehabilitated Wadi Hanifah to not only serve as a natural drainage system for Riyadh city but also function as a leisure park for city residents as well as provide a sustainable water supply through wastewater bioremediation. Led by Moriyama & Teshima Planners and Buro Happold Design Office, the Wadi Hanifa project focused on rehabilitating the valley's ecosystem while ensuring long-term benefits for local communities. The initiative received global recognition, earning the Aga Khan Award for Architecture for its innovative approach to sustainable urban planning and ecological restoration.

The CDPWH worked through two components: the Wadi Hanifah Restoration Project (immediate actions) and the Wadi Hanifah Development Programme (long-term actions). The immediate actions focused on stopping harmful activities and

assessing flood performance and water quality, while the long-term actions focused on environmental rehabilitation and the cleaning of polluted sites, renaturing, protecting ecologically valuable sites and developing recreational spaces. Through the second component, nine major public parks have been implemented along the valley's riverbed. The parks, which attract over 200,000 visitors per week, were designed to suit Saudi culture, integrating outdoor family "privacy rooms", recreational trails, adequate parking and sanitary facilities.

With local materials and plant species in mind, limestone blocks were used for structures and aggregates for recreational trails in the parks, while 35 different types of native plants were brought from areas that were least polluted and reintroduced throughout the valley grounds. Using urban wastewater bioremediation, 92.5 million gallons of potable water were saved per day for park amenities and irrigation. The wastewater treatment plant integrates environmentally sensitive technologies to reuse water efficiently, helping to stabilize water availability, improve soil health, and support biodiversity across the region.

By balancing urban growth with ecological restoration, the Wadi Hanifa project sets a precedent for sustainable landscape management in arid environments. Its multifaceted approach ensures environmental resilience, community engagement, and enhanced tourism opportunities, contributing to Riyadh's urban livability and green infrastructure goals.

Figure 49 Walking trails and family compartments, Wadi Hanifa, Riyadh, Saudi Arabia

Note. Photo: Aga Khan Award for Architecture / Arriyadh Development Authority From the Aga Khan Development Network. (n.d.). Wadi Hanifa Wetlands. AKDN. https://the.akdn/en/how-we-work/our-agencies/aga-khan-trust-culture/akaa/wadi-hanifa-wetlands

Figure 50 Water Filtration Facility, Wadi Hanifa, Riyadh, Saudi Arabia

Note. The Water filtration facility in Wadi Hanifa. Flood performance of the channel is improved by reprofiling and regrading. Wadi Hanifa Wetlands, Riyadh, Saudi Arabia. Photo: Aga Khan Award for Architecture (AKAA) / Arriyadh Development Authority. From the Aga Khan Development Network. (n.d.). Wadi Hanifa Wetlands. AKDN. https://the.akdn/en/how-we-work/our-agencies/ga-khan-trust-culture/akaa/wadi-hanifa-wetlands

Sources

- Buro Happold. (n.d.). Wadi Hanifah Flood Management Plan. Retrieved from Buro Happold - Integrated Consulting Engineers and Advisers: https://www.burohappold.com/projects/wadi-hanifah-flood management-plan/
- Royal Commision for Riyadh City. (n.d.). Environmental Rehabilitation Program for Wadi Hanifa and its Tributaries. Retrieved from Royal Commision for Riyadh City: https://www.rcrc.gov.sa/en/projects/wadi-hanifah
- Trottier, J., & Eidick, K. (2015). Wadi Hanifah Comprehensive Development Plan | Landscape Performance Series. https://doi.org/10.31353/cs1040
- The Aga Khan Development Network. (n.d.). Wadi Hanifa Wetlands. AKDN. https://the.akdn/en/how-we-work/our-agencies/aga-khan-trust-culture/akaa/wadi-hanifa-wetlands

Source photograph by Halima Bouchouicha. Visual by Omnia Moussa

24. Al Fay Park in Abu Dhabi, UAE

Location	Abu Dhabi, UAE
Existing Ecosystems	Arid, urban ecosystem
Climate Change Challenges	Aridity, sand and dust storms, land degradation, high temperatures
Complementary NbS Type	Agroecology and Sustainable Land Management
NbS Approach	Green Spaces: Urban Park

Context

Urban green spaces play a crucial role in enhancing biodiversity, improving air quality, and regulating microclimates in cities. However, in arid regions such as Abu Dhabi, conventional park designs may not be suitable due to high water consumption demands. Furthermore, sand and wind movement patterns as well as extreme temperatures require planning solutions that integrate native vegetation well suited to these conditions. By creating self-sustaining ecosystems that require minimal intervention, such parks maximize resource efficiency and provide environmental and social benefits to their cities.

Applied NbS Methods

Al Fay Park in Abu Dhabi serves as a good example of sustainable greening that is well adapted to the local context. Besides utilizing native plants, grasses, and bushes to establish a self-sustaining ecosystem that thrives in desert conditions, the project strategically leverages natural topography, its downward slope directing cooler southern breezes into the park's center to enhance ventilation and reduce ambient temperatures. Additionally, native vegetation mitigates sand infiltration and movement, strengthening the park's resilience against harsh environmental conditions.

The park's resource efficiency is further enhanced by advanced soil conditioning and irrigation systems, which cut water consumption by 50% compared to conventional parks. Dense planting of native trees, shrubs, and bushes fosters local biodiversity, supporting bird, insect, and animal populations that contribute to the broader urban ecosystem. Beyond its environmental benefits, Al Fay Park offers an immersive green space for recreation and community engagement, setting a benchmark for sustainable park design in arid landscapes.

Sources

- Department of Municipalities and Transport. (n.d.). Al Fay Park. **https://pages.dmt.gov.ae/en/fay-park-page**

25. Al-Wathba Wetland Reserve, UAE

Location	Abu Dhabi, UAE
Existing Ecosystems	Seasonal floodplain, wetland
Climate Change Challenges	Aridity, land degradation, biodiversity loss
NbS Approach	Ecological restoration through a constructed wetland

Context

Wetlands play an essential role in biodiversity conservation, water management, and climate resilience. In arid regions, like in the United Arab Emirates, sustaining wetland ecosystems is a challenge due to limited water availability and harsh climatic conditions. Al Wathba Wetland Reserve (AWWR) is a remarkable example of ecological restoration and conservation in a challenging arid environment. Originally a seasonal floodplain, this constructed wetland, fed by treated wastewater, has evolved into a protected ecosystem, providing habitat for diverse species and serving as a model for sustainable water management and conservation.

Applied NbS Methods

The transformation began in 1998 when the Greater Flamingo (Phoenicopterus roseus) was successfully bred in the area for the first time since 1922, highlighting the site's ecological potential. As a result, AWWR was designated as a protected wetland and became one of the first IUCN Green List protected areas in the Gulf Cooperation Council region. Spanning 5 square kilometers, the reserve is positioned at the edge of a dune system transitioning into a sabkha (salt flat), which creates unique conditions for diverse wildlife. The wetland's water bodies range from freshwater to brackish and saline, shaped by the natural interactions between the treated wastewater inputs from the Mafraq Wastewater Treatment Plant and the sabkha substrate. This variety in salinity creates conditions suitable to support over 260 bird species, along with numerous insects and wetland organisms, making AWWR an internationally significant biodiversity hotspot. In recognition of its ecological importance, AWWR was designated a Ramsar wetland site in 2013, further securing its role in regional conservation.

The reserve, managed by the Environment Agency Abu Dhabi serves multiple purposes beyond conservation, including research, education, and eco-tourism. During the winter months (November to March), it attracts visitors for birdwatching and sustainable tourism activities, fostering public appreciation for wetland ecosystems.

The presence of the Mafraq Wastewater Treatment Plant to the north and northwest of the reserve, using stabilization ponds, is integral to its maintenance, as it provides the treated water that sustains the lake. The utilization of wastewater supports biodiversity, demonstrating the potential

for integrating waste management with ecological conservation. Al Wathba Wetland Reserve showcases the potential for sustainable water management and ecological restoration in arid landscapes, setting a model for other regions facing similar environmental challenges.

Figure 51 Al Wathba Wetland Reserve

Note. From Gordontour, 2013, "Al Wathba Wetland Reserve," photograph. CC BY-NC-ND 2.0 Flicker. https://www.flickr.com/photos/gordontour/8440859165

Sources

- Environment Agency Abu Dhabi. (n.d.). Al Wathba Wetland Reserve Terrestrial Protected Area Factsheet. Environment Agency Abu Dhabi. https://www.ead.gov.ae/-/media/Project/EAD/EAD/Documents/Resources/ALWATHBA_V1---English.pdf

26. Constructed Wetlands and Artificial Ponds, Qatar

Location	Outskirts of Doha, Qatar
Existing Ecosystems	Inland water, urban and dryland ecosystems
Climate Change Challenges	Aridity, Water Scarcity
NbS Approach	Constructed Wetland, phytoremediation

Context

In the arid landscapes of Qatar, effective wastewater treatment plays a critical role in environmental sustainability. In 1982, two major ponds—Abu-Hamour and Abu-Nakhla—were established 12 km southwest of Doha to manage excess Treated Sewage Effluent. Initially designed as storage reservoirs, these ponds have since transformed into functional wetlands, contributing to both wastewater reuse and ecological conservation. Abu-Hamour receives untreated wastewater, while Abu-Nakhla is fed treated wastewater, which makes the latter more suitable for agricultural and landscape irrigation.

Applied NbS Methods

Abu-Nakhla Pond receives treated wastewater from the Doha-South and Doha-West wastewater treatment stations, where it undergoes several filtration and purification stages. The primary, secondary, and tertiary treatments ensure: debris and grit are removed, organic suspended solids are filtered out, soluble organic matter is oxidized, finer suspended particles are refined, and water is chlorinated for improved water safety.

Due to its treated wastewater, Abu-Nakhla has contributed to extensive greening efforts in Doha, particularly benefiting alfalfa fields and urban gardening practices. Over time, the pond evolved into a wetland ecosystem, with riparian vegetation taking root, creating a habitat for migratory and sedentary bird species.

The transformation of Abu-Nakhla Wetland into a thriving ecological space highlights the potential of nature-based wastewater solutions. The wetland has become a biodiversity hub, offering a natural refuge for wildlife while enhancing urban sustainability. Additionally, it serves recreational purposes, providing residents and visitors with green spaces to appreciate Qatar's evolving environmental landscape.

By integrating wastewater treatment with ecological restoration, Abu-Nakhla showcases how innovative water management practices can contribute to both biodiversity conservation and urban resilience.

Figure 52 Map of Qatar showing the location of the two ponds on the outskirts of Doha

Note. From Al-Thani, R.F., Yasseen, B.T. (2021, January 6). Perspectives of future water sources in Qatar by phytoremediation: biodiversity at ponds and modern approach. International Journal of Phytoremediation 23, 866–889. https://doi.org/10.1080/15226514.2020.1859986

Figure 53 Waste Waterponds

Note. (left) Untreated wastewater pond (Abu-Hamour). Species such as the Phragmites australis plants and Aeluropus lagopoides can survive in this habitat. (center) Treated wastewater pond (Abu-Nakhla). Good habitat for many aquatic plants; Typha domingensis and phytoplanktons thrived in this pond. (right) Photo depicting the biodiversity of these ponds. From Al-Thani, R.F., Yasseen, B.T. (2021, January 6). Perspectives of future water sources in Qatar by phytoremediation: biodiversity at ponds and modern approach. International Journal of Phytoremediation 23, 866–889 https://doi.org/10.1080/15226514.2020.1859986

Sources

- Al-Thani, R.F., Yasseen, B.T. (2021, January 6). Perspectives of future water sources in Qatar by phytoremediation: biodiversity at ponds and modern approach. International Journal of Phytoremediation 23, 866–889. https://-doi.org/10.1080/15226514.2020.1859986
- Abulfatih, H. A., Al-Thani, R. F., Al-Naimi, I. S., Sweileh, J. A., Elhag, E. A., & Kardousha, M. M. (2002). Ecology of wastewater ponds in Qatar. Qatar University Environmental Science Center. https://www.qu.edu.qa/en-us/research/esc/documents/-books/99921-52-28-1.pdf

27. Indigenous Aflaj Systems, Oman
Al Habeesah Rainwater Storage

Location	Various valleys and mountainous regions across Oman, including Jebel Akhdar and wadi systems like Wadi Muaydin in northern Hajar Mountains and other rural wadis—Sultanate of Oman
Existing Ecosystems	Oases and agro-ecosystems in mountainous regions
Climate Change Challenges	Rising temperatures, declining precipitation, and increased variability demand resilient water management to cope with erratic rainfall and flash floods. Urban growth (e.g., Sayh Qatanah) increases pressure on traditional water sources
NbS Approach	▪ Rainwater harvesting via Al Habeesah – small rockandmud dams in wadis/valleys to retain seasonal runoff ▪ Integration with falaj systems: Harvested water is channeled through traditional irrigation tunnels (aflaj) supporting agriculture, livestock, pollinators, and soil conservation

Context

Oman's relationship with water management is deeply rooted in its arid environment, where scarcity has historically driven communities to develop innovative solutions. The ancient aflaj (plural for falaj) systems exemplify this ingenuity, functioning as subterranean tunnels and open channels that transport groundwater or surface runoff over long distances to support agriculture and settlements. Dating back to approximately 2,450 BCE, aflaj emerged as a social and technological adaptation to declining precipitation during the late Bronze Age. This shift from reliance on surface streams to groundwater tapping was crucial in sustaining communities amid changing climatic conditions.

The architectural features of the Falaj system are very precise, as are their systems of operation for irrigation and water circulation, and the ways in which they were maintained.

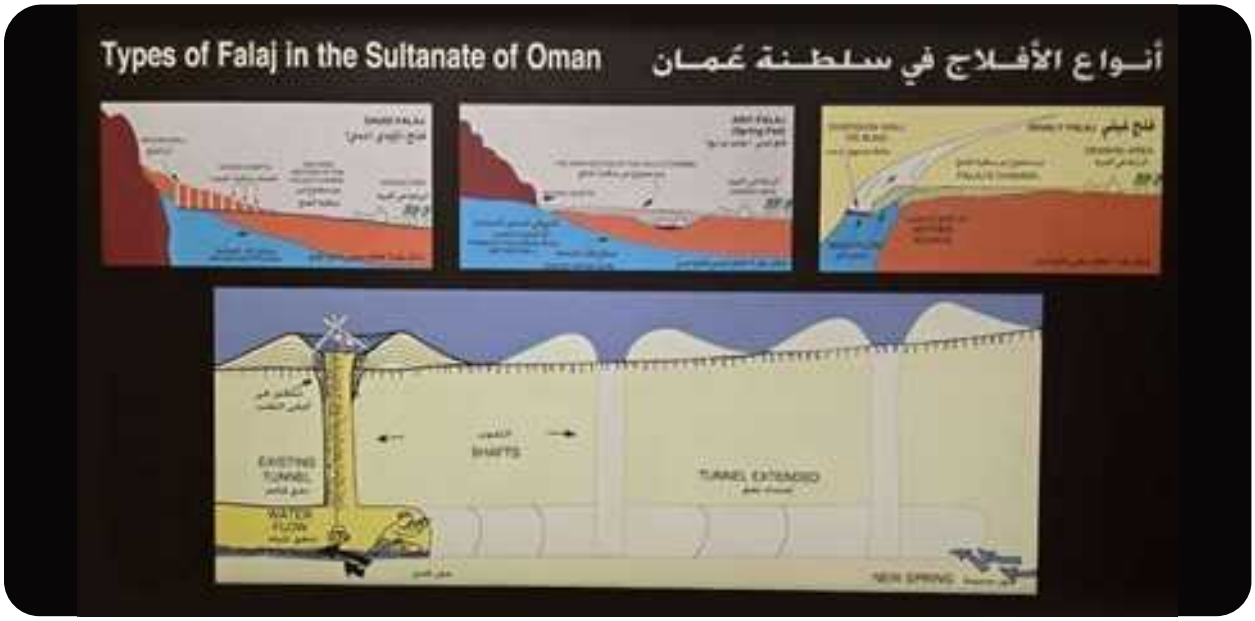
In Oman, three principal types of falaj exist:

1. **Aflaj Daoudiyat ('Addiyat)** are underground tunnels of 12 km length
2. **Aflaj Ghayliyat** are open-air canals of 2 km length located in the floor of valleys
3. **Aflaj Ayniyat:** their springs gush out of the bases of mountains. Water circulates in open-air canals or under bridges towards villages and cultivated lands

In 2006, five Aflaj Irrigation Systems of Oman were added to the UNESCO list of World Heritage Sites: Falaj Al-Khatmeen, Falaj Al-Malki, Falaj Daris, Falaj Al-Mayassar and Falaj Al-Jeela.

The three primary types of falaj—Iddi (deep groundwater tunnels), Ayni (spring-fed channels), and Ghaili (surface runoff canals)—reflect the diverse hydrological and geological contexts across Oman.

Figure 54 Types of Aflaj Systems in Oman



Note. Photo of Placard on the Types of Falaj (plural = aflaj) in the Sultanate of Oman, Museum of the Frankincense Land, Salalah, Oman. Photo: Yasmine Mostafa

As water demand increased and precipitation further declined, communities innovated by constructing Al Habeesah structures—small, geometric rock-and-mud dams strategically placed in valleys and mountainous areas to capture and store seasonal rainwater runoff. These basins serve as critical reservoirs, slowly releasing water into the falaj networks, thereby ensuring a more reliable and extended water supply through dry seasons. Beyond their practical function, Al Habeesah and aflaj systems embody a collective cultural heritage, with community management practices that regulate water allocation, maintenance, and conflict resolution. This intergenerational knowledge continues to complement modern water infrastructure, highlighting the resilience of indigenous water management in the face of climate variability, as documented by Oman's Ministry of Water Resources and recognized in scientific hydrological studies.

Applied NbS Methods

The project integrates traditional NbS by revitalizing and constructing Al Habeesah basins using locally sourced stone and mud in targeted valley locations prone to seasonal runoff. These structures capture episodic but intense rainfall, storing water that would otherwise be lost to rapid downstream flow. The stored water is then channeled into the falaj irrigation networks, enabling sustained agricultural use and supporting surrounding ecosystems throughout dry periods. This approach enhances multi-sectoral benefits by simultaneously sustaining crops, providing water for pastoral animals, and maintaining habitats for native pollinators such as bees and birds.

Furthermore, these community-managed systems preserve the cultural identity and social cohesion associated with the falaj, with some networks, like Al-Khutmain (Falaj Al-Khatmeen) in Birkat al-Mouz, historically serving philanthropic functions by

providing water to travelers. The Al Habeesah interventions also complement government-led water initiatives such as recharge dams and cisterns, collectively forming an integrated landscape-scale strategy that promotes groundwater recharge, flood retention, and climate resilience. This synergy between indigenous knowledge and formal water management frameworks aligns with national water security goals articulated by Oman's Ministry of Regional Municipalities and Water Resources and has been validated by recent academic research on sustainable water governance in arid regions.

Sources

- UNESCO World Heritage Centre. (2006). Aflaj Irrigation Systems of Oman. https://artsandculture.google.com/story/aflaj-irrigation-systems-of-oman-oman-unesco/cwWxW03NezuzLQ
- Ministry of Agriculture, Fisheries and Water Resources, Sultanate of Oman. (2025, March 28). Develop traditional agricultural systems in Al-Aflaj villages. https://gov.om/en/w/develop-traditional-agricultural-systems-in-al-aflaj-villages
- Oman News Agency. (2025, April 17). UNESCO Chair for Aflaj Studies implements projects to promote Omani falaj system. Oman News. Retrieved from https://omannews.gov.om/topics/en/83/show/116286/
- Oman Information Service. (2024). Traditional water systems in Oman. Retrieved from https://www.omaninfo.om/topics/85/show/14515
- Oman News Center. (2014, August 12). "Al-Habisa", a traditional method of capturing valley water to use it for irrigating crops. [Video]. YouTube. https://youtu.be/QdwKycn5oEM

Oasis in Misfah al Abriyyin, Oman. Source photograph by Andy Arbeit. Visual by Omnia Moussa

28. Ecohaus Constructed Wetlands, Oman

Location	Halban, near Muscat, Sultanate of Oman
Existing Ecosystems	Constructed wetland ecosystem
Climate Change Challenges	Water scarcity and risks of water pollution and depletion of freshwater resources under climate stress
NbS Approach	▪ Constructed Wetland (CW) technology, specifically a Horizontal Flow Constructed Wetland (HFCW) for onsite wastewater treatment ▪ Integration of natural processes (reed plants, microbial activity) to treat wastewater sustainably ▪ Water reuse for irrigation creates a closed-loop system

Context

The EcoHaus project was developed in 2011 at the German University of Technology in Oman (GUtech) as a pioneering initiative to demonstrate sustainable building and resource management practices in an arid, hot climate. Situated on the GUtech campus near Muscat, Oman, the EcoHaus serves as a net-zero-energy residential building designed to showcase environmentally conscious solutions adapted for water-scarce regions. The project addresses critical challenges related to water scarcity, limited freshwater availability, and the need for efficient wastewater treatment methods that minimize energy consumption. In addition, it tackles issues such as pollution risks from untreated wastewater and the difficulty of maintaining sanitation in hot, dry environments. Targeting a small community scale, roughly equivalent to five inhabitants, EcoHaus exemplifies how buildings in harsh climates can integrate low-impact technologies that conserve resources and reduce environmental footprints, supporting the broader goals of sustainable development in the Middle East.

Applied NbS Methods

The core nature-based solution at EcoHaus is an onsite constructed wetland system designed to treat domestic wastewater efficiently without requiring external energy inputs. Wastewater from the EcoHaus flows by gravity into a covered septic tank with a capacity of 5 cubic meters, where solids settle and fats separate from the water. The partially treated effluent then passes into a 15-square-meter horizontal flow constructed wetland planted with local common reeds (Phragmites australis), which were replanted in 2019 to maintain system performance. The wetland is carefully managed to keep the water level just below the gravel surface, a design feature that prevents odors, reduces mosquito breeding, and minimizes health risks by avoiding direct contact between wastewater and

humans or wildlife. After treatment, the clean effluent is reused to irrigate local trees and shrubs, promoting a sustainable cycle of water recycling within the landscape. This system operates without any external energy input and requires minimal maintenance, making it a cost-effective, environmentally friendly solution well-suited for arid regions like Oman.

Sources

- Stefanakis, A. (2022, October 12). Constructed Wetlands for Sustainable Wastewater Treatment in Oman: Experiences from Research and Case Studies. In: Stefanakis, A. (eds) Constructed Wetlands for Wastewater Treatment in Hot and Arid Climates. Wetlands: Ecology, Conservation and Management, vol 7. Springer, Cham. https://doi.org/10.1007/978-3-031-03600-2_12

Visual by Omnia Moussa

29. Nimr Water Treatment Plant, Oman

Location	Nimr region, Sultanate of Oman
Existing Ecosystems	Constructed wetland ecosystem
Climate Change Challenges	High energy consumption and carbon emissions from conventional water disposal and Limited renewable energy availability in arid desert conditions
NbS Approach	▪ Hybrid system combining green infrastructure (constructed wetlands, free water surface wetlands) with grey infrastructure (hydro-cyclones, buffer ponds, evaporation ponds) ▪ Use of natural processes for water treatment and evaporation ponds for salt recovery ▪ Ecological restoration via wetland creation supporting biodiversity

Context

The Nimr region, located in Oman's arid desert landscape, faces a significant environmental challenge due to the large volumes of produced water generated during oil exploration and production. With a water-to-oil ratio reaching 10:1, much of this water traditionally required disposal through deep-well injection—a method that is energy-intensive, environmentally risky, and particularly challenging given the limited power resources in the desert. This situation created a pressing need for an alternative approach to manage produced water that is both cost-effective and sustainable, while minimizing the environmental footprint. Additionally, the opportunity to enhance ecological value in this previously barren area and contribute to circular economy principles by reusing treated water for irrigation and biomass cultivation further motivated the development of innovative solutions.

Applied NbS Methods

To address these challenges, the Nimr Water Treatment Plant implements a hybrid nature-based solution combining green and grey infrastructure. The process begins with passive hydro-cyclones that separate and recover most of the oil from the produced water. The water is then directed into a vast 360-hectare free water surface wetland, where natural biological processes further treat the water. Following this, the treated water flows by gravity into 500 hectares of evaporation ponds, allowing the water to evaporate and leaving behind salts that are processed into industrial-grade products. The system operates largely on gravity, eliminating the need for energy-intensive pumps and reducing energy consumption by 98%, which corresponds to a reduction of over 1.5 million tons of CO emissions annually. Beyond treatment efficiency, the wetlands

and ponds have created critical habitats along a major migratory bird flyway, supporting over 120 bird species. Experimental efforts to reuse the treated water for cultivating salt-tolerant plants with economic value underscore the plant's role as a model for sustainable water management and zero-waste production. Expansion efforts are underway to increase wetland capacity by an additional 130 hectares, further enhancing treatment volumes and ecological benefits.

Sources

- Stefanakis, A. (2022, October 12). Constructed Wetlands for Sustainable Wastewater Treatment in Oman: Experiences from Research and Case Studies. In: Stefanakis, A. (eds) Constructed Wetlands for Wastewater Treatment in Hot and Arid Climates. Wetlands: Ecology, Conservation and Management, vol 7. Springer, Cham. https://doi.org/10.1007/978-3-031-03600-2_12

Yellow reeds. Source photograph by Jonathan Marchant. Visual by Omnia Moussa.

30. Al Ansab Wetlands, Oman

Location	Muscat, Sultanate of Oman
Existing Ecosystems	Artificial wetland ecosystem
Climate Change Challenges	Limited natural surface water flow, mostly episodic during storms, Dependence on treated wastewater inflows to sustain the wetland ecosystem and Potential risks of changes in water availability due to climate variability and increased evaporation
NbS Approach	Constructed artificial wetlands using treated wastewater for habitat restoration

Context

Situated in a region characterized by extreme aridity and limited natural freshwater resources, the Al Ansab Wetlands serve as an innovative interface between urban wastewater management and biodiversity conservation. Managed by Haya Water, the facility that operates the connected wastewater treatment system, the wetlands transform what would otherwise be a waste product into a life-sustaining resource for a diverse bird population and other wetland-dependent species. The site has gained recognition as an important conservation area and a popular destination for birdwatchers locally and internationally. Over time, the volume of treated effluent discharged into the wetland ponds has increased from about 2.5 million cubic meters per year in 2006 to approximately 6 million cubic meters per year currently, reflecting enhanced water availability that supports the wetland's ecological functions.

Applied NbS Methods

The primary NbS implemented at Al Ansab is the construction and management of artificial wetland ponds that receive and treat wastewater effluent. This system provides a sustainable water source that allows for the creation of diverse habitats essential for resident and migratory birds. Alongside habitat creation, the wetlands have become a focal point for biodiversity monitoring, with data collection by the Oman Bird Group and other stakeholders informing conservation efforts. The site also supports ecotourism and environmental education, serving as an accessible natural area for the public to engage with local biodiversity. This integrated approach, combining wastewater management with habitat restoration and community engagement, represents a successful model of NbS in a desert environment.

Figure 55 Ansab Wetland Site Maps

Note. From Ramsar. (2020, March 21). Al Ansab Wetland. Ramsar Sites Information Service.**https://rsis.ramsar.org/ris/2406**

Sources

- Ramsar. (2008, December 16). Al Ansab Wetland Site Management Plan Jan 2009 – Dec 2013. Ramsar Sites Information Service. **https://rsis.ramsar.org/RISapp/files/27542068/documents/OM2406_mgt190414.pdf**
- Ramsar. (2020, March 21). Al Ansab Wetland. Ramsar Sites Information Service. **https://rsis.ramsar.org/ris/2406**

31. Mangrove Restoration Project, Oman

Location	Multiple governorates including Muscat in the Sultanate of Oman
Existing Ecosystems	Coastal ecosystem
Climate Change Challenges	Coastal erosion and damage from tidal storms, Salinity changes affecting ecosystems, Loss of natural carbon sinks and Threats to biodiversity and fisheries impacting food security
NbS Approach	▪ Mangrove restoration and afforestation (planting mangrove seedlings) ▪ Protection and expansion of existing mangrove forests

Context

Historically, Oman's coastline and islands were covered by dense mangrove woodlands that played a crucial role in supporting local livelihoods and protecting the environment. These mangrove ecosystems provided essential resources such as camel fodder, timber, cleaner air, and fertile fishing grounds while naturally resisting salinity and shielding coastal areas from tidal storms. Over time, however, these vital habitats declined significantly, threatening biodiversity, fisheries, and the resilience of coastal communities to climate-related challenges. Recognizing the ecological and socioeconomic importance of mangroves, the Omani government launched a restoration initiative in 2000, partnering with international organizations such as the Japanese International Cooperation Agency, the Regional Organization for the Protection of the Marine Environment, and UNEP. This collaboration aims to restore the natural balance of coastal ecosystems and inspire a broader regional strategy for marine and coastal management. The initiative also aligns with global environmental efforts, such as Oman's participation in the UNEP's Clean Seas Campaign, underscoring the country's commitment to sustainable coastal conservation and the enhancement of ecosystem services, including carbon sequestration, coastal protection, and food security.

Applied NbS Methods

The core nature-based solution implemented under this initiative is the large-scale restoration and expansion of mangrove forests through the planting of approximately 700,000 mangrove seedlings across seven of Oman's governorates, with a target of reaching one million seedlings. These seedlings are carefully transplanted in sites selected for their suitability, achieving survival rates of 70 to 80 percent. Restoration efforts include protecting existing mangrove stands to prevent further degradation. Community engagement plays a vital role in these efforts, with awareness-raising campaigns designed to involve local populations in conservation activities and promote the sustainable use of mangrove resources. To support both ecological and economic goals, ecotourism infrastructure has been developed, notably the creation of mangrove boardwalks and visitor

facilities at the Qurm Reserve near Muscat, a Ramsar-designated wetland. Additionally, Oman has launched beach clean-up campaigns as part of its Clean Seas commitment to reduce marine pollution. These combined measures not only rehabilitate critical habitats that serve as nurseries for fish and other marine species but also provide livelihoods, enhance climate resilience by absorbing greenhouse gases, and protect coastlines from erosion, embodying a comprehensive approach to coastal ecosystem management.

Sources

- United Nations Environment Programme. (2018, January 11). Mangrove restoration paying dividends in Oman. News, Stories & Speeches | UNEP – UN Environment Programme. **https://www.unep.org/news-and-stories/story/mangrove-restoration-paying-dividends-oman**

Mangrove forest. Source photograph by Matheenulla Khan; visual by Omnia Moussa.

Coastal and Marine Ecosystem Restoration

Coastal caves and seaview, El Haouaria, Tunisia. Source photograph by Envato; visual by Egyptian Broadcast Systems.

The Arab region is home to a wide range of coastal and marine ecosystems that support rich and diverse flora and fauna. These ecosystems provide critical environmental, social, and economic benefits while maintaining natural ecological balance, but they are highly sensitive to climate change impacts. Additionally, coastal cities are at severe risk of sea level rise and are facing growing threats from flooding, saltwater intrusion and shoreline erosion, especially in river deltas.

NbS offer significant potential to address these challenges, by stabilising ecosystem chains and habitats, as well as protecting cities from storm surges and sea level rise. They also generate economic benefits for local communities whose livelihoods depend on healthy coastal systems. This chapter provides 11 case studies from across the Arab region, including mangrove planting, coral reef rehabilitation, and natural shoreline stabilisation and protection.

32. Marine Protected Areas (MPAs), Morocco

Location	Al Hoceima National Park/Mar Chica Lagoon, Morocco
Existing Ecosystems	Marine, coastal and inland water ecosystems
Climate Change Challenges	Biodiversity loss
NbS Approach	Development of coral and artificial reefs, use of biodegradable bulrush creels

Context

The establishment of marine protected areas (MPAs) such as Al Hoceima National Park, Mar Chica Lagoon, and areas along the Alborán Sea focuses on restoring marine ecosystems, protecting biodiversity, and sustaining fish stocks. These MPAs apply ecosystem-based management and mitigation strategies, ensuring a balance between resource use and conservation.

Only 1.1% of Morocco's territorial waters, extending to its Exclusive Economic Zone, are designated as MPAs. These coastal protected areas are classified under IUCN Category VI, which focuses on the sustainable use of natural resources. Their primary purpose is to maintain fishery sustainability and support the recovery of fish stocks.

Applied NbS Methods

Al Hoceima National Park

Al Hoceima National Park, covering 48,460 ha on Morocco's Mediterranean coast, is the country's most important marine protected area, home to rare species and red coral. The park faces threats from climate change, pollution, and destructive illegal fishing practices such as dynamite fishing, drift nets, and bottom trawling, which degrade habitats and reduce fish stocks.

To address these challenges, AGIR (Association de Gestion Intégrée des Ressources) was created in 2008 to promote sustainable marine resource management. Key actions included enforcement and monitoring through community surveillance and geo-location devices to reduce trawling, alongside policy changes banning dynamite fishing and drift nets. Restoration efforts involved coral and artificial reef rehabilitation, creation of 2,000 ha of no-take zones, and restoration of 900 ha of shallow reefs. Livelihood improvements included forming sustainable fishing cooperatives, supporting women-led cooperatives producing eco-friendly gear, and providing infrastructure such as cold storage and refrigerated transport. Over 2,000 fishers received training in maritime safety, cooperative management, and sustainable practices.

As a result, illegal fishing practices have significantly declined, and marine biodiversity has shown signs of recovery, with marine resources increasing by an estimated 20–30% and 1,900 hectares of coastal and marine ecosystems now under protection. The

ban on destructive fishing methods reduced cetacean bycatch by 70%, while habitat restoration improved species populations, with osprey nesting up by 10% and fish catch for birds increasing by 20%. These environmental gains were matched by socioeconomic benefits: poverty among 1,200 artisanal fishers dropped by 30%, and local cooperatives generated over €650,000 in revenue. Economic resilience improved through income diversification, enhanced fish quality and value, and expanded market access, while gender equality advanced as women gained leadership roles and economic opportunities.

AGIR's integrated approach has restored marine ecosystems and strengthened community livelihoods, positioning Al Hoceima as a model for NbS in marine conservation.

Sources

- Institut Royal des Études Stratégiques (IRES). (2023). Marine Protected Areas (Focus No. 18, p. 82). https://www.ires.ma/iip/wp-content/uploads/2023/04/18-Focus-p.82-Marine-Protected-Areas.pdf
- United Nations Development Programme. (2019). Association de Gestion Intégrée des Ressources (AGIR), Morocco. Equator Initiative Case Study Series. New York, NY. https://www.equatorinitiative.org/wp-content/uploads/2019/11/AGIR-Morocco.pdf
- Association de Gestion Intégrée des Ressources (AGIR). (2013). Rapport final global: Appui et accompagnement à la création/post création d'activités génératrices de revenus et de coopératives des pêcheurs néo-alphabétisés au sein du littoral du Rif central et oriental Marocain. PANORAMA| Solutions for a Healthy Planet. https://panorama.solutions/sites/default/files/rapport-final-projet-agir_-app.pdf
- UNESCO. (2023, January 20). Preserving the ecosystem of the Al Hoceima National Park Marine Protected Area. Newsroom| UNESCO. https://www.unesco.org/en/articles/preserving-ecosystem-al-hoceima-national-park-marine-protected-area
- Regional Activity Center for Specially Protected Areas (RAC/SPA). (n.d.). Al Hoceima. RAC/SPA. https://www.rac-spa.org/sites/default/files/doc_spamis/spamis/12_hoceima.pdf

33. Dakhla-Oued Ed-Dahab Aquaculture Development, Morocco

Location	Bay of Dakhla-Bay of Cintra, Morocco
Existing Ecosystems	Marine, coastal and inland water
Climate Change Challenges	Pressure on marine biodiversity
NbS Approach	Shellfish farming, restoration of marine biodiversity.

Context

The Dakhla-Oued Ed-Dahab Aquaculture Development project in Morocco, implemented under the Halieutis Plan, spans 6,556 hectares across three key zones: the Bay of Dakhla, Bay of Cintra, and the area between these two bays. It includes the development of 878 aquaculture production units for farming species such as oysters, clams, and abalone. This initiative has been designed to balance economic development with environmental conservation, generating 3,350 direct jobs and producing 115,450 tons of aquaculture products annually. It incorporates innovative systems for water filtration, spawning, and nursery management while integrating sustainability throughout its operations.

Applied NbS Methods

By cultivating species that support ecosystem health (like filter-feeding shellfish), the project reduces pressure on wild fish stocks and contributes to the restoration of marine biodiversity. These practices align with the ecosystem approach to aquaculture, which integrates environmental sustainability into aquaculture.

The project mitigates climate impacts by enhancing coastal ecosystems' ability to adapt to environmental stressors. Shellfish farming, for example, contributes to water filtration and sediment stabilization, which are critical for maintaining marine ecosystem services.

By creating jobs and promoting sustainable aquaculture practices, the project strengthens local communities' resilience to economic and environmental challenges.

Sources

- MoroccoTomorrow. (2016, February 10). Morocco: HM The King Inaugurates Aquaculture Farm in Oued Ed-Dahab. MoroccoTomorrow. **https://moroccotomorrow.org/morocco-hm-the-king-inaugurates-aquaculture-farm-in-oued-ed-dahab/**

34. The Martil Artificial Reef Project, Morocco

Location	Southeast of Negro Cape, Morocco
Existing Ecosystems	Marine and coastal ecosystems
Climate Change Challenges	Marine biodiversity loss
NbS Approach	Artificial Reef

Context

In Morocco, fishing activities are a critical component of the national economy. However, the country's fishery resources are currently in a fragile state. The coastal strip faces numerous anthropogenic pressures, including poor resource management and extensive destruction of natural habitats, which have significantly damaged the marine environment. It has been established that all Moroccan fisheries resources have reached the stage of full exploitation. As such, it is imperative to preserve and enhance marine resources to ensure their sustainable and beneficial use for current and future generations. Artificial reefs have emerged as essential components of integrated fishery and aquatic management plans across various countries.

Artificial reefs can be classified into three types:

- **Productive Economic Reefs**: Designed to create biodiversity, increase biomass, and enhance marine resources for sustainable fishing.
- **Environmental Protection Reefs:** Focused on mitigating damage caused by trawling.
- **Recreational Reefs:** Developed to support activities such as diving.

Artificial reefs, typically constructed from concrete to mimic natural reef systems, aim to enrich marine environments and enhance biodiversity. In some regions, shipwrecks are also used for similar purposes.

Applied NbS Methods

To raise awareness about the importance of preserving coastal marine ecosystems, Morocco's Ministry of Agriculture and Fisheries and the National Institute for Research in Marine Fisheries collaborated to design and develop the Martil Artificial Reef project. Implemented in December 2011 as part of the "Plan Halieutis" strategy for marine fisheries development, the project received funding of 37.5 million dirhams from the Fisheries Development Fund.

This initiative aims to ensure sustainable coastal development, conserve natural resources, and sustain human coastal activities. The Martil Artificial Reef, located southeast of Negro Cape, approximately 1 km from the coast, spans a total area of 52 hectares (730 x 770 meters) on a sandy seabed at depths ranging from 21 to 40 meters. The reef was strategically placed to take advantage of

the seabed slope, creating a reef area along a bathymetric gradient.

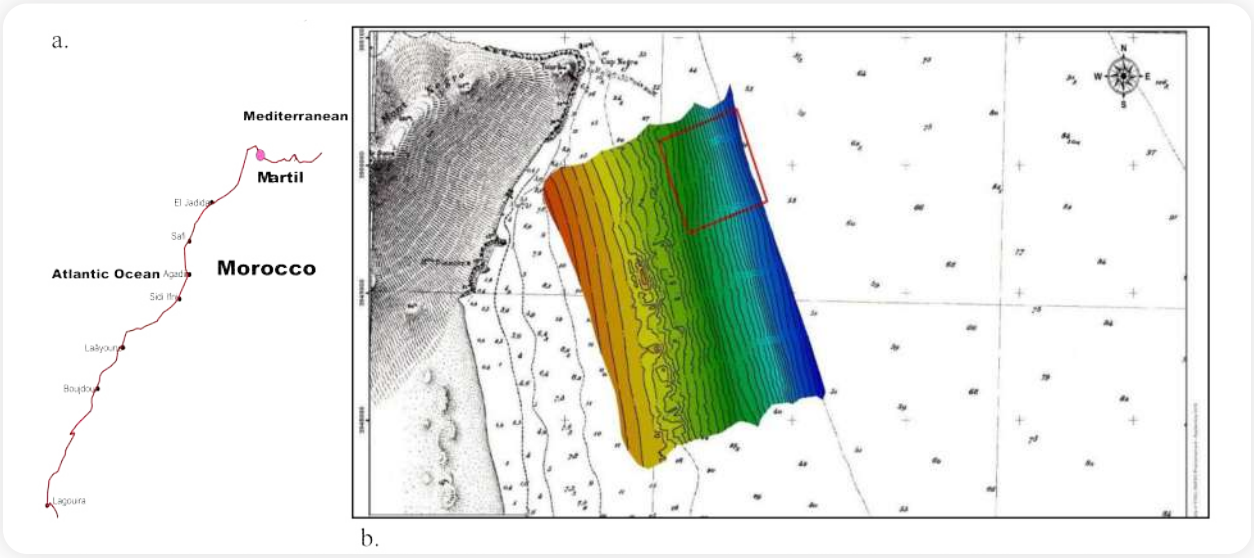
Deployed in 2012, the Martil Artificial Reef was designed to enhance traditional fisheries, protect biodiversity, and combat illegal trawling. Its architecture incorporates two types of structural units: the production reef unit and the protection reef unit. The production reef unit consists of cubic concrete blocks (1.5 m³) with perforations on four sides and a central part to increase resistance and colonizable surface area. The protection reef unit uses tetrapods, grouped in sets of five, with a total underwater weight of 7 tons, serving as a physical barrier against illegal trawling.

The reef is arranged into two ellipsoidal circles: a median circle at 25 meters depth and a deeper circle at 40 meters depth. Each circle includes an external belt of 22 clustered tetrapods and an internal belt of 22 chaotic pyramids composed of 36 cubic blocks. Studies have shown a positive correlation between structural complexity and fish abundance. At the center of the internal belt are 12 chaotic pyramids of 36 cubic blocks, along with a grid of 17 individual cubic units. The two circles are connected by a corridor comprising two rows of 10 clusters of tetrapods.

The Martil Artificial Reef program is the first of its kind on Morocco's western Mediterranean coast. It was developed with an integrated management strategy for local fishery resources and has been subject to scientific monitoring since its immersion. The project aimed to assess the fish population within two years of deployment. Results revealed a significant increase in biodiversity, with the reef transitioning from very few rare species pre-deployment to 16 species, seven of which are permanent residents. Visual census data showed that the observed fish species richness aligns with other Mediterranean artificial reefs.

More than half of the observed species hold commercial value for local fisheries. To support reef development, a decision was made to prohibit fishing in the area for three years post-deployment. However, local fishermen continued to use the area despite the restriction.

Figure 56 Location of the Martil artificial reef (Mediterranean)

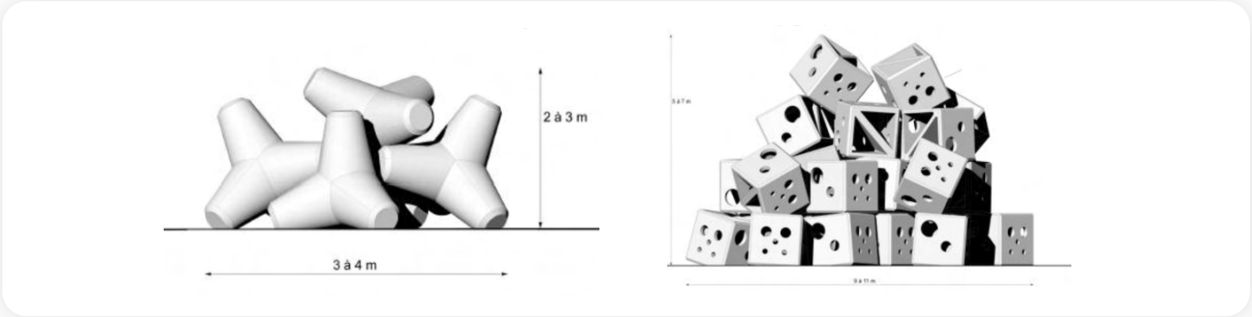


Note. a.: Artificial reef site, b. immersion zone. From El mdari m., idhalla m., tamsouri n., kaddioui a., nhalla h., hilmi k., el hamoumi r. (2018, September 21). Analysis of fish community at the first artificial reef in Morocco (Martil, Mediterranean). International Journal of Advanced Research (IJAR). 726-735] (ISSN 2320-5407). https://dx.doi.org/10.21474/IJAR01/7730

After two years, the Martil Artificial Reef provided increased shelter and heterogeneity due to its production unit architecture. The reef also offered new trophic resources, as evidenced by the colonization of invertebrate fauna and the presence of cephalopod eggs, indicating reproductive activity.

The Martil Artificial Reef project demonstrates how artificial structures can effectively rehabilitate marine ecosystems, protect biodiversity, and promote sustainable fisheries.

Figure 57 Martil artificial reef structure units characteristics and architecture

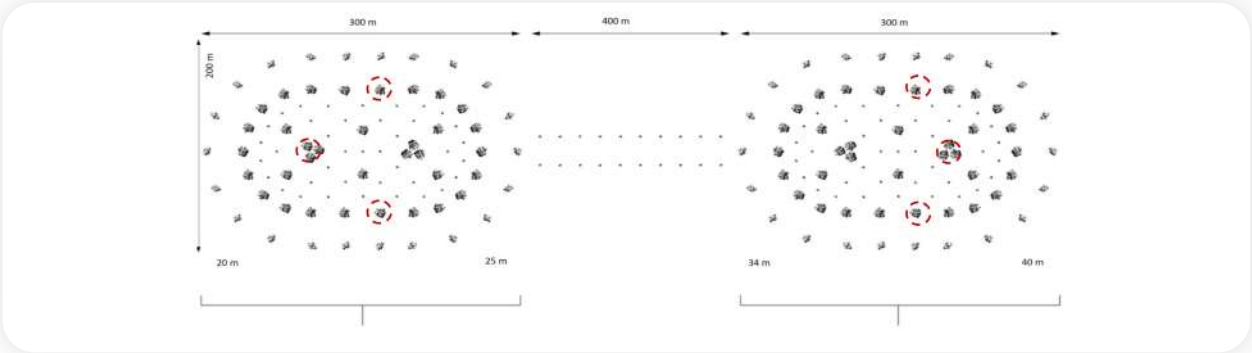


A: protection unit; a cluster of 5 tetrapods

B: protection unit; a chaotic pyramid of 36 cubic blocks

Note. From El mdari m., idhalla m., tamsouri n., kaddioui a., nhalla h., hilmi k., el hamoumi r. (2018, September 21). Analysis of fish community at the first artificial reef in Morocco (Martil, Mediterranean). International Journal of Advanced Research (IJAR). 726-735] (ISSN 2320-5407). https://dx.doi.org/10.21474/IJAR01/7730

Figure 58 Artificial reef of Martil Architecture and Sampling Plan; 6 circled pyramids



Note. From El mdari m., idhalla m., tamsouri n., kaddioui a., nhalla h., hilmi k., el hamoumi r. (2018, September 21). Analysis of fish community at the first artificial reef in Morocco (Martil, Mediterranean). International Journal of Advanced Research (IJAR). 726-735] (ISSN 2320-5407). https://dx.doi.org/10.21474/IJAR01/7730

Sources

- Mohamed Tafraouti. (2023, April 25). Artificial Reefs in Northern Morocco: An Underwater Oasis to Protect Marine Biodiversity. Earth.Org – Environmental News. https://earth.org/artificial-reefs-morocco/
- El mdari m., idhalla m., tamsouri n., kaddioui a., nhalla h., hilmi k., el hamoumi r. (2018, September 21). Analysis of fish community at the first artificial reef in Morocco (Martil, Mediterranean). International Journal of Advanced Research (IJAR). 726-735] (ISSN 2320-5407). https://dx.doi.org/10.21474/IJAR01/7730

35. Protecting the Environment and Biodiversity in Algeria's Coastal Regions (PEBLA), Algeria

Location	Algeria
Existing Ecosystems	Coastal ecosystem
Climate Change Challenges	Ecosystem degradation
NbS Approach	Integrated Coastal Zone Management (ICZM)

Context

Algeria's coastline spans 2,148 kilometers, featuring pristine natural landscapes rich in biodiversity. However, urban expansion, industrial development, and overexploitation of marine resources have increasingly disrupted coastal ecosystems. In response to these growing environmental challenges, in 2015, Algeria adopted its Integrated Coastal Zone Management (ICZM) Strategy 2020–2030, with aim of protecting marine habitats while ensuring sustainable use, balancing economic development with ecological conservation, and preserving Algeria's coastal and marine heritage.

Applied NbS Methods

Protecting the environment and biodiversity in Algeria's coastal regions (PEBLA) project builds on the ICZM strategy. Implemented by GIZ in partnership with IUCN and GFA Consulting Group, with support from the Ministry of the Environment and Renewable Energies, Algeria, and funded by German Federal Ministry for Economic Cooperation and Development (BMZ), the project aims to improve the environmental, economic, and planning conditions for ICZM. Key actions of the project include:

- Updating the National Strategy and developing a budgeted action plan that is now in progress,
- Providing guidance to partner organizations on data management, geographical information systems, and communication,
- Enhancing the skills of resource users, including entrepreneurial and technical training, to support ecosystem services.

Additionally, to improve the management of protected coastal areas, the project has focused on capacity-building for administrative staff and civil society organizations, as well as developing methodological and technical guidelines for the management of marine and coastal reserves.

Consequently, this Algerian-German cooperation led to the designation of Monts de l'Edough as a protected area in September 2023, conserving critical habitats for both coastal and inland ecosystems. The project also involves identifying new coastal and marine protected areas, potentially designating them as national parks, and updating the status of existing protected areas.

The project through its holistic approach of integrating sustainable coastal management, biodiversity protection, and economic development, promotes Algeria's resilience and ensures that marine ecosystems remain viable while supporting local communities.

Sources

- Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). (2024, February). Protecting the environment and biodiversity in Algeria's coastal regions. Giz.de. **https://www.giz.de/en/worldwide/141889.html**

Coast in Annaba Annaba, Algeria. Source photograph by Ondrej Bocek. Visual by Omnia Moussa

36. Enhancing Climate Change Adaptation in the North Coast and Nile Delta Regions Project (ECCADP), Egypt

Location	Governorates in the Nile Delta and across the North Coast in Egypt (Port Said, Damietta, Dakahlia, Kafr El-Sheikh and Beheira)
Existing Ecosystems	Coastal, inland water (lakes, canals, and drainage basins) and terrestrial (Agricultural lands, vegetated dunes, and riverbanks within the Nile Delta) ecosystems
Climate Change Challenges	Sea-level rise and coastal flooding, increased frequency and intensity of storms, and salinization of land and water resources
NbS Approach	Using traditional reed fences, native vegetation, and dune-mimicking soft dikes to naturally stabilize the coastline, reduce flooding, and restore ecosystems

Context

Egypt's Nile Delta and North Coast are among the most climate-vulnerable regions in the world. Identified as an "extreme climate hotspot," the area faces severe risks from sea level rise, coastal erosion, salinization, and increasingly frequent and intense storm events. A projected 1-meter rise in sea level could submerge up to 20% of the Delta, threatening agriculture, freshwater resources, infrastructure—including the strategic international coastal road—and the livelihoods of millions living in this densely populated and economically vital region. The Delta alone contributes approximately 20% of Egypt's GDP.

In response to these escalating risks, the Egyptian Ministry of Water Resources and Irrigation, with support from the United Nations Development Programme (UNDP) and funding from the Green Climate Fund (GCF), launched the Enhancing Climate Change Adaptation in the North Coast and Nile Delta Regions in Egypt Project (ECCADP) in 2019. With a total GCF grant of US$31 million, the seven-year project runs through 2026 and aims to reduce coastal flood risk across five vulnerable governorates. The project focuses on integrated and sustainable coastal protection measures, including the construction of low-cost dikes along 69 kilometers of coastline. These structures are designed to replicate natural dune systems using reed fences, native vegetation, and recycled dredged materials, contributing to both flood defense and ecosystem restoration. ECCADP directly supports the resilience of approximately 17 million people and protects critical infrastructure, agricultural lands, and economic assets along Egypt's northern coast

Applied NbS Methods

The ECCADP incorporates a suite of innovative and cost-effective NbS designed to protect Egypt's most climate-vulnerable coastal areas. Central to the

project is the large-scale deployment of soft coastal protection systems, modeled on traditional methods and enhanced through scientific refinement and environmental planning.

A core NbS intervention under ECCADP is the construction of soft-engineered dikes across 69 kilometers of highly exposed shoreline. These dikes are built to mimic natural sand dunes, using reed fences to trap windblown sand and facilitate dune formation. Initially based on traditional local practices, these reed fence systems were piloted, tested, and refined over a year before being scaled up under the project. To stabilize the formed dunes, the project employs native vegetation and locally sourced dredged sediments, repurposing materials from nearby sites in an environmentally sound manner. This approach offers a sustainable alternative to hard infrastructure, such as concrete sea walls, and enhances ecosystem function while reducing coastal erosion and flood risk.

These soft dike systems not only serve as physical barriers against storm surges and sea level rise but also contribute to dune ecosystem restoration, support biodiversity, and enhance natural coastal resilience. The interventions directly benefit over 768,000 people living in immediate high-risk zones and contribute to the protection of up to 17 million individuals across the broader Nile Delta region by safeguarding infrastructure, agricultural land, and freshwater resources.

In parallel with these physical measures, ECCADP advances a broader Integrated Coastal Zone Management (ICZM) framework, which serves as the institutional and planning backbone for long-term coastal resilience. This includes the development of a climate-resilient coastal management plan, strengthening legal and institutional frameworks, integrating ecological and socio-economic data into decision-making, and establishing coastal observation and early warning systems. These efforts help mainstream adaptation into national governance structures and ensure that coastal planning accounts for long-term risks, including sea level rise and increased storm intensity.

The ECCADP's NbS approach aligns closely with Egypt's NDCs under the Paris Agreement, as well as the country's GCF Country Work Programme. Implemented by the Ministry of Water Resources and Irrigation, in partnership with the Shore Protection Authority, the Coastal Research Institute, UNDP, and the GCF, the project demonstrates how nature-based interventions can offer scalable, sustainable, and community-centered solutions to the growing impacts of climate change.

Traditional Reed Fences, Damietta, Egypt. Source photograph by Nermin Dessouky.
Visual by Omnia Moussa

Figure 59 Traditional Reed Fences in Damietta, Egypt

Note. (top left) Close-up of the fence showing fixation of the structure. (top right) Two consecutive fence walls installed on the sand dune. (bottom left) close-up of the reed fence. (bottom right) photo showing fence and sand dune with the sea in the background. Photos: Nermin Dessouky, UN-Habitat

Sources

- United Nations Development Programme (UNDP). (n.d.). Enhancing Climate Change Adaptation in the North Coast of Egypt. UNDP Climate Change Adaptation. **https://www.adaptation-undp.org/projects/enhancing-climate-change-adaptation-north-coast-egypt**
- United Nations Development Programme (UNDP). (n.d.). Enhancing Climate Change Adaptation in North Coast and Nile Delta in Egypt. UNDP. **https://www.undp.org/egypt/projects/enhancing-climate-change-adaptation-north-coast-and-nile-delta-egypt**
- Green Climate Fund (GCF). (n.d.). FP053: Enhancing Climate Change Adaptation in the North Coast and Nile Delta Regions in Egypt. Green Climate Fund. **https://www.greenclimate.fund/project/fp053**
- Enhancing Climate Change Adaptation in the North Coast and Nile Delta Regions in Egypt Project (ECCADP). (n.d.). Community Development Activities. **https://eccadp.com/en/activities**

37. Mangrove Ecosystem Restoration Solution (MERS), Egypt

Location	Hamata, Safaga, Halayeb and Shalateen in the Red Sea Governorate, Egypt
Existing Ecosystems	Coastal, marine and dryland ecosystems
Climate Change Challenges	Sea-level rise, increased coastal erosion, loss of marine biodiversity and decreased carbon sequestration capacity
NbS Approach	Mangrove reforestation and Green Infrastructure (through nature-based shoreline protection)

Context

The Mangrove Ecosystem Restoration Solution (MERS) is a five-year initiative launched in 2021 by HSBC in partnership with the Center for Applied Research on the Environment and Sustainability at The American University in Cairo as part of HSBC's Global Climate Solutions Partnership. It was developed to address increasing environmental pressures on Egypt's Red Sea coast, where vital Avicennia marina mangrove ecosystems have been degraded due to unsustainable coastal development, pollution, and climate change impacts such as sea level rise and increased salinity. This degradation has resulted in the loss of essential ecosystem services including shoreline stabilization, marine biodiversity support, and carbon sequestration.

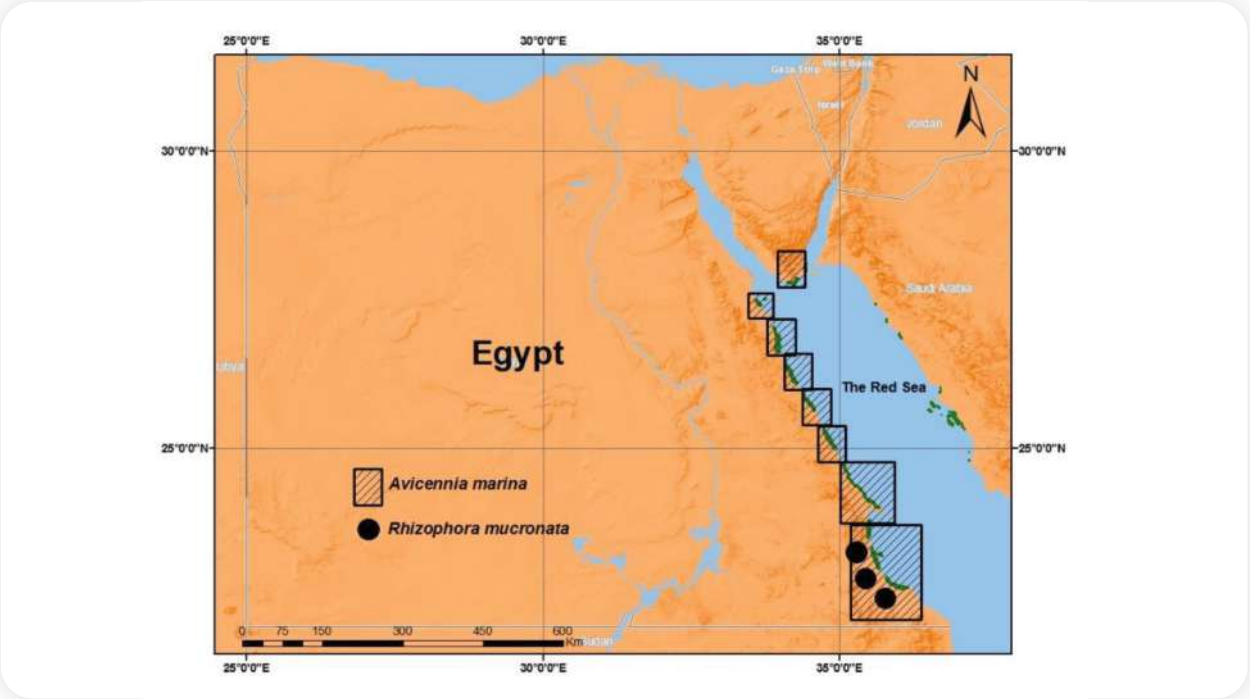
Spanning coastal areas from El Gouna to Shalateen, MERS adopts a nature-based restoration approach grounded in scientific research and aligned with Egypt's national climate goals and the UN Decade on Ecosystem Restoration (2021–2030). The project actively engages local communities in Hamata and Safaga through planting and stewardship activities, fostering sustainable livelihoods via conservation and eco-tourism. It also incorporates a GIS-based knowledge platform to support effective monitoring and adaptive management. By restoring mangrove forests, MERS aims to enhance both environmental and socio-economic resilience in the region.

Applied NbS Methods

MERS employs a comprehensive suite of NbS to address climate adaptation and mitigation challenges specific to Egypt's Red Sea coast. The core strategy involves the annual planting of 10,000 Avicennia marina seedlings, targeting 50,000 over five years, to restore degraded mangrove ecosystems. This restoration strengthens coastal resilience by stabilizing shorelines, reducing erosion, and providing natural defenses against sea level rise and storm surges. It also revitalizes biodiversity by recreating critical habitats for fish, birds, and marine invertebrates.

In addition to ecological benefits, MERS significantly contributes to climate change mitigation through enhanced carbon sequestration. Much of the carbon stored in Egypt's mangroves is held in soil sediments, and expanding mangrove coverage increases the landscape's capacity to capture and store carbon in both biomass and sediment, thus reducing greenhouse gas concentrations. The project further integrates community-based approaches by involving local residents in conservation efforts, environmental education, and the development of sustainable livelihoods such as eco-tourism and mangrove-based aquaculture. These solutions not only protect ecosystems but also support local socio-economic well-being, illustrating how ecosystem restoration can serve as a scalable, cost-effective tool for building resilience and sustainability.

Figure 60 Map locations of the two mangrove species that stand along the Red Sea and Gulf of Aqaba in Egypt



Note. From Afefe, A. (2021). Linking Territorial and Coastal Planning: Conservation Status and Management of Mangrove Ecosystem at the Egyptian - African Red Sea Coast. Aswan University Journal of Environmental Studies, 2(2), 91-114. doi: 10.21608/aujes.2021.65951.1013

Figure 61 Mangroves in Ras Muhammad Nature Reserve, South Sinai, Egypt

Note. From Hatem Moushir, 2017, "File: Ras Muhammad Protected Area, photo by Hatem Moushir 5.jpg" CC-BY-SA-4.0. Wikimedia Commons. **https://commons.wikimedia.org/wiki/File:Ras_Muhammad_Protected_Area_,_photo_by_Hatem_Moushir_5.jpg#filelinks**

Figure 62 Mangroves in Wadi Lahami, Red Sea, Egypt

Note. From Matt Kieffer, 2008, "Wadi Lahami mangrove swamp", CC BY-SA 2.0, Flickr. **https://www.flickr.com/photos/mattkiefer/2813691048/in/photostream/**

Sources

- The American University in Cairo – Center for Applied Research on the Environment and Sustainability. (n.d.). Mangrove Ecosystem Restoration Model. sse.aucegypt.edu. **https://sse.aucegypt.edu/centers-labs/cares/community-initiatives/mangrove-ecosystem-restoration**

38. Mangrove Restoration Project, Bahrain

Location	Tubli Bay, Manama, Bahrain
Existing Ecosystems	Coastal ecosystem
Climate Change Challenges	Sea level rise; rising temperatures and extreme heat
NbS Approach	Mangrove rehabilitation and restoration

Context and Applied NbS Methods

The mangrove restoration project in Bahrain focuses on rehabilitating and restoring mangrove habitats along the urban fringes of Manama. These efforts aim to create opportunities for recreation, ecotourism, and awareness while contributing to national climate mitigation and adaptation goals. Mangrove ecosystems play a critical role in biodiversity conservation, water filtration, and disaster mitigation. Coastal habitats like seagrass beds, mangroves, and mudflats are vital for carbon sequestration, making them essential for global climate change mitigation.

Tubli Bay, covering 13.5 square kilometers, is home to Bahrain's largest mangrove forest. Declared a protected area in 1995 and designated as a Ramsar Wetlands Site of International Importance in 1997, Tubli Bay represents a unique intersection of natural ecosystems and dense urban development, highlighting challenges and opportunities for integrating nature into urban planning.
A partnership between UN-Habitat and HSBC, launched in March 2023, aims to enhance Bahrain's urban coastal ecosystems for biodiversity, community well-being, and climate action. Funded by HSBC as part of its global Climate Programme, the project will rehabilitate and restore mangrove habitats in Tubli Bay, contributing to Bahrain's broader climate goals.

Project Key Objectives:

- Increase blue natural carbon sinks in Bahrain.
- Enhance and protect biodiversity and provide co-benefits for urban communities through nature-based activities.
- Support socio-economic documentation of coastal ecosystems, identifying barriers and opportunities for scaling up similar actions nationally.

The project aligns with Bahrain's goal to quadruple mangrove coverage by 2035, supporting ongoing efforts by the Supreme Council for the Environment and the Ministry of Municipalities Affairs and Agriculture. The construction of a visitor center at Ras Sanad in Tubli Bay will further promote community engagement and environmental education.

Benefits include:

- Strengthened urban coastal ecosystems for climate mitigation and adaptation.
- Increased recreational and ecotourism opportunities.
- Enhanced community well-being and connection to the marine environment.

Sources

United Nations in Bahrain. (2023, March 13). HSBC, UN-Habitat partner to save Bahrain's mangroves. https://bahrain.un.org/en/236327-hsbc-un-habitat-partner-save-bahrain%E2%80%99s-mangroves

Mangrove Tree. Source photograph by Bernd Dittrich. Visual by Omnia Moussa

39. Mangrove Restoration Initiatives in the UAE

Location	Abu Dhabi, UAE
Existing Ecosystems	Coastal ecosystem
Climate Change Challenges	sea level rise, coastal erosion, habitat loss and degradation
NbS Approach	Mangrove forests restoration

Context

Mangroves are a crucial component of UAE's coastal ecosystem, providing numerous ecosystem services such as carbon sequestration, erosion control, and provision of vital nursery habitats for marine and terrestrial species. The grey mangrove (Avicennia marina) is the most prominent of the mangrove species, capable of thriving in the region's saline conditions.

Despite their ecological significance, mangrove habitats have faced steady decline due to land reclamation, dredging, coastal construction, and the worsening impacts of climate change. Recognizing the urgency of conservation, the UAE has positioned itself as a regional leader in mangrove restoration, launching ambitious programs to protect and expand these ecosystems.

Applied NbS Methods

UAE's mangrove forests cover approximately 13,615 hectares, with 79.5% of these located in Abu Dhabi, largely due to the restoration efforts initiated in the 1990s. The initiatives focus on rehabilitating degraded areas, increasing mangrove coverage, and enhancing biodiversity.

One of the most significant projects is the one led by the Marine Studies Unit of the Abu Dhabi Marine Studies Center (AMSC) at Abu Al Abyad Island. This unit operates intertidal nurseries, producing over 1.2 million mangrove plants annually, covering 5,026 hectares across Abu Al Abyad Island, Ras Ghanada, and Yasat Island. Additionally, 3,020 hectares have been reclaimed and prepared for future planting.

Besides restoring grey mangrove habitats, efforts have been made to reintroduce red mangroves (Rhizophora mucronata). In 2008, the Marine Studies Unit successfully germinated seeds imported from Pakistan, cultivating them in open intertidal zones and existing grey mangrove forests. The seedlings thrived, some reaching 2.25 meters in height, flowering in September and October, and producing fruit. This successful endeavor revived a species once extinct in the region, opening doors for further diversification and ecosystem enhancement.

Mangrove restoration plays a key role in UAE's broader environmental strategy, promoting climate resilience, biodiversity conservation, and sustainable coastal management. Combining large-scale planting programs, native species reintroduction efforts, and ecosystem restoration, the UAE is not only safeguarding its natural heritage but also strengthening its ability to adapt to evolving environmental challenges.

Sources

- Omer Mohamed Yousif, Krishnakumar Krishnankutty Menon, Sumitro Sen. (2022, July 18). Marine ecosystem restoration and aquaculture-based stock enhancement for fishery resource conservation in Abu Dhabi Emirate, United Arab Emirates. World Journal of Advanced Research and Reviews. 15, 382–390. https://doi.org/10.30574/wjarr.2022.15.1.0717

Jubail Mangrove Park, Abu Dhabi, UAE. Source photograph by Vivek Vg. Visual by Omnia Moussa

40. Coral Reef and Sea Grass Restoration, UAE

Location	Abu Dhabi, UAE
Existing Ecosystems	Coastal Ecosystem
Climate Change Challenges	Environmental degradation and habitat loss
NbS Approach	Ecological Restoration through: Coral Reef Restoration, Seagrass Restoration, Artificial Coral Reefs Construction

Context

The Arabian Gulf's coral reefs and seagrass habitats form a resilient yet highly vulnerable marine ecosystem. These habitats endure extreme environmental conditions, including significant temperature fluctuations and high salinity levels, making their survival remarkable. However, despite their adaptability, they face increasing threats as a result of climate change, pollution, and human activity, leading to habitat degradation.

Currently, 44 coral species in the UAE are listed as near threatened or vulnerable on the IUCN Red List. Key species such as Boulder corals (Porites spp.) and Branching corals (Acropora spp.) play a vital role in supporting marine biodiversity, including the critically endangered Hawksbill turtle. However, with mounting pressures from environmental and human activities, less than half of Abu Dhabi's coral reefs still contain living corals, covering only 310.66 km². In addition to coral reef decline, seagrass habitats, which provide essential ecosystem services such as carbon sequestration and sustenance for the world's second-largest dugong population (Dugong dugon), are also under pressure. Given these environmental concerns, restoration efforts have been launched to protect and rehabilitate these ecosystems.

Applied NbS Methods: Coral Reef and Seagrass Restoration Efforts

To combat habitat degradation, the Environment Agency – Abu Dhabi has undertaken comprehensive conservation initiatives, including mapping coral reef distribution and implementing a long-term coral reef conservation plan. These efforts have already shown promising signs of reef resilience and regeneration.

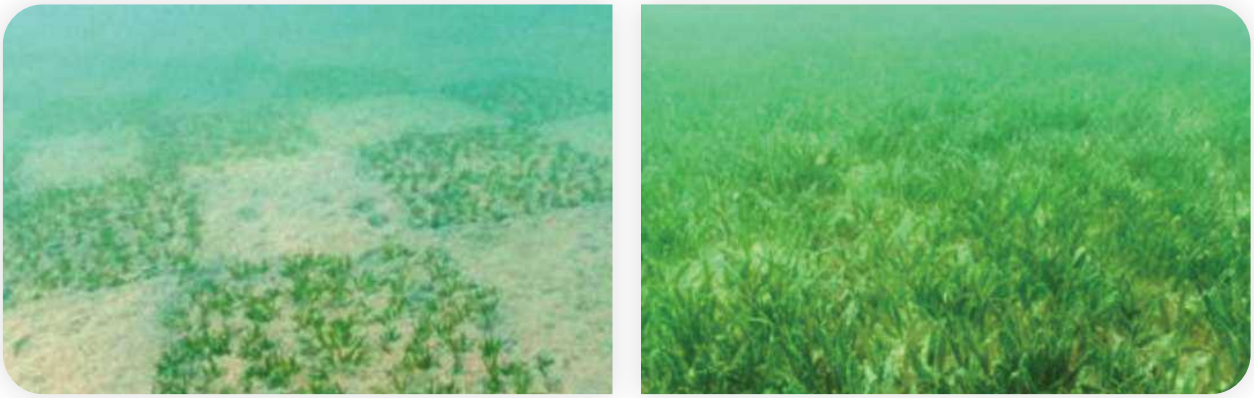
One of the most ambitious restoration programs began in 2009, when the Abu Dhabi Marine Studies Center launched a coral restoration initiative at Abu Al Abyad Island. By 2016, the program had successfully cultured over 7,500 corals in more than 150 nursery units, achieving an impressively low mortality rate of under 5%. These nursery-grown corals were later transplanted into degraded reef sites, resulting in the restoration of 20,000 corals

over a 0.3-hectare area by 2017. The project further expanded in 2021, when an additional 2,500 m² of coral nurseries at Abu Al Abyad Island and Yasat Island were established, incorporating diverse coral species such as Cyphastrea spp., Psammocora spp., Acropora spp., and Porites spp.. In addition to transplantation, the initiative also involved constructing artificial reefs using three-dimensional structures, including steel frames and building blocks, providing new habitats for reef-dwelling fish.

Parallel to these efforts, seagrass restoration programs have played a crucial role in the stabilization of marine ecosystems. Since 2009, scientists have worked to restore seagrass meadows, despite the initial challenges resulting from the lack of standardized restoration methods in the Arabian Gulf. By refining methodologies, the program successfully established 2,500 m² of seagrass meadows, in place of previously barren sandy seafloors. These restored habitats, primarily composed of Halodule uninervis, Halophila stipulacea, and Halophila ovalis, help support fish populations, sustaining marine biodiversity, and function as blue carbon sinks, contributing to climate change mitigation.

Through the integration of scientific research, large-scale ecosystem restoration, and adaptive management strategies, the coral reef and seagrass restoration efforts emphasize the UAE's commitment to sustainable marine conservation. These projects serve as a blueprint, highlighting the importance of preserving biodiversity, mitigating climate change impacts, and enhancing ecosystem resilience across the Arabian Gulf.

Figure 63 Seagrass Restoration in Abu Al Abyad, Abu Dhabi, UAE



Note. From Omer Mohamed Yousif, Krishnakumar Krishnankutty Menon, Sumitro Sen. (2022, July 18). Marine ecosystem restoration and aquaculture-based stock enhancement for fishery resource conservation in Abu Dhabi Emirate, United Arab Emirates. World Journal of Advanced Research and Reviews. 15, 382–390. https://doi.org/10.30574/wjarr.2022.15.1.0717

Figure 64 Reefballs in Al Yasat Island, Abu Dhabi, UAEI

A) coral transplantation on reefballs in Al Yasat Island

B) fish congregation in reefballs

Note. From Omer Mohamed Yousif, Krishnakumar Krishnankutty Menon, Sumitro Sen. (2022, July 18). Marine ecosystem restoration and aquaculture-based stock enhancement for fishery resource conservation in Abu Dhabi Emirate, United Arab Emirates. World Journal of Advanced Research and Reviews. 15, 382–390. **https://doi.org/10.30574/wjarr.2022.15.1.0717**

Sources

- Omer Mohamed Yousif, Krishnakumar Krishnankutty Menon, Sumitro Sen. (2022, July 18). Marine ecosystem restoration and aquaculture-based stock enhancement for fishery resource conservation in Abu Dhabi Emirate, United Arab Emirates. World Journal of Advanced Research and Reviews. 15, 382–390. **https://doi.org/10.30574/wjarr.2022.15.1.0717**

Coral Reefs. Visual by Egyptian Broadcast Systems

41. Mangrove Restoration Efforts, Qatar

Location	Qatar
Existing Ecosystems	coastal ecosystem
Climate Change Challenges	Sea level rise, coastal erosion and environmental degradation
NbS Approach	Mangrove Restoration

Context

Qatar's coastal environment is home to diverse marine ecosystems that provide critical ecological functions, including mangrove forests, seagrass beds, and coral reefs. However, these habitats face increasing threats due to climate change, coastal development, and environmental degradation. Protecting and restoring these ecosystems is essential for enhancing marine biodiversity, preventing coastal erosion, and supporting sustainable fisheries. Given their interconnected nature, an integrated approach to conservation can amplify their benefits, ensuring long-term resilience and environmental sustainability.

Applied NbS Methods

To address these challenges, the Qatar Ministry of Environment and Climate Change, in partnership with Qatar University and Qatar Foundation, has launched a comprehensive national program supported by the MSC Foundation. This initiative focuses on developing a scalable model for conserving and restoring coastal ecosystems by strategically managing mangrove forests, seagrass beds, and coral reefs..

By studying the interactions between these habitats, the program aims to identify the most effective methods for ensuring their health and maximizing their ecological contributions.

The initiative integrates NbS to bolster Qatar's marine environment. Its primary goals include:

1. Strengthening marine biodiversity and sustainable fisheries
2. Implementing coastal erosion protection measures
3. Expanding ecotourism opportunities
4. Supporting sustainable development through ecosystem restoration

These conservation efforts build upon existing environmental initiatives in Qatar, such as: The Al-Reem Biosphere Reserve (established in 2005), which includes significant mangrove habitats, and the Ras Laffan mangrove planting and conservation program (launched in 2012), which contributes to habitat restoration and coastal stability.

By leveraging scientific research and collaborative strategies, this initiative reinforces Qatar's commitment to environmental resilience and long-term sustainability. Through mangrove restoration, seagrass preservation, and coral reef protection, the program promotes ecological balance. Furthermore, it fosters economic benefits through conservation strategies that enhance Qatar's marine biodiversity and fisheries, protect against coastal erosion, create opportunities for ecotourism, and promote sustainable development through a nature-based approach.

Sources

- Mohan, M., Dutta Roy, A., Montenegro, J.F., Watt, M.S., Burt, J.A., Shapiro, A., Ouerfelli, D., Daniel, R., de-Miguel, S., Ali, T., Ortega Pardo, M., Al Sayah, M., Aboobacker, V.M., El Beyrouthy, N., Reef, R., Adrah, E., AlMealla, R., Arachchige, P.S.P., Selvam, P., Jaafar, W.S.W.M., Sujud, L., Bahzad, J., Alawatte, I., Hussein, S., López-Martínez, C., Sidik, F., Nithyanandan, M., Abdullah, M., Al-Khalid, M., Abulibdeh, A., Cardil, A., Chambers, J.Q. (2024, September 16). Mangrove forest regeneration age map and drivers of restoration success in Gulf Cooperation Council countries from satellite imagery. Remote Sensing Applications: Society and Environment 36, 101345. https://doi.org/10.1016/j.rsase.2024.101345
- MSC Foundation. (2022, November 13). Programme to conserve and restore Qatar's coastal ecosystems announced. News & Media Room | MSC Foundation. https://www.mscfoundation.org/news/qatar-foundation

Mangrove Forest. Visual by Egyptian Broadcast Systems

42. Ghuba Mangroves Restoration Project, Yemen

Location	Socotra, Yemen
Existing Ecosystems	Coastal and mangrove ecosystems
Climate Change Challenges	Coastal erosion; Extreme weather events e.g. cyclones
NbS Approach	Mangrove restoration, which is a type of ecosystem-based adaptation

Context and Applied NbS Methods

In Socotra, an archipelago Yemen, mangroves play a critical role in protecting its coastal ecosystem and providing livelihood opportunities, as well as other benefits to the local community. Mangrove ecosystems provide raw materials that are used by the locals as building materials and for fire-making. However, due to overgrazing, extensive logging and negative climate change impacts, the mangrove population has drastically decreased. For example, cyclones that hit the archipelago in 2015 and 2018 have caused extensive damage to mangroves.

In response to these challenges and hazards, the Ghuba Mangroves Restoration Project was launched in 2019 by the Arab Regional Centre for World Heritage, in collaboration with Friends of Soqotra and the Environment Protection Authority of Socotra. The project was implemented by a local Socotri NGO called the Al Tamek Association for the Protection of the Mangrove Tree, which was established to emphasize the importance of mangrove restoration within the Socotran Archipelago. The project focused on rehabilitating the mangrove ecosystem in the north coast of Socotra to address and minimize the destructive effects of coastal erosion. As one of the most effective carbon sinks, climate change mitigation was a co-benefit of the mangrove restoration efforts. Moreover, mangroves in Socotra are considered a critical habitat for many endemic species, including the Socotra Cisticola and Socotra Warbler, as well as endemic reptile species and shellfish.

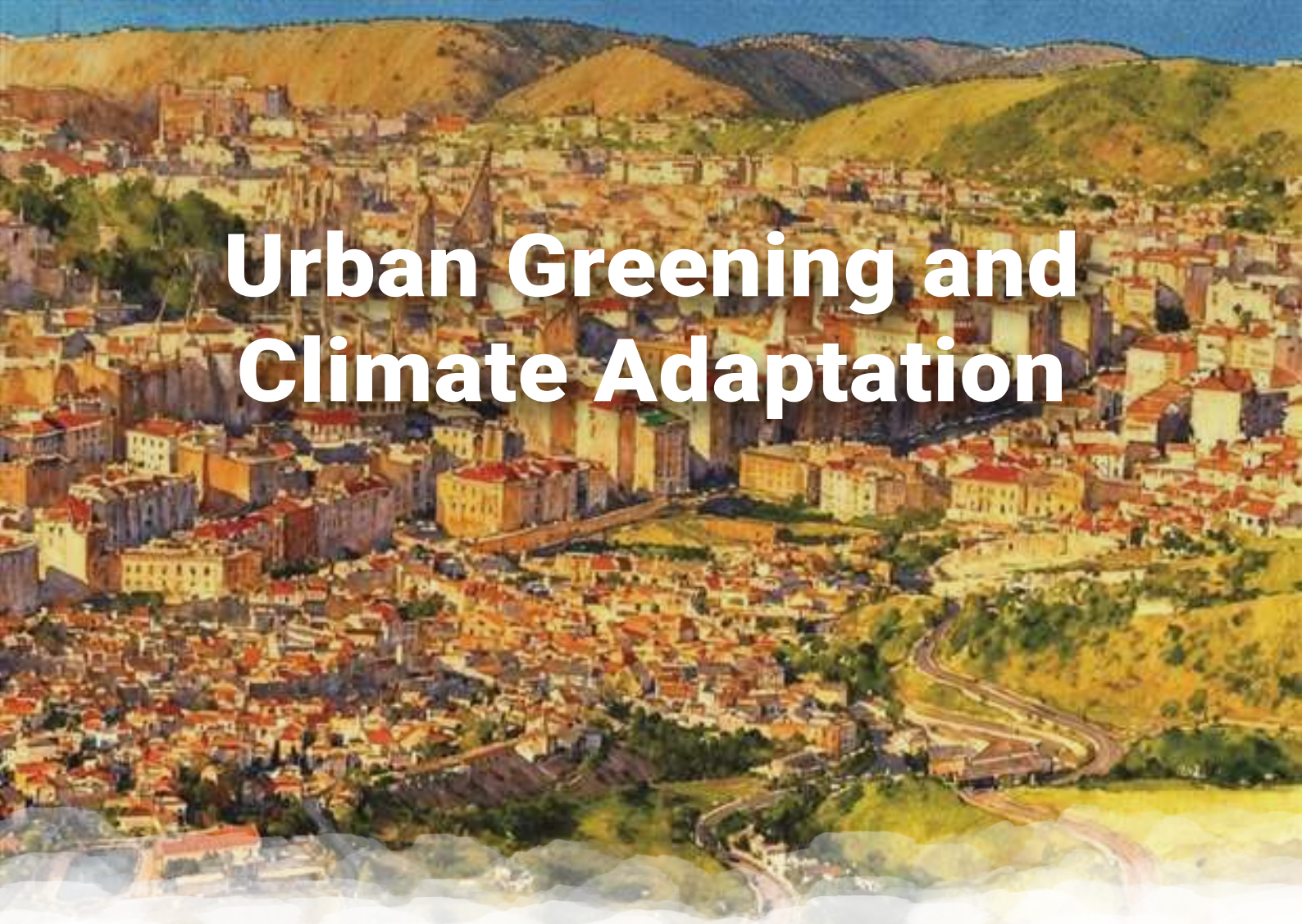
The project took a participatory and active engagement approach including the local community in the restoration and conservation efforts, with the aim of instilling the importance of mangrove conservation among the local community, especially youth. Through this approach, the project went beyond the physical restoration efforts highlighted the long-term benefits of mangrove ecosystems as vital habitats for various species, a significant disaster risk reduction measure and a critical contributor to community wellbeing.

Sources

- Arab Regional Centre for World Heritage. (n.d.). Ghuba Mangroves Restoration Project in Socotra – Phase I. Activities - Arab Regional Centre for World Heritage (ARC-WH). **https://arcwh.org/events/ghuba-mangroves-restoration-project-in-socotra-phase-i/arcwh.org+2arcwh.org+2arcwh.org+2**
- Arab Regional Centre for World Heritage. (2018, October 22). Ghuba Mangroves Restoration Project on Socotra Island. News - Arab Regional Centre for World Heritage (ARC-WH). **https://www.arcwh.org/ghuba-mangroves-restoration-project-on-socotra-island/**

Mangrove Trees. Source photograph by Bernd Dittrich. Visual by Omnia Moussa

Urban Greening and Climate Adaptation



Aerial drone view of Fes at sunset, Morocco. Source photography by Envato. Visual by Egyptian Broadcast Systems

Most countries in the Arab region contribute only marginally to global greenhouse gas (GHG) emissions, yet they are expected to be among the most severely affected by the impacts of climate change. Although climate impacts differ across countries, several shared vulnerabilities characterize the region. The Arab region is already marked by high temperatures, prolonged summers, and chronic water scarcity, all of which are only exacerbated by climate change. Rising temperatures and shifting climate patterns place mounting pressure on already stressed water resources, ecosystems, and infrastructure, adversely affecting agricultural productivity and public health while driving energy demand, and disrupting overall economic activity. Extreme weather events are becoming increasingly frequent, often manifesting as prolonged heatwaves and shorter yet more intense rainfall episodes. These sudden and severe incidents can overwhelm existing infrastructure, causing major disturbances and having great repercussions for the agricultural sector agriculture and food security. In addition, urban areas face a growing challenge from the Urban Heat Island effect, which exacerbates temperature extremes and further strains city environments.

Nature based Solutions (NbS) offer effective tools for enhancing urban climate adaptation. In city centers, interventions such as green roofs, urban forests, and other nature based cooling solutions help reduce heat stress, improve air quality, and increase access to green public spaces. This chapter highlights 20 case studies from across the Arab region that focus on urban greening and climate adaptation strategies. These examples include the development of urban parks, rooftop and community based urban agriculture, as well as large scale afforestation and city greening initiatives.

43. Bouskoura-Merchich Forest Development, Morocco

Location	Casablanca, Morocco
Existing Ecosystems	Forest and urban ecosystems
Climate Change Challenges	Desertification
NbS Approach	Urban Forests and greening

Context

The Bouskoura-Merchich Forest Development Project is a landscaping and recreational development initiative aimed at rehabilitating the Bouskoura-Merchich Forest, located in the Casablanca suburbs, approximately 20 kilometers from the city center. Covering an area of 29.92 square kilometers, the forest is one of Casablanca's key green spaces, often referred to as the city's "green lung." The forest is predominantly covered with eucalyptus trees, spanning 11.87 square kilometers, and plays an important role in local forestry operations.

The project is part of the Greater Casablanca Development Plan 2014-2020, which aims to create a healthy and secure environment for visitors and forest users.

Applied NbS Methods

The initiative seeks to meet the growing demand for recreational spaces while ensuring the sustainable management of the forest ecosystem. The development is designed to balance ecosystem preservation with public access, and it is divided into four major spatial sectors:

1. **The Little Canton (The Active Forest):** This area is designed for sports and leisure, featuring four playgrounds with 27 units covering 7,483 square meters. Additional amenities include a reception area, 17.2 kilometers of pedestrian and bicycle tracks, a restaurant, eight sanitary blocks, an 800-meter pathway, and five access points.
2. **The Laboratory Forest:** This section focuses on raising awareness about the forest ecosystem. It includes a playground, an ecological education center with eight buildings, a house of agriculture, an ecological garden, two reception areas, and sanitary facilities.
3. **The Forest of Discovery:** Serving as a space for knowledge about the forest's fauna and flora, this area contains ten tree shelters, a sensory path, a recreational clearing, two reception areas, sanitary facilities, a rest area, and a playground.

4 The Young Forest:
Representing the forest's biorhythm, this area features a lookout tower, various circuits and equipment, an adventure park, and a house dedicated to the "big forest."

In addition to these ecological and recreational zones, the project includes the development of facilities for the Royal Gendarmerie's equestrian division and three brigades: the Dog Brigade, the Bicycle Brigade for the Royal Gendarmerie, and the Teams Brigade for the Auxiliary Forces.

The project is owned and developed by the High Commission for Water and Forests and the Fight Against Desertification, with funding provided by multiple entities: $4 million from the Ministry of Interior, $4 million from the High Commission for Water and Forests and the Fight Against Desertification, and $3 million from the Casablanca-Settat region. The contractor responsible for implementing the project is Casa Aménagement, a public limited-liability company established in October 2008 following the Master Plan for Urban Development for the Grand Casablanca Region.
The Bouskoura-Merchich Forest Development Project is expected to attract a wide range of visitors, including individuals, families, and athletes. The recreational and ecological areas offer a variety of spaces for relaxation, play, and exercise, with particular appeal to cyclists and runners due to the extensive pedestrian and bicycle tracks. The development is designed to serve as a key destination for both the local population and visitors from surrounding neighborhoods, enhancing urban livability and promoting sustainability.

The project's master plan was developed by a consortium consisting of the Carey Duncan studio, Fadel El Guerraoui, and Arep Ville.

Figure 65 Bouskoura-Merchich Forest

Note. (left) From Milamber's portfolio, n.d., "Bouskoura's forest, Casablanca, Morocco" photograph, CC BY-NC-ND 2.0. Flickr https://www.flickr.com/photos/milamber/2124765929 (right) From Milamber's portfolio, n.d., "Bird in Bouskoura forest, Morocco", photograph, CC BY-NC-ND 2.0, photograph. Flickr **https://www.flickr.com/photos/milamber/170311196**

Sources

- Arab Urban Development Institute. (n.d.). The Bouskoura-Merchich Forest Project. Projects - Arab Urban Development Institute. **https://araburban.org/en/infohub/projects/?id=7686**
- Casa Aménagement (Casablanca Development). (n.d.). Development of the Forest of Bouskoura Merchich. **https://www.casa-amenagement.ma/en/nos-projets/foret-de-bouskoura-merchich**

44. Oued Smar Urban Park, Algeria

Location	Algiers, Algeria
Existing Ecosystems	Urban ecosystem
Climate Change Challenges	Environmental degradation, high temperatures and pollution
NbS Approach	Rehabilitation of a former landfill into an ecological and recreational space

Context

As cities expand, former industrial sites and landfills, once on the outskirts of the cities, become a health and environmental hazard to urban dwellers. The Oued Smar Landfill was no different, posing serious challenges to the city of Algiers from pollution and odor emissions to ecological degradation. Operational since 1978 until its closure in 2011, it was one of the largest waste sites in the city of Algiers, reaching 45 meters in height. The site's deterioration affected nearby communities, prompting a comprehensive transformation project aimed at mitigating its environmental impact and repurposing it into a functional green space. In alignment with Algiers' Green Plan for 2035, the Oued Smar Urban Park was designed to eliminate pollution, promote ecotourism, and provide recreation opportunities for the city's rapidly growing eastern suburbs.

Applied NbS Methods

Oued Smar Urban Park is an urban transformation project, repurposing Algiers' largest former landfill into a recreational and ecological space. Covering an area of 0.5 square kilometers, the park's plan includes 0.2 km² of tree cover, 0.11 km² of natural grass, 0.09 km² of pedestrian and cycling pathways, and dedicated areas for irrigation and infrastructure support. The rehabilitation process consisted of reshaping the landfill and replanting vegetation with 23 native species to stabilize the terrain and restore soil health, as well as the construction of roads and cycling paths for accessibility. The park includes an exhibition center and a landfill museum, 20 wooden canopies, 350 benches, 5 food outlets, public restrooms and a parking facility for 2,500 vehicles.

Additionally, a biogas collection system was installed to utilize landfill emissions in generating usable renewable energy. Biogas extracted from the landfill powers the entire park, including 220 streetlamps.

Water is produced through waste osmosis treatment, supported by a leachate treatment system with 127 wells with a total capacity 720 m³/day. A 400-meter-deep well ensures a reliable water supply, complementing the drip and sprinkler irrigation system, backed by two 150-cubic-meter water tanks.

The Oued Smar Urban Park demonstrates how former landfills can be repurposed into functional, green urban spaces, blending environmental restoration, social activities, and renewable energy utilization.

Figure 66 Map showing Oued Smar Urban Park Before and After Implementation

Note. (left) Oued Smar Urban Park site in 2011, a closed landfill. Map data: Google Earth, Maxar Technologies. (right) Oued Smar Urban Park, 2024. Map data: Google Earth, Airbus.

Figure 67 Oued Smar Urban Park Top View

Note. Map data: Google Earth, Airbus, 2024

Sources

- Arab Urban Development Institute. (n.d.). The Oued Smar Urban Park. Projects - Arab Urban Development Institute. https://araburban.org/en/infohub/projects/?id=7911

45. The Green Belt of Algiers, Algeria

Location	Algiers, Algeria
Existing Ecosystems	Urban ecosystem
Climate Change Challenges	Air quality, high temperatures and desertification
Complementary NbS Type	Agroecology and Sustainable Land Management
NbS Approach	Urban greening

Context

Rapid urbanization in Algiers has placed increasing pressure on agricultural land, biodiversity, and air quality, prompting the need for sustainable urban planning solutions. Green infrastructure not only enhances environmental health but also promotes social well-being by providing recreational spaces, improving air quality, and mitigating climate change effects. In recognition of these benefits, the Green Belt of Algiers was launched in 2016 as part of a broader environmental initiative, integrating green spaces into the urban fabric while reinforcing the Green Dam anti-desertification program.

Applied NbS Methods

The Green Belt of Algiers strategically incorporates Agro Parks, public gardens, and allotment spaces to create a continuous green zone encircling the capital. It aligns with the Urban Management Plan for the Algiers Region, initially introduced in 2010 and updated in 2015, ensuring long-term environmental balance and climate resilience. The project aims to protect agricultural land from urban expansion, create natural recreational spaces for residents, enhance air quality and reduce CO_2 emissions, promote biodiversity through green zones, and restore ecological connectivity in degraded areas.

The project is designed to be implemented in phases, with early efforts focusing on enhancing existing parks, while ongoing efforts involve tree planting, public awareness campaigns, and expanding green spaces to ensure long-term environmental sustainability.

The first phase of the project features two primary types of green spaces. Public gardens, such as the Tafourah Public Garden (inaugurated in 2016) and Sofia Garden, offer urban dwellers accessible recreational areas. Additionally, 23 Agro Parks have been established in urban and peri-urban areas, including Reghaïa, Rouiba, and Dely Ibrahim. These parks incorporate agricultural zones with diverse tree species, such as orange, loquat, and vineyards. Notable examples include Kheraïssia Park, with an area of 3.72 square kilometers, and Cheraga Park, spanning 5.6 square kilometers.

In addition to green space enhancement and expansion, the project places strong emphasis on biodiversity conservation and rehabilitation of degraded ecosystems as well as fostering local community engagement. Residents, non-profit organizations, and farmers are all actively involved in tree planting and vegetation management, reinforcing the program's outreach and long-term sustainability. The project operates under a collaborative framework, led by the Algerian government, regional authorities, and local municipalities. Funding sources include national and regional budgets, alongside non-financial contributions such as land, labor, and expertise from state services and engaged citizens.

The Green Belt of Algiers represents an exemplar model for climate adaptation and ecological resilience, contributing to healthier and more sustainable urban environments in Algeria.

Sources

- Arab Urban Development Institute. (n.d.). The Green Belt of Algiers. Projects - Arab Urban Development Institute. **https://araburban.org/en/infohub/projects/?id=7909**
- Urban Nature Atlas. (2021, October). The Green Belt of Algiers. Urban Nature Atlas. **https://una.city/nbs/algiers/green-belt-algiers**

Bainem Forest, Algiers, Algeria. Source photograph by Abderrahmane Chablaoui. Visual by Omnia Moussa

46. Urban Agriculture, Tunisia

Location	Great Tunis Region, Tunisia
Existing Ecosystems	Urban ecosystem
Climate Change Challenges	Food insecurity
NbS Approach	Community gardens for food production

Context

Great Tunis Region is facing growing food security concerns, exacerbated by the combined effects of the Ukrainian-Russian war and the lingering impacts of the Covid-19 pandemic. These challenges are particularly pronounced in municipalities with high poverty rates and vulnerable populations, including homeless individuals and migrant communities. The disruption of global supply chains has led to increased food shortages and rising costs, disproportionately affecting those with limited access to essential resources. In response to this crisis, local and international organizations have collaborated to assess food security risks and implement solutions aimed at strengthening resilience and ensuring equitable food distribution.

Applied NbS Methods

UN-Habitat, in partnership with the United Nations Economic Commission for Africa and the UN Resident Coordinator's Office, is assisting the Tunisian government in evaluating and addressing food security challenges in the Great Tunis region. In 2023, the organization launched the project "Uncovering the Effects of the Ukrainian-Russian War: Anticipating and Preparing for the Impact of the Ukrainian-Russian War on Food Security in Tunisia," whose goal is to raise awareness among local decision-makers, civil society, and citizens regarding food insecurity while facilitating direct support to those most in need, particularly within Tunis and La Marsa. As part of broader efforts to improve food sovereignty and sustainable urban agriculture, the initiative integrates into the AfriFOODlinks program, coordinated by Hivos in collaboration with local partners and the Observatory of Food Sovereignty and the Environment.

One of the standout elements of the program is the community vegetable garden in Jbal Lahmer (Red Mountain), a densely populated neighborhood in Tunis. This initiative revitalizes underutilized spaces like Belvédère Park, transforming neglected urban areas into productive and sustainable gardens. The community vegetable garden is currently run by 30 residents of Jbal Lahmer, most of whom are unemployed, with a significant number of women involved. For these individuals, the garden represents not just a source of fresh vegetables, but a step toward food sovereignty, providing both financial and nutritional benefits.

Unlike many short-term initiatives, this project ensures long-term sustainability by placing

Figure 68 Urban Farming in Belvedere Park, Tunis, Tunisia

Note. (left) Siwar Arfaoui, one of the beneficiaries participating in planting an urban vegetable garden in Belvedere park, Tunis. (right) Head of UN-Habitat in Tunisia and Siwar Arfaoui participating in planting an urban vegetable garden. From UN-Habitat. (2023, June 26). Addressing food security among Tunisia's vulnerable grounds and migrants. News and Stories | UN-Habitat. https://unhabitat.org/news/27-jul-2023/addressing-food-security-among-tunisias-vulnerable-grounds-and-migrants

management responsibilities directly in the hands of the local community. With support from the National Gene Bank, participants receive training in agroecology (environmentally sustainable agriculture), equipping them with essential skills to maintain and expand the garden beyond the project's duration.

Beyond its agricultural benefits, the initiative integrates educational and psychological support through organizations like Réseau Enfants de la Terre, fostering a sense of social responsibility among participants. The garden is expected to yield its first harvest in early 2025, demonstrating the potential of community-led urban agriculture in addressing food security challenges.
Furthermore, the project facilitates food aid distribution. Carried out through a transparent and inclusive process, food aid distribution is conducted through a web-based application that helps connect vulnerable communities with food resources, ensuring that assistance reaches those most affected by economic and supply-chain disruptions. Aligning with UN-Habitat's urban inclusion policy, which focuses on leaving no one behind, particularly homeless people and migrants, and recognizes their role in fostering local cohesion and social change, the project has benefited approximately 1,000 individuals, including migrant populations and at-risk groups, who have been either reached through the web application or identified through local NGOs.
This project serves as a model for sustainable urban agriculture, inspiring similar efforts across Tunisia under the AfriFOODlinks initiative. Through coordinated collaboration between local governments, organizations, and community members, the initiative strengthens food sovereignty, social cohesion, and environmental sustainability. By integrating both emergency food aid distribution and long-term agricultural resilience strategies, UN-Habitat's approach provides a comprehensive response to food security concerns, helping Tunisia build a more resilient and inclusive future.

Sources

- Hivos. (n.d.). Tunis' new community garden is planting seeds of change for residents. Hivos - People Unlimited. https://hivos.org/story/tunis-new-community-garden-is-planting-seeds-of-change/
- UN-Habitat. (2023, June 26). Addressing food security among Tunisia's vulnerable grounds and migrants. News and Stories | UN-Habitat. https://unhabitat.org/news/27-jul-2023/addressing-food-security-among-tunisias-vulnerable-grounds-and-migrants

47. The Dignified Life Initiative Rooftop Urban Agriculture in Gharbia and Cairo Governorates, Egypt

Location	Rural villages in Gharbiah Governorate and multiple urban districts in Cairo Governorate, Egypt
Existing Ecosystems	Cultivated and urban systems
Climate Change Challenges	Water scarcity, land degradation, and urban heat island effects
NbS Approach	Rooftop urban agriculture

Context

In response to escalating rural poverty, diminishing agricultural land, and intensifying climate stress, the Egyptian government launched the Haya Karima (Dignified Life) initiative in 2020. This comprehensive rural development program is a cornerstone of Egypt Vision 2030, aiming to improve quality of life, expand access to basic services, and promote sustainable development in the country's most vulnerable communities. With an initial investment of over EGP 295 billion, the initiative targets more than 18 million citizens across approximately 1,500 villages.

Within this framework, a pilot rooftop urban agriculture project was introduced in Gharbia Governorate, located in the agriculturally rich Nile Delta. The initiative focused on utilizing underused rooftop spaces in rural households, especially those with limited or no access to arable land. Ten households were equipped with rooftop cultivation systems, each costing around EGP 10,000. These systems included plastic boxes for vegetable growing, barrels for fruit plants and shrubs, and drip irrigation systems. The intervention aimed to enhance household food security, support climate-resilient farming practices, and promote low-cost, sustainable urban agriculture.

Complementing this rural pilot, a parallel initiative was launched in Cairo targeting densely populated urban neighborhoods and educational institutions. These efforts focused on integrating green infrastructure and urban farming techniques such as rooftop gardens and hydroponics to improve food production, environmental conditions, and awareness around sustainability in cities.

The rooftop agriculture projects align with Egypt's broader national priorities and contribute directly to several SDGs, particularly those focused on poverty reduction, zero hunger, and sustainable urban development.

Applied NbS Methods

The Dignified Life Initiative integrated innovative NbS by converting underutilized rooftop spaces into productive, climate-resilient micro-agricultural ecosystems in both rural and urban settings. In Gharbia Governorate, ten rural households were equipped with cultivation infrastructure comprising plastic planting boxes for vegetables, barrels for fruit shrubs, and drip irrigation systems. This approach enabled multi-layered vegetation growth and efficient water use, critical in Egypt's arid environment. Weekly agronomic supervision was provided, ensuring local capacity building and empowering residents to manage crop cycles, pest control, and system maintenance effectively.

In Cairo, the project employed a diversified set of NbS on green roofs in densely populated neighborhoods and educational institutions. These included traditional potted plants that provide thermal regulation and aesthetic benefits, plastic boxes designed for vegetable cultivation, and advanced hydroponic systems utilizing the Nutrient Film Technique. This hydroponic method enhances water efficiency and crop productivity by circulating nutrient-rich water in a closed loop, reflecting an adaptive approach tailored to urban constraints and resource availability.

Together, these systems demonstrate a practical, scalable application of NbS principles by restoring ecological functions such as food production, microclimate regulation, and water conservation within built environments. The initiative exemplifies how low-cost, small-scale urban and peri-urban agriculture can bolster local food security, reduce environmental stress, and build household resilience to climate variability. The integration of technical support alongside infrastructure delivery was fundamental in transitioning beneficiaries into active stewards of their rooftop ecosystems, ensuring long-term sustainability.

Sources

- Desouki, M., Madkour, M., Abdeen, A. et al. Multicriteria decision-making tool for investigating the feasibility of the green roof systems in Egypt. Sustain Environ Res 34, 2 (2024). https://doi.org/10.1186/s42834-024-00207-z
- Ministry of International Cooperation (MOIC). (2024, December 8). The Ministry of Planning, Economic Development, and International Cooperation issues a report on the executive status of the first phase of the presidential initiative "Haya Karima" until the end of November. Ministry of International Cooperation – Latest News. https://moic.gov.eg/news/1870

Urban gardening. Source photograph by Jonathan Kemper. Visual by Omnia Moussa

48. Shaduf's Green Solutions Initiative, Egypt

Location	Cairo, Egypt
Existing Ecosystems	Urban ecosystems
Climate Change Challenges	Water Scarcity, Urban Heat Island Effect and Air Pollution
NbS Approach	Green Rooftop Gardens (Vertical farming, Hydroponic Systems, Soil-Based Systems and Aquaponics)

Context

The Shaduf Green Solutions Initiative was developed in response to the complex socio-economic and environmental challenges faced by Cairo's informal and low-income urban districts, including neighborhoods such as Sakiet Mekky, Ezbet Naser, Maasarah, Dar El-Salam, and Helwan. These areas are characterized by dense construction, minimal public green space, and high poverty rates. Climate change factors—such as rising temperatures, water scarcity, and increased air pollution—have further compounded vulnerabilities, contributing to food insecurity and limited access to affordable fresh produce. Within this challenging environment, Shaduf identified unused rooftops as an opportunity to create productive, ecological spaces. The initiative aims to empower residents by providing modular, water-efficient farming systems paired with training and ongoing technical support. This NbS targets both environmental resilience and social equity by enabling low-income families to cultivate food locally and sustainably.

Applied NbS Methods

Building on this context, Shaduf implemented modular hydroponic and soil-based rooftop farming units starting in 2011 in Maadi and surrounding neighborhoods. These systems supported the cultivation of lettuce, chicory, herbs, molokhia, and other leafy greens, with ongoing trials of aquaponics technologies to enhance productivity. Installation, training, and agronomic supervision were provided free of charge, with users repaying through a share of their crop yields over time, ensuring economic sustainability.

From 2018 to 2021, the Rooftop Urban Farming Project in Helwan, funded by the Swiss-based DROSOS Foundation, expanded this approach by establishing 500 hydroponic rooftop farms in Helwan and adjacent low-income settlements. Designed to maximize water savings through soil-less systems, these farms produced crops well suited to Egypt's water-scarce climate, including molokhia and lettuce. Families contributed approximately 5% co-payment, while Shaduf covered installation costs (~12,000 EGP per unit) and

training for over 850 participants, including young girls, household members, engineers, and supervisors. Bi-monthly harvests improved food security and incomes, complemented by a packaging and drying unit to support market entry. In total, the initiative yielded approximately 157,500 servings of fresh produce annually, impacting an estimated 2,000 people in the Helwan region. The project also contributed to increased urban greenery, improved air quality, and enhanced community resilience through capacity building and environmental stewardship.

Figure 69 Schaduf Green Solutions

Note. (left) A new hydroponic growing system, growing directly in the supermarket - a hydroponic refrigerator grows different types of lettuce directly in the shop, ready to sell once the growth cycle is complete. This ensures freshness of the leafy greens, as they're only removed from the growing medium to be directly used by a customer. (right) A standalone wall garden, with a table farm unit to its left. Photo: Omnia Moussa, 2024, UN-Habitat's field visit to Schaduf

Sources

- Schaduf. (n.d.). Helwan Project. **https://schaduf.com/projects/helwan-project/**
- Arab Urban Development Institute. (n.d.). Rooftop Urban Farming Project in Helwan. Projects - Arab Urban Development Institute. **https://araburban.org/en/infohub/projects/?id=4041**
- DROSOS Foundation. (n.d.) Rooftop Farming. **https://drosos.org/en/projekte/rooftop-farming/**

49. Urban Gardening, A Source of Hope and Livelihood in Refugee Camps, Iraq

Location	Domiz Refugee Camp, northern Iraq
Existing Ecosystems	Urban ecosystem
Climate Change Challenges	Rising temperatures; water scarcity
NbS Approach	Urban agriculture; urban greening; community gardens

Context and Applied NbS Methods

Domiz Refugee Camp, located between Mosul and Duhuk in the Kurdish region of northern Iraq, was established in 2012 to accommodate approximately 2,000 refugees. Over time, the camp's population has surged to over 40,000, predominantly housing Syrians forcibly displaced by war. Initially consisting of fragile tents, the camp has evolved into a settlement with sturdier breezeblock shelters, interspersed with fruit trees, herbs, vegetables, and spice gardens, transforming the environment into a more sustainable and livable space.

The Lemon Tree Trust, a UK-based nonprofit organization, has been instrumental in enabling innovative greening and urban agriculture in refugee camps across Iraq, Jordan, and Uganda. The Trust primarily focuses on capacity-building, providing financial support and supporting already existing agricultural activities in camps. Its operations in Iraq are fully staffed by refugees from the camps, emphasizing local partnerships and participation. This approach not only creates employment and income opportunities but also reduces reliance on external donors. By empowering refugees to cultivate their own food gardens, the Trust enables them to actively shape their livelihoods, fostering creativity, productivity, and sustainability. This self-sustaining model ensures the continuation of greening efforts beyond the involvement of the Trust's staff.

Urban agriculture also plays a significant role in empowering women within refugee camps. Women, often left behind while their husbands seek work elsewhere, benefit from training programs that provide employment, food security, and a sense of purpose. Additionally, agroforestry initiatives in and around the camp reduce reliance on firewood collected from distant locations, mitigating the risks of sexual assault during such trips. By cultivating wood locally, these initiatives enhance safety and offer social protection for vulnerable women.

Another intervention promoted by the Lemon Tree Trust is community gardening, which fosters social cohesion, education, and small business development. For instance, one of the refugees who started a small plant nursery, expanded his business with the Trust's support. The organization supplied seeds and seedlings and encouraged greening across the camp, increasing demand for his plants.

One of the challenges to urban agriculture in refugee camps is the perception of gardens as symbols of permanence, which contradicts the transient nature

often associated with refugee camps. However, the co-founder of the Lemon Tree Trust argues that camps often become "accidental cities," with refugees staying for 15 to 20 years on average. As such, integrating urban agriculture during the initial construction of camps is both appropriate and necessary. This proactive approach allows inhabitants to start planting immediately, avoiding the challenges of retrofitting agriculture into limited spaces later on.

For the approximately 65 million people living in refugee situations globally, one-third of whom facing protracted periods of uncertainty, gardens offer more than just food and income. They provide beauty, hope, and a sense of home in difficult circumstances. Khalid, a refugee in Domiz who created an aviary and garden, describes how tending to his birds and plants brings him joy and helps him momentarily forget his status as a refugee.

Sources

- Schulze, H. (2018, January 15). Greening Iraq's refugee camps: "This garden is my kingdom". Food Tank. https://foodtank.com/news/2018/01/greening-iraqs-refugee-camps-urban-agriculture/

Urban gardening. Source photograph by Jonathan Kemper. Visual by Omnia Moussa

50. Improving Living Conditions in Disadvantaged Areas of Amman (ILCA), Jordan

Location	Amman, Jordan
Existing Ecosystems	Urban and cultivated systems
Climate Change Challenges	Urban heat waves, poor air quality, biodiversity loss flooding and soil pollution.
NbS Approach	Urban green spaces and Urban forests

Context

The Improving Living Conditions in Disadvantaged Areas of Amman (ILCA) project (2017–2021), funded by BMZ (€5M) and implemented by GIZ with the Jordanian Ministry of Environment and Greater Amman Municipality (GAM), aimed to improve urban life in East Amman through public open spaces and green infrastructure (GI).

East Amman suffers from dense unplanned development, limited green areas (2.5% of city coverage), poor connectivity, and restricted access to services like transport and waste management. These conditions create flooding, soil and air pollution, urban heat islands, and biodiversity loss—issues worsened by climate change and disproportionately affecting vulnerable groups.

ILCA demonstrated how GI and green spaces can mitigate these challenges while promoting social cohesion and climate resilience.

Applied NbS Methods

Phase 1: Pilot Interventions

The first phase focused on implementing practical green infrastructure solutions across three pilot sites in East Amman. These interventions transformed neglected spaces into functional public areas by adding shaded recreational spots with benches and amenities, renovating public staircases to enhance safety and connectivity, and introducing greenery to unused open spaces. Sidewalks and footpaths were widened to improve accessibility, while playgrounds were upgraded to ensure safety for children and better access for the elderly and people with disabilities. Collectively, these measures aimed to reduce urban heat, stabilize soil, minimize pollution, and strengthen social cohesion by actively involving local communities in the planning and design process.

Phase 2: Expansion and Replication

Successful pilots were replicated in new locations and integrated into urban planning.

Phase 3: Capacity Building

A handbook, “Stepwise Implementation Strategy: 11 Steps for Participatory Green Infrastructure Projects,” guided GAM staff on participatory planning. Workshops and engagement sessions ensured local input and institutional capacity building.

Urban Micro-Lungs Initiative

This initiative focused on transforming underutilized urban spaces, such as traffic islands and roundabouts, into small urban forests using the Miyawaki Method. Its primary goals were to enhance urban livability, build climate resilience, and support biodiversity.

This initiative focused on transforming underutilized urban spaces, such as traffic islands and roundabouts, into small urban forests using the Miyawaki Method. Its primary goals were to enhance urban livability, build climate resilience, and support biodiversity. Two pilot plots, each between 100 and 250 square meters, were afforested with climate-appropriate species through a process that included soil preparation, collaborative planting with community members, and a maintenance phase lasting two to three years to ensure sustainability. The initiative also included training programs for municipal staff and public awareness campaigns to promote green infrastructure. It was implemented by GIZ in collaboration with the Ministry of Environment, Greater Amman Municipality, and TAYYUN Research Studio, with funding from BMZ.

Sources

- Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). (2021, October). Improving green infrastructure in Amman. Giz.de. https://www.giz.de/en/worldwide/83767.html
- C40 Cities. (2019, June). Improving living conditions in poverty-stricken areas in Amman by implementing green infrastructure. Case Studies Archive – C40 Cities. https://www.c40.org/case-studies/improving-living-conditions-in-poverty-stricken-areas-in-amman-by-implementing-green-infrastructure/
- Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). (2021, August). Stepwise Implementation Strategy: 11 Steps for participatory green infrastructure projects. Giz.de. https://www.giz.de/en/downloads/giz-2022-en-Implementation%20Strategy.pdf
- International Association of Horticultural Producers (AIPH). (2022). Green city case study: Amman, Jordan. https://aiph.org/green-city-case-studies/amman-jordan/
- Arab Urban Development Institute. (n.d.). Improving Living Conditions in Disadvantaged Areas of Amman. Projects Arab Urban Development Institute. https://araburban.org/en/infohub/projects/?id=7572
- Miyawaki, A. (1999). Creative ecology: Restoration of native forests by native trees. Plant Biotechnology. 16(1), 15-25. https://doi.org/10.5511/plantbiotechnology.16.15
- Mauvais, L. (2022, June 1). In Jordan, the Middle East's first Miyawaki-style 'baby' forests take root. Mongabay. https://news.mongabay.com/2022/06/in-jordan-the-middle-easts-first-miyawaki-style-baby-forests-take-root/
- Deema Assaf. (2020, December 22). Urban micro-lungs: Mini-forests for climate, biodiversity & wellbeing. Urbanet: Expert Platform for Sustainable Urban Development. https://www.urbanet.info/urban-micro-lungs-mini-forests-for-climate-biodiversity-wellbeing/
- Arab Urban Development Institute. (n.d.). Urban Micro-lungs Initiative. Projects - Arab Urban Development Institute https://araburban.org/en/infohub/projects/?id=3981
- International Association of Horticultural Producers (AIPH). (2022). Green city case study: Amman, Jordan. https://aiph.org/green-city-case-studies/amman-jordan/
- Arab Urban Development Institute. (n.d.). Improving Living Conditions in Disadvantaged Areas of Amman. Projects Arab Urban Development Institute. https://araburban.org/en/infohub/projects/?id=7572
- Urban Nature Atlas. (2023, March). Urban Micro-lungs. https://una.city/nbs/amman/urban-micro-lungs
- Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). (2021, February). Urban Micro-Lungs Implementation Manual. https://www.giz.de/de/downloads/giz2021_en_ar_UML%20MANUAL.pdf
- United Nations Development Programme. (2024, October 31). UNDP Jordan and Greater Amman Municipality launch Jordan's first urban farming training centre. Jordan - United Nations Development Programme https://www.undp.org/jordan/press-releases/undp-jordan-and-greater-amman-municipality-launch-jordans-first-urban-farming-training-centre
- GIZ. (2021, March 30). The Urban-Micro Lungs Initiative in Amman, Jordan [Video]. YouTube. https://www.youtube.com/watch?v=TfjYKkqiOcQ

51. Community-based Urban Garden in Queen Rania Park, Jordan

Location	Amman, Jordan
Existing Ecosystems	Urban and cultivated systems
Climate Change Challenges	Food Insecurity
NbS Approach	Community urban garden, urban agriculture

Context

The Inclusive, Safe, Resilient, and Sustainable Development in Urban Areas Hosting Syrian Refugees in Jordan and Turkey project focuses on strengthening the capacities of local and national authorities to promote sustainable urban development in refugee-hosting areas. It aims to address fragmented, short-term approaches by equipping governments, humanitarian organizations, and NGOs with tools, knowledge, and skills to enhance urban governance. The project emphasizes integrating sustainability and environmental priorities into urban development strategies while ensuring inclusivity and gender sensitivity.

Applied NbS Methods

A key initiative under this project is the establishment of a community urban garden at Queen Rania Al Abdullah Park in the Al Qwiesmeh District of Amman, Jordan. The garden demonstrates the potential of NbS and multifunctional green infrastructure to foster social cohesion, improve urban climate resilience, and provide vocational training for both refugees and host communities.

Prior to implementation, an extensive analysis of global and local urban gardening practices was conducted. This research explored various community garden models, identifying their benefits, challenges, and best practices. It also included case studies and recommendations to ensure the urban garden aligns with sustainability objectives and serves as a replicable model for other urban areas. This initiative showcases the value of integrating long-term environmental and social goals into urban development efforts.

Figure 70 Community-based Urban Garden in Queen Rania Park

Note. From UN-Habitat Jordan. (2023, November 6). Explore the urban community garden at Queen Rania Al Abdullah Park and hear the participants' opinions [Video]. Facebook. **https://www.facebook.com/watch/?v=1812433209192432**

Sources

- UN-Habitat. (2022, December 13). Syrian refugees, host community train on urban gardening in Amman. News and Stories | UN-Habitat. **https://unhabitat.org/news/13-dec-2022/syrian-refugees-host-community-train-on-urban-gardening-in-amman**
- United Nations in Jordan. (2022, October 6). UNEP and UN-Habitat launch Community-based Urban Garden Project in Queen Rania Al Abdullah Park. **https://jordan.un.org/en/205409-unep-and-un-habitat-launch-community-based-urban-garden-project-queen-rania-al-abdullah-park**
- UN-Habitat Jordan. (2023, November 6). Explore the urban community garden at Queen Rania Al Abdullah Park and hear the participants' opinions [Video]. Facebook. **https://www.facebook.com/watch/?v=1812433209192432**

Urban farming. Visual by Egyptian Broadcast Systems

52. Urban Agriculture Initiatives, Jordan

Location	Amman, Jordan
Existing Ecosystems	Urban and cultivated systems
Climate Change Challenges	Scarce water resources
NbS Approach	Roof gardens, Community-Based Markets

Context

Urban agriculture in Amman faces significant challenges, including limited community engagement, reliance on paid labor instead of a cultural gardening practice, social and cultural barriers, scarce water resources, and restricted space for cultivation.

The mapping of urban agriculture sites in Jordan highlights the potential for urban farming despite these challenges. This initiative identifies areas suitable for agricultural activities, aiming to expand urban farming practices across the country.

Applied NbS Methods

Jadal for Knowledge and Culture Rooftop Garden
Located in downtown Amman, Jadal for Knowledge and Culture features a rooftop garden linked to its café. Designed by Greening the Camps in 2017 for 2,500 JD, the garden includes greenhouses for soil-based and hydroponic cultivation, and a composting bin. The project employs sustainable gardening techniques and fosters gradual transfer of care to Jadal's staff.

Community-Based Markets
Markets play a crucial role in supporting small food producers and promoting urban agriculture.

- **Nour Al Barakah Saturday Market:** This initiative, established in 2009, supports individuals with special needs and promotes planting as a therapeutic activity. Held in Princess Iman Garden, the market offers stalls for growers and food vendors. The organization also runs composting activities, processing organic waste into fertilizer.
- **Al-Shams Farmers' Market:** Supported by Investbank, this market features organic produce grown by Ajloun farmers trained by the Royal Society for the Conservation of Nature and the Jordanian Organic Farming Association.

Amman's Jabal al-Qal'ah district
The Greater Amman Municipality (GAM) has undertaken several urban agriculture initiatives, but many have failed due to inconsistent institutional support. One notable project, launched in 2010 during Omar Maani's tenure as mayor, targeted Amman's Jabal al-Qal'ah district, a significant heritage area near the Amman Citadel. Initially, the project aimed to clean rooftops and decorate them with pumice stone.

It later expanded to establish rooftop gardens, with GAM providing basic training, plants, containers, and beds to the local community under the leadership of Hisham al-'Umari, who later headed GAM's urban agriculture department.

Approximately 30 rooftop gardens were installed, and GAM planned to scale the initiative to 10,000 rooftops citywide. However, after Maani's tenure ended, the project was gradually abandoned. Today, only a few of the original rooftop gardens remain, mostly those that predated the initiative. This highlights the challenges of sustaining urban agriculture projects without long-term institutional commitment.

Capacity Building

UN-Habitat conducted capacity-building initiatives to equip local communities in Amman with sustainable green agriculture skills and strategies for implementing small-scale home and community garden projects. A 5-day training session titled Community Mobilization and Logistical Preparations for the Community Resilience Priority Actions to Flash Floods was held in collaboration with a local permaculture expert. The training focused on utilizing rainwater for agricultural and domestic purposes, reducing flash flood impacts, enhancing food security, and fostering social cohesion. These efforts also mitigated the socioeconomic impacts of COVID-19 by providing livelihood opportunities.

To extend the initiative's reach, UN-Habitat and its partners developed a Water Harvesting System Installation Manual for households, offering a step-by-step guide for implementing these solutions. Additionally, awareness campaigns were launched across digital platforms in collaboration with the GAM. These campaigns included TV appearances and instructional videos addressing flash flood risks and resilience strategies. By engaging diverse audiences, these initiatives aimed to enhance community awareness and promote proactive climate adaptation measures, ensuring sustainability and improved quality of life for vulnerable populations in Amman.

Figure 71 community vocational training on sustainable green agriculture

Note. From UN-Habitat. (2023, May). Strengthening the Social Stability and Resilience of Vulnerable Jordanian Communities and Syrian Refugees in Amman Against Flash Floods. UN-Habitat. **https://unhabitat.org/sites/default/files/2023/05/230319-en_flash_flood_project_brief_spreads.pdf**

Sources

- Al-Asad, M., Zurekat, L. (2018, December). Urban Agriculture in Amman : A Holistic View. Friedrich Ebert Stiftung Library. **https://library.fes.de/pdf-files/bueros/amman/15779.pdf**
- UN-Habitat. (2023, May). Strengthening the Social Stability and Resilience of Vulnerable Jordanian Communities and Syrian Refugees in Amman Against Flash Floods. UN-Habitat. **https://unhabitat.org/sites/default/files/2023/05/230319-en_flash_flood_project_brief_spreads.pdf**

53. Beirut's RiverLESS Forest, Lebanon

Location	Beirut, Lebanon
Existing Ecosystems	Urban and cultivated systems
Climate Change Challenges	River pollution and biodiversity threats
NbS Approach	Vegetation, urban forest and rainwater collection

Context

The Beirut River Watershed Project represents a comprehensive strategy for the revitalization of the Beirut River and its watershed, by theOtherDada - a regenerative consultancy & architecture practice - in collaboration with the Lebanese Center for Energy Conservation and UN-Habitat. Its overarching aim is to enhance the urban corridor surrounding the Beirut River and restore its green and blue infrastructure.

As a pilot phase, the project focused on the neighborhoods of Bourj Hammoud and Badawi, analyzing the specific challenges of this context. An initial study was conducted to assess the status and conditions of the river, forming the basis for developing guidelines that outline potential interventions tailored to these challenges.

The project emphasizes two core aspects: fostering connections between the community and nature. Through a human-centered design approach, it seeks to address environmental and social concerns while involving local stakeholders to develop solutions adapted to the area. Community mobilization and collaboration with local authorities are considered essential to create a self-sufficient and sustainable network that empowers both human and natural resources.

Rooted in the principles of biomimicry—design inspired by nature—and biophilia, the project recognizes the inherent human need to connect with nature. By focusing on rehabilitating the Beirut River ecosystem, the initiative aims to enhance living conditions for the surrounding communities. The project evaluated ecosystem services and ecological performance standards to facilitate biodiversity connections and restore existing green spaces, ultimately contributing to the revitalization of the area's ecological processes.

The proposal developed by theOtherDada aims to replace the existing deficient Gray Infrastructure with an environmentally friendly Blue and Green Infrastructure. This is done by studying the Ecosystem Services provided by a healthy river and translating them into Ecological Performance Standards. The proposal by theOtherDada keeps people at the heart of the design by engaging local stakeholders and tackling their issues/concerns, developing social and environmental solutions adapted to the site.

Applied NbS Methods

Among the interventions of blue-green infrastructure: Streets that use vegetated facilities as sustainable stormwater strategy are referred to Blue-Green streets. They mimic natural systems to reduce flow, air and water pollution. By capturing, treating and storing water runoff, the natural water cycle is restored, and groundwater recharge is sustained. They provide cooling microclimates in the city and increase neighborhood livability. They also recreate landscape connectivity for wildlife movement, supports biodiversity conservation and enhance natural ecosystem functions.

Building rooftops can be seen as potential spaces for interventions. Rooftops could act as a rainwater collector to harvest water, a space to produce the energy needed for a building's needs, a space for gardens that can be used as recreational areas, or vegetable gardens to produce food. The resources obtained from the rooftops allow homeowners to be less dependent on the external sources of energy, water and food.

Biodiversity: The fauna, flora and overall ecosystem of the river are degraded. The natural river has been transformed into a concrete channel receiving mostly wastewater from adjacent neighborhoods. There is a need to regenerate urban biodiversity. The aim is to increase the area's vegetated surfaces and provide green corridors. Choosing native species is a vital element to attract birds and pollinators and hopefully restore the natural habitat. The recreation of a biodiversity scheme plays a role in improving the livability of the neighborhoods and the health of residents.

Sustainable Urban Drainage Systems (SUDS):

- Parking interventions Oversized parking spaces could be adjusted to create space for vegetated swales between the parking lot and the street.

  Median strips interventions Long uninterrupted stretches of landscape can be converted into a structure to capture and manage runoff. These areas can be retrofitted to serve as vegetated swales. Continuous strips of leftover space can incorporate functional landscape depressions while taking into consideration pathways adapted to pedestrians. Flow-controls can be inserted within swales like rocks and check dams to slow the flow of runoff. Planters can fit in narrow street curbs between driveways. Dashed lines show where show where the planter could be added.
- Side-walk interventions Planters are incorporated in places where space is limited and a path for pedestrians is required. The concrete sides of the structure replace the side slopes typically used in swales, allowing for more storage volume in less space.
- Street interventions Underutilized spaces adjacent to streets can become appropriate locations for bio-retention basins and provide the greatest stormwater flow and volume benefit because of their large size.

Figure 72 SUDS insertion in underutilized urban spaces.

Note. From TheOtherDada. (2015). Beirut Riverless: Bringing Beirut River Back to Life. UN-Habitat. https://unhabitat.org/sites/default/files/2024/01/15-07-01_beirut_river_booklet.pdf

Figure 73 Cross section of a street showing SUDS integration

Note. From TheOtherDada. (2015). Beirut Riverless: Bringing Beirut River Back to Life. UN-Habitat. https://unhabitat.org/sites/default/files/2024/01/15-07-01_beirut_river_booklet.pdf

Sources

- TheOtherDada. (2015). Beirut Riverless: Bringing Beirut River Back to Life. UN-Habitat. https://unhabitat.org/sites/default/files/2024/01/15-07-01_beirut_river_booklet.pdf
- SUGi Project. (n.d.). Beirut's RiverLESS Forest. https://www.sugiproject.com/forests/beirut-riverless-forest

54. Afforestation Efforts, Bahrain

Location	Bahrain
Existing Ecosystems	Coastal and urban ecosystems
Climate Change Challenges	Sea level rise; Sand and dust storms; rising temperatures and extreme heat; desertification
NbS Approach	Afforestation and urban greening

Context and Applied NbS Methods

The kingdom of Bahrain, an island country in West Asia, is highly vulnerable to the impacts of climate change. With a predominantly urban population (90% as of 2023), Bahrain suffers from freshwater scarcity, desertification, pollution especially from sand and dust storms, and coastal ecosystem degradation. These challenges are exacerbated by a lack of adequate greenery and green public spaces.

To this end, Bahrain's National Afforestation Plan (2022 -2035) seeks to increase tree coverage and expand mangrove areas. By 2035, the plan aims to increase the tree count from 1.8 to 3.6 million. Although the plan was developed with an emissions reduction target, it has several adaptation co-benefits. For instance, the afforestation efforts contribute to enhancing urban environments and public spaces, which could mitigate the impacts of extreme heat and sand and dust storms.

Seizing this opportunity, UN-Habitat and FAO have partnered to implement a technical assistance project entitled Building Greener and Sustainable Cities to support the efforts of with Bahrain's Ministry of Municipalities Affairs and Agriculture.

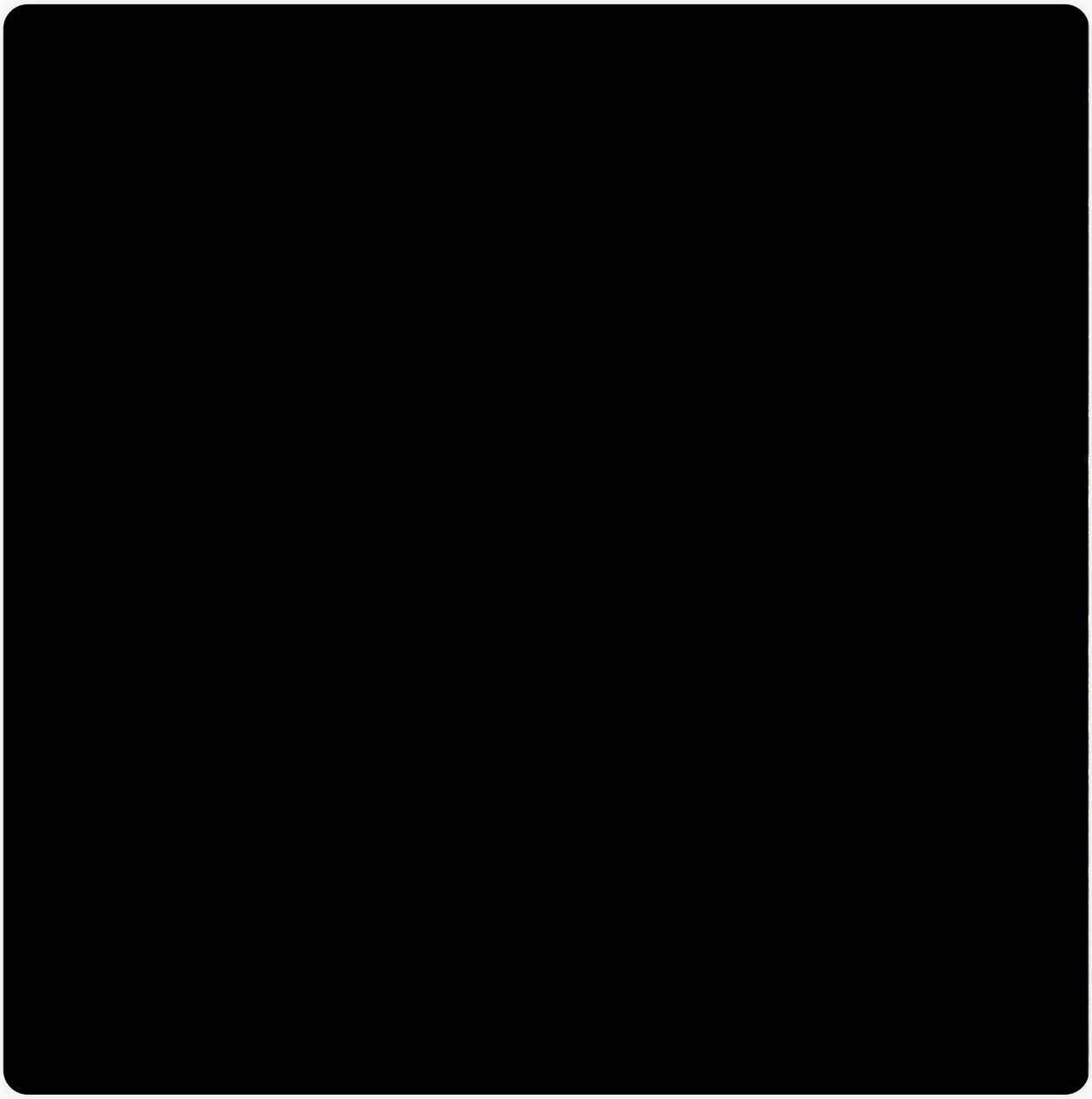
The project focuses on promoting the transition of Bahrain's urban systems toward sustainability and climate adaptation through increasing the quality and use of green public spaces and enhancing environmental quality for improved health and well-being of residents.

The project's main activities include:

1. A nationwide Afforestation and Green Space Assessment to evaluate public spaces and afforestation efforts, considering connectivity, accessibility, landscaping, and overall quality
2. Awareness raising and the strengthening of the capacities of stakeholders to improve urban systems and green infrastructure suitable for Bahrain's arid climate.

By increasing green coverage, the project seeks to demonstrate how green spaces can mitigate climate challenges in arid regions and set an example for sustainable city planning in drylands. Through this initiative, Bahrain takes a comprehensive approach to combating climate change, integrating afforestation with sustainable urban planning for long-term environmental and societal benefits.

Figure 74 Green public spaces in Bahrain



Note. Public spaces and afforestation contribute to a greener and healthier urban and social fabric while contributing to mitigating climate change and improving heat resiliency. Photo: UN-Habitat. From United Nations Bahrain. (2023, September 5). UN-Habitat and FAO support Bahrain's afforestation plans. United Nations in Bahrain. https://bahrain.un.org/en/244752-un-habitat-and-fao-support-bahrain%E2%80%99s-afforestation-plans

Sources

- World Bank. (n.d.). Urban population (% of total population) - Bahrain. World Bank Open Data. https://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS?locations=BH
- United Nations Bahrain. (2023, September 5). UN-Habitat and FAO support Bahrain's afforestation plans. United Nations in Bahrain. https://bahrain.un.org/en/244752-un-habitat-and-fao-support-bahrain%E2%80%99s-afforestation-plans

55. Forever Green Afforestation Campaign, Bahrain

Location	Bahrain
Existing Ecosystems	Urban ecosystem
Climate Change Challenges	Sand and dust storms; rising temperatures and extreme heat; desertification
NbS Approach	Afforestation and urban greening

Context and Applied NbS Methods

The Forever Green campaign is a national Afforestation Campaign that is aligned with Bahrain's National Afforestation Plan and focuses on supporting agricultural projects dedicated to tree planting in public areas and along streets across the country's four governorates. The campaign primarily focuses on planting large, evergreen trees that are suitable to Bahrain's arid climate, ensuring responsible water usage and long-term sustainability. Tree planting locations include parks, walkways, public transport stations, schools, and public spaces, which improves the aesthetic quality and air quality of cities.

The campaign has seven overarching objectives:

1. Encourage youth to volunteer in agriculture.
2. Support the United Nations' Decade on Ecosystem Restoration 2021-2030.
3. Protect the environment through climate change mitigation and adaptation actions.
4. Enhance the partnerships between the community and civil society institutions and other relevant authorities.
5. Encourage private sector involvement and investment in green spaces expansion projects.
6. Contribute to Bahrain's commitments towards the Sustainable Development Goal 13 on climate action.
7. Support the Ministry of Municipalities Affairs and Agriculture's plans to increase green spaces across the Kingdom.

To achieve its aims and objectives, the Forever Green campaign adopts a blended finance approach, facilitating cooperation between the public and private sectors to implement its planned projects. The campaign was launched in October 2021 and is currently in its fourth phase. Each phase has its own set of goals and targets. **The table below summarizes the achievements of the campaign's first 3 phases**

	Phase 1 (Oct. 2021 - June 2022)	Phase 2 (Oct. 2022 - June 2023)	Phase 3 (Oct. 2023 – July 2024)
Targeted Locations	70 locations across Bahrain	57 locations across Bahrain	47 locations across Bahrain
Total Area	73,000 m^2	13,589 m^2	14,243 m^2
Total Cost	$700,000 or 270,000 Bahraini Dinars	$471,000 or 177,686 Bahraini Dinar	156,000 Bahraini Dinar
Total Number of Planted Trees and Shrubs	48,876 (half of which were planted in partnership with municipalities)	50,814	40,043

In addition to the physical greening interventions, the Forever Green campaign also works on raising awareness and educating the public about the benefits of urban greening and tree planting. Moreover, the campaign adopts a participatory approach prioritizing engaging local communities, residents, and businesses in the process of greening and tree planting, which promotes environmental stewardship and sustainability within the community. Through its public-private collaborations approach, key partners include the Supreme Council for the Environment, Gulf International Bank (GIB), Bahrain National Gas Company, and Bank of Bahrain and Kuwait.

Sources

- Arab Urban Development Institute. (n.d.). Forever Green – Afforestation Campaign. Projects – Arab Urban Development Institute. **https://araburban.org/en/infohub/projects/?id=3953**
- National Initiative for Agricultural Development. (n.d.). Forever Green **https://araburban.org/en/infohub/projects/?id=3953**
- National Initiative for Agricultural Development. (2024, September). Forever Green Campaign: First Phase Report (October 2021 – June 2022). **https://niadbh.com/wp-content/uploads/2024/09/First-Phase-Report.pdf**
- National Initiative for Agricultural Development. (2024, September). Forever Green Campaign: Second Phase Report (July 2022 – September 2023). **https://niadbh.com/wp-content/uploads/2024/09/Second-Phase-Report.pdf**
- National Initiative for Agricultural Development. (2024, September). Forever Green Campaign: Third Phase Report (October 2023 – July 2024). **https://niadbh.com/wp-content/uploads/2024/09/Third-Phase-Report.pdf**

56. Urban Landscaping Design and Beautification, Bahrain

Location	Budaiya, Bahrain
Existing Ecosystems	Urban ecosystem
Climate Change Challenges	Sand and dust storms; rising temperatures and extreme heat; desertification
NbS Approach	Urban greening

Context and Applied NbS Methods

The Urban Landscaping Design and Beautification Execution Project (2015–2017) aimed to enhance Bahrain's urban environment through greening and beautification, supporting national sustainable development goals and the "Green the Country" vision. Implemented by the Ministry of Works, Municipalities Affairs and Urban Planning (later divided into three ministries) in partnership with the Taiwan Technical Mission, the project focused on upgrading public spaces and urban roads with improved landscaping.

The project sought to develop landscape designs for major highways, beautify approximately 10 kilometers of roads, and create around 20 hectares of new public green spaces. It further aimed to strengthen Bahrain's landscaping services, support the beautification of public areas, and contribute to national initiatives such as the Bahrain International Garden Show. In addition, it assisted in the development of key facilities, including the Budaiya Experimental Nursery and the Agriculture Incubation Center.

In 2016, the project expanded into three sub-projects: supervising landscaping along Shk. Khalifa Bin Salman Highway, preparing new urban design layouts, and offering technical consultation nationwide.

Key achievements included:

- **2015:** Al Estiqlal Highway median landscaping (1.6 km, 3 ha); Hamad Town Walkway 1209 project; design for Shk. Khalifa Bin Salman Highway junction.
- **2016:** Landscaping plans for Shk. Khalifa Bin Salman Highway and Water Garden; new design for King Fahd Causeway Customs Inspection Station; planting plans for the Agriculture Incubation Center and Budaiya Nursery entrance.
- **2017:** Designs for Hawar A'Ali Farmers Market, Al-Dair Agricultural Land, and Bahrain Fort and Museums access road; first prize at the Bahrain International Garden Show for innovative design.

The project expanded Bahrain's green areas, improved air quality, and enhanced the urban landscape, contributing to residents' quality of life.

It streamlined landscaping operations through stronger review processes and expert consultation, ensuring projects stayed on time and within budget.

Overall, it elevated national landscaping standards and promoted long-term environmental sustainability.

Sources

- Arab Urban Development Institute. (n.d.). Urban Landscaping Design and Beautification Execution Project. Projects - Arab Urban Development Institute. **https://araburban.org/en/infohub/projects/?id=7686**
- TaiwanICDF. (2020, September 3). Urban Landscaping Design and Beautification Execution Project (Bahrain). TaiwanICDF. **https://www.icdf.org.tw/wSite/ct?xItem=31502&ctNode=31795&mp=2**

Greenery in public spaces. Visual by Egyptian Broadcast Systems

57. Bahrain Regains Greenery

A research project to promote green roofs in private and public buildings

Location	City, Bahrain
Existing Ecosystems	Urban ecosystem
Climate Change Challenges	Sand and dust storms, rising temperatures and extreme heat and desertification
NbS Approach	Urban greening and rooftop farming

Context and Applied NbS Methods

Under the leadership of HRH Princess Sabeeka Bint Ibrahim Al Khalifa, Bahrain has undertaken significant efforts to protect and develop its agricultural sector. These efforts aim to strike a balance between agricultural land preservation and urban development, recognizing the importance of sustainable food production for the health and well-being of the population. This initiative is particularly crucial in ensuring Bahrain's food security, reducing reliance on external sources, and fostering domestic agricultural capabilities. In line with these goals, the Kingdom University in Bahrain has launched several research activities, educational programs, and community services aimed at addressing environmental and sustainability issues to promote the prosperity and welfare of the Bahraini community.

One of the flagship projects stemming from these efforts is the collaborative multi-disciplinary research project titled Bahrain Regains Greenery - Green Roofs in Private & Public Buildings, implemented in partnership with the National Initiative for Agriculture Development and the University of Kaiserslautern in Germany. The project focuses on maximizing the use of available spaces and utilizing water that would otherwise be wasted to reach self-sufficiency in planting, while also sustaining the environment and improving the overall quality of life for residents.

The project was officially launched following an international and interdisciplinary workshop held at Kingdom University in early 2014. This workshop brought together various experts who shared knowledge and developed new ideas for greening Bahrain. A key insight from the workshop was the untapped potential of the vast areas of underutilized rooftops on both private and public buildings, which could be transformed into green spaces. The project has two primary goals. First, it seeks to address the local climatic conditions by implementing urban vegetation that can help mitigate the urban heat island effect, improve air quality, and reduce air-conditioning costs for buildings. Second, it aims to enhance irrigation capabilities, making the most of

available water resources. These benefits will not only improve the local climate but also contribute to a more sustainable and healthier lifestyle for the people of Bahrain.

To begin the process, an urban vegetation database was established to identify suitable plants for rooftop gardening in Bahrain's hot and arid climate. This database includes over 200 different types of trees, shrubs, grasses, and crops, all selected for their ability to thrive on flat rooftops with high sun exposure. Early studies indicate that careful planting of vegetation on rooftops can result in energy savings of up to 80% in hot and dry climates. However, while numerous studies have suggested that urban vegetation, particularly trees, can reduce energy consumption in buildings, much of the evidence remains anecdotal. The actual energy savings will vary depending on factors such as the building's properties, its operational characteristics, and the specific effects of the vegetation.

Figure 75 Simulation of the flat rooftops before and after the "Bahrain Regains Greenery" project

Note. From Henninger, S., Elmarsafawy, H. and Tobias, K. (2015, September 9). Bahrain Regains Greenery. Journal of Environmental Protection, 6, 929-934. http://dx.doi.org/10.4236/jep.2015.69082

Sources

- Henninger, S., Elmarsafawy, H. and Tobias, K. (2015, September 9). Bahrain Regains Greenery. Journal of Environmental Protection, 6, 929-934. http://dx.doi.org/10.4236/jep.2015.69082

Urban farming. Visual by Egyptian Broadcast Systems

58. Rooftop Gardens Project, Bahrain

Location	Manama, Bahrain
Existing Ecosystems	Urban ecosystem
Climate Change Challenges	Sand and dust storms; rising temperatures and extreme heat; desertification
NbS Approach	Urban greening and rooftop farming

Context and Applied NbS Methods

Rooftop gardening in Bahrain is an innovative method of urban agriculture, designed to integrate vegetation through green roofs in areas with limited space for traditional gardening. This initiative was launched through a pilot project seeking to transform abandoned rooftops into productive, multi-purpose spaces. The project aligns with the broader vision of alleviating rising temperatures and improving air quality in crowded urban areas, contributing to the development of healthier neighborhoods. Additionally, it seeks to encourage gardening as a hobby among residents, fostering community engagement and environmental awareness.

The rooftop gardening project aims to

1. Enhance the aesthetic quality of urban areas by adding greening and transforming unused rooftops into multi-purpose, lively spaces.
2. Encourage creative agricultural practices among households, fostering a deeper connection to the environment and promoting sustainable food production.
3. Promote water conservation, enhance soil health, reduce labor costs, and facilitate organic waste production, all contributing to a more sustainable urban ecosystem.
4. Reduce carbon emissions and create habitats for local wildlife through the selective planting of appropriate vegetation.
5. Strengthen communal cohesion by encouraging residents to engage in gardening, share knowledge, and educate their families, particularly children, about climate-appropriate and environmentally friendly planting techniques.

The project was implemented in multiple phases, beginning in 2019 with the planting of pepper seedlings and expanding to include a variety of vegetables and small fruit trees, such as fig and green almond trees. The project's phases also focused on developing gardening skills among residents, starting with literature reviews, interviews, and learning from digital content on platforms like YouTube. The initial phase helped raise awareness and provided the necessary knowledge to initiate rooftop farming.

Today, the rooftop gardens in Bahrain have become vibrant spaces for growing vegetables and fruit trees, with many participants continuing to use their rooftops regularly, eager for each season's harvest. The gardens not only contribute to the greening of the urban environment but also enhance the quality of life for residents by offering a space for recreation and family bonding.

The main beneficiaries of the project are the households and their family members, who actively engage in the gardening process. Each family member contributes to the project in various ways, where Children are introduced to the process of designing and planting, gaining familiarity with climate-appropriate and environmentally benign techniques. By involving the entire family, the project not only builds local capacities but also fosters a culture of sustainability and environmental stewardship within the community. It encourages residents to take pride in their contributions to a greener, more sustainable urban environment.

The rooftop gardens project is the result of a collaboration between various stakeholders, including

1. **Households/Residents:** The primary participants and beneficiaries, who actively engage in the gardening process.
2. **UN-Habitat:** Providing expertise and guidance in sustainable urban development.
3. **FAO:** Supporting agricultural initiatives and promoting sustainable food production.

Figure 76 Rooftop gardens in Bahrain

Note. From UN-Habitat. (2024, February 16). Greening cities in Bahrain one rooftop at a time. News and Stories | UN-Habitat. https://unhabitat.org/news/16-feb-2024/greening-cities-in-bahrain-one-rooftop-at-a-time

4 **Bahrain's Ministry of Municipalities Affairs and Agriculture:** A key partner in the project, providing local insights and resources.

5 **National Initiative for Agricultural Development:** Working alongside UN-Habitat and FAO to promote sustainable agricultural practices in Bahrain.

In addition to the hands-on involvement of residents, the FAO and UN-Habitat conducted a survey to understand the motivations and practices of Bahraini residents involved in rooftop gardening. This survey aimed to gather insights into how urban greening, beautification, and gardening as a hobby are practiced within the community, ultimately supporting initiatives to enhance sustainable urban living in Bahrain.

Sources

- Arab Urban Development Institute. (n.d.). Roof Gardens. Projects - Arab Urban Development Institute. https://araburban.org/en/infohub/projects/?id=8515
- UN-Habitat. (2024, February 16). Greening cities in Bahrain one rooftop at a time. News and Stories | UN-Habitat. https://unhabitat.org/news/16-feb-2024/greening-cities-in-bahrain-one-rooftop-at-a-time
- United Nations Bahrain. (2024, February 1). Rooftop gardens offer opportunities to increase greenery in dense urban areas. United Nations in Bahrain https://bahrain.un.org/en/259411-rooftop-gardens-offer-opportunities-increase-greenery-dense-urban-areas-bahrain

Rooftop farming. Visual by Egyptian Broadcast Systems

59. The Green Riyadh Project, Saudi Arabia

Location	Riyadh, Saudi Arabia
Existing Ecosystems	Aris and Urban ecosystems
Climate Change Challenges	desertification, poor air quality, overheating
NbS Approach	Urban afforestation – the process of establishing new forests or increasing tree cover in urban areas where there were previously few or no trees – and greening.

Context

Riyadh, like many cities in the Gulf Cooperation Council region, faces challenges related to urban expansion, rising temperatures, and limited green spaces. Extensive urban and infrastructure development has contributed to heat retention and reduced air quality, making afforestation a critical solution for enhancing environmental sustainability and urban livability. Recognizing the importance of green infrastructure, Saudi Arabia has prioritized large-scale afforestation through the Green Riyadh Project, aligning with Vision 2030's commitment to urban sustainability and climate action.

Applied NbS Methods

Green Riyadh Project for Large-Scale Urban Greening

Launched in 2019 by King Salman bin Abdulaziz, the Green Riyadh Project is one of the city's four wellbeing megaprojects, aiming to transform Riyadh into a green oasis.

With a budget of $32 million, the initiative seeks to increase green space across 120 neighborhoods, with an ambitious target of planting of 7.5 million trees and creating 545 square kilometers of urban greenery.

The Green Riyadh Project aims to increase the per capita share of green space in the city, from 1.7 square meters to 28 square meters, and expand the overall percentage of greenery by initiating widespread and intensified tree planting across all elements and areas of the city. It also seeks to optimize the use of treated water for irrigation, contributing to improved air quality, reduced urban temperatures by up to 2°C, and enhanced biodiversity and ecological resilience in urban settings, as well as encourage residents to adopt a more active and vibrant lifestyle in line with the goals of Saudi Vision 2030.

The project aims to integrate trees and green spaces into strategic locations across the city. These include 1,204 kilometers of main roads, 43 city parks, 387 neighborhood parks, 4,500 mosques, 4,515 schools, 4,500 government compounds, 4,936 health facilities, 148 square kilometers of valleys and tributaries.

To support long-term sustainability, the city shall plant trees from a list of 72 carefully selected local

tree species that are well-suited to the environment of Riyadh. Furthermore, the project includes the development of a water treatment network with a daily irrigation capacity of 1 million cubic meters and the establishment of nurseries to meet the demand for saplings.

Additionally, urban regulations are being refined to integrate afforestation into private and public spaces, and awareness campaigns are conducted to encourage community participation.

Beyond environmental restoration, Green Riyadh enhances quality of life in the city by: encouraging outdoor activities through public green spaces, boosting mental and social well-being among residents, reducing electricity consumption and associated GHG emissions by moderating urban heat islands, and increasing property values and creating investment opportunities in horticulture, landscaping, and irrigation industries.

Managed by the Royal Commission for Riyadh City, the first phase began in 2020 and included the planting 31,000 trees across 144 kilometers of main roads, such as: King Fahd Road, Makkah Al Mukarramah Road, North Ring Road, Eastern Ring Road, King Salman Road, and King Khaled Road. And in April 2022, the project was officially launched in seven Riyadh neighborhoods, including Al-Aziziyah, Al-Naseem, Al-Jazeera, Al-Araija, Qurtuba, Al-Ghadir, and Al-Nakhil.

By integrating afforestation, treated water irrigation, and community participation, Green Riyadh sets a precedent for urban sustainability in arid climates, demonstrating how large-scale environmental initiatives can enhance urban resilience and foster economic growth and social well-being.

Sources

- Arab Urban Development Institute. (n.d.). The Green Riyadh Project. Projects - Arab Urban Development Institute. https://araburban.org/en/infohub/projects/?id=3728
- Saudi Vision 2030. (2024, July 8). Green Riyadh. https://www.vision2030.gov.sa/en/explore/projects/green-riyadh
- Riyadh Green. (n.d.). Riyadh's Four Wellbeing Projects. https://riyadhgreen.sa/Home/EN

Greenery in urban settings. Visual by Egyptian Broadcast Systems

60. The Emirates Environmental Group Million Tree Campaign, UAE

Location	UAE
Existing Ecosystems	Arid, coastal and urban ecosystems
Climate Change Challenges	Desertification, land degradation, reduced biodiversity and soil erosion
NbS Approach	Urban greening campaign, with a goal of planting 1 million trees and raising public awareness

Context

Rapid urban expansion in the UAE has led to the reduction of green spaces, leaving vast areas exposed to environmental degradation. Many development projects have prioritized infrastructure over sustainable green spaces, resulting in reduced biodiversity, soil erosion, and heightened risks of desertification. The UAE's hot and dry climate, coupled with limited annual rainfall and high summer temperatures, exacerbates these challenges.

Applied NbS Methods

In response, the Emirates Environmental Group (EEG), a non-profit professional working group dedicated to environmental advocacy through education and community-driven initiatives, launched the EEG Million Tree Campaign. The campaign, launched under the umbrella of UNEP's Billion Tree Campaign, is a significant initiative aimed at greening the UAE and combating desertification. Seeking to enhance the quality of life for affected populations, enhance ecosystem resilience, and foster environmental awareness, **this campaign focuses on:**

- Increasing the number of trees and green spaces in urban areas to improve air quality and mitigate heat stress.
- Rehabilitating degraded soils to reduce erosion and support sustainable land use.
- Enhancing community participation in environmental protection through educational initiatives.
- Supporting biodiversity by creating new habitats for wildlife.

By planting indigenous tree species, the initiative directly contributes to soil stabilization, moisture retention, and carbon sequestration. Native trees such as Neem, Ghaf, Date Palm, Sidra, Acacia, and mangroves are particularly well adapted to the UAE's harsh climate and play a vital role in enhancing ecological balance.

Additionally, the initiative educates the public about environmental conservation and instills a sense of responsibility towards protecting the UAE's natural resources. By engaging with communities, schools, universities, and corporate partners, to raise awareness about the importance of green spaces, the campaign includes activities aimed at:

- Organizing large-scale tree planting events in parks, forests, educational institutions, and urban settings. create habitats for insects, birds, and other wildlife.
- Collaborating with the private sector to encourage corporate environmental responsibility and CO2 reduction efforts.
- Conducting educational programs to highlight the ecological significance of indigenous plant species and their role in combating desertification.

Through outreach mechanisms such as newsletters, lectures, and community events, EEG actively raises environmental consciousness while providing hands-on opportunities for individuals to contribute to conservation efforts.

Since its inception, the EEG Million Tree Campaign has successfully facilitated the planting of more than 1.6 million trees across the UAE's seven emirates. By mobilizing different sectors of society, this initiative has made a substantial impact in reversing environmental degradation and fostering a culture of sustainability.

Sources

- WOCAT. (2010, October 11). EEG's Million Tree Campaign [United Arab Emirates]. WOCAT SLM Database. https://qcat.wocat.net/en/unccd/view/unccd_260/

Greenery in urban settings. Visual by Egyptian Broadcast Systems

61. Greening Education City, Qatar:
The Park and Plant Initiative in Doha

Location	Education City, Doha, Qatar
Existing Ecosystems	Arid and urban ecosystems
Climate Change Challenges	Biodiversity loss, urban heat islands and dust storms
NbS Approach	Urban Greening through the Park and Plant initiative - a community-driven project focused on rejuvenating local landscapes, fostering healthier and more vibrant environments.

Context

In rapidly urbanizing landscapes, maintaining ecological balance and improving air quality are critical challenges. Qatar, characterized by its arid climate and urban expansion, faces increasing environmental concerns, including rising temperatures, biodiversity loss, and air pollution. Green spaces not only enhance aesthetic appeal of cities but also contribute to climate resilience by supporting biodiversity and mitigating the impacts of dust contamination. To address these concerns, community-driven greening initiatives have emerged as an effective approach to restoring native ecosystems and creating healthier urban environments.

Applied NbS Methods

The Park and Plant initiative for Urban Rejuvenation is a community-driven effort launched by Qatar Foundation (QF) with the aim of revitalizing Qatar's landscapes through widespread tree planting and the development of green spaces.

Initially conceived to provide shade along the pathways of Education City, the initiative quickly expanded, recognizing its broader potential to enhance biodiversity, improve air quality, and foster community engagement.

Demonstrating the organization's dedication to sustainability, the initiative seeks to plant 2,500 trees across Education City within its first three months. The first tree-planting event was held at Carnegie Mellon University in Qatar, a distinguished partner of QF.

A central focus of the initiative is the restoration of indigenous landscapes, ensuring that planted vegetation aligns with Qatar's environmental conditions. Over 60 native tree species and shrubs well adapted to the Qatari climate have been planted to create a resilient and sustainable ecosystem. These efforts not only help green urban spaces but also support the habitat of insects, birds, and domestic animals, enriching local biodiversity. Its emphasis on native species ensures long-term sustainability, reducing water consumption while maintaining ecological integrity.

Beyond landscape beautification, the initiative aims to improve air quality by strategically planting

greenery in pedestrian zones and establishing green barriers to combat dust pollution. In partnership with the Qatar Environment and Energy Research Institute, air monitoring stations have been deployed to measure the long-term impact of increased vegetation on local air quality.

The initiative thrives on community participation, drawing volunteers and organizations from across Qatar to contribute to urban restoration efforts. By encouraging collective action, the project fosters environmental awareness and promotes sustainable practices. Since the launch of the Park & Plant initiative, numerous centers and organizations have stepped forward to offer their support. Contributors to tree planting efforts around Education City represent a diverse range of entities across Qatar, including Friends of the Environment, Tarsheed, Qatar Academy Doha—one of the schools within QF's pre-university education network—Qatar Social Work, and members of the local community.

As the initiative continues to evolve, its success in Education City highlights the potential for expanding urban greening efforts to other regions in Qatar. By integrating ecological restoration, air quality improvement, and community involvement, Park and Plant demonstrates how strategic environmental initiatives can shape healthier and more sustainable urban spaces.

Sources

- Qatar Foundation. (2019, October 29). Qatar Sustainability Week: QF initiative aims to create Qatar's first urban forest. News & Stories | Qatar Foundation **https://www.qf.org.qa/stories/qf-initiative-aims-to-qatar-first-forest**

Visual by Egyptian Broadcast Systems

62. Oman Botanic Gardens

Location	Near Al Khoudh village, just outside Muscat, Sultanate of Oman
Existing Ecosystems	Arid and mountainous ecosystems
Climate Change Challenges	Water scarcity and increasing pressure on natural water resources due to climate variability and urbanization
NbS Approach	Conservation and restoration of native plant species within naturalistic habitats; use of indigenous low-water-demand plants in landscaping to minimize water use; and integration of biodiversity conservation with cultural heritage and sustainable water management

Context

Oman faces significant water scarcity challenges, which are being intensified by the impacts of climate change and rapid urban development. The Gulf region, including Oman, relies heavily on desalinated seawater to meet the growing demands of municipal and domestic water use, placing additional pressure on energy and natural resources. Against this backdrop, the Oman Botanic Garden was conceived as a major initiative to conserve and celebrate the country's unique native flora and diverse ecosystems—from arid deserts and mountainous areas to monsoon cloud forests. Beyond conservation, the garden also aims to demonstrate sustainable water management practices by showcasing how indigenous plant species, adapted to Oman's harsh climate, can be used effectively to reduce water consumption in urban landscaping.

Applied NbS Methods

The Oman Botanic Garden encompasses a 430-hectare protected natural area near Muscat, designed to replicate Oman's diverse natural habitats through the careful cultivation of all native plant species. This large-scale conservation effort helps restore and protect the country's biodiversity while providing a living showcase of its unique ecosystems. A key nature-based solution implemented is the exclusive use of indigenous, low-water-demand plants for landscaping. This approach significantly reduces reliance on traditional water sources by using only solar-desalinated seawater for irrigation, demonstrating a sustainable model of water use in a water-scarce region. By prioritizing native species adapted to local climatic conditions, the project not only conserves biodiversity but also serves as a replicable example across the Gulf region of how urban landscapes can be made more sustainable and resilient to climate change.

Sources

- Oman Botanic Garden. (n.d.). Research & Conservation. https://omanbotanicgarden.om/research-conservation/
- British-Omani Society. (n.d.). The Role of the Oman Botanic Garden in Conserving Oman's Agriculture Environment. . https://www.britishomani.org/uploads/downloads/spotlight%20on%20-%20botanic%20garden.pdf
- Oman Observer. (2022, October 3). Plants play key role in restoration of biodiversity. https://www.omanobserver.om/article/1130949/features/travel/plants-play-key-role-in-restoration-of-biodiversity

Botanical garden. Visual by Egyptian Broadcast Systems

Agroecology and Sustainable Land Management

Closeup shot of a farmer's hand holding a freshly-harvested organic carrot. Soure photograph by Envato. Visual by Egyptian Broadcast Systems

The Arab region is widely regarded as the most water-scarce area in the world. Water use rates reach approximately 76.6 percent of available resources, compared with a global average of around 7.5 percent. Agriculture is by far the largest consumer, accounting for around 81 percent of available water resources, highlighting substantial potential for efficiency improvements through more sustainable farming practices.[8]

Water scarcity already affects 19 of the 22 Arab countries and is becoming more severe due to climate change, particularly through rising temperatures and shifting precipitation patterns. In addition, 17 countries experience desertification and land degradation. These environmental challenges, combined with recurrent heatwaves and declining water availability, are further compounded by structural issues such as insecure land tenure, increasing fragmentation of agricultural holdings, reliance on food imports, and the expansion of urban areas into productive farmland. Together, these factors place significant pressure on food security across the region.

Nature based Solutions (NbS) offer effective pathways to address these interconnected challenges by promoting sustainable agricultural practices and improved land management. Such approaches support efforts to combat desertification, enhance food security, and restore degraded ecosystems. This chapter showcases 11 case studies from the Arab region focusing on sustainable land management practices and agroecology, including afforestation and remediation, traditional irrigation and agricultural techniques, and innovative techniques such as Miyawaki forests and permaculture practices.

[8] AbuZeid, K., Alroudy, M., CEDARE, & Arab Water Council. (2014). Second State of Water Report for the Arab Region - 2012. Water Resources Programme - CEDARE and Arab Water Council; AbuZeid, K., Wagdy, A., Ibrahim, M., CEDARE, & Arab Water Council. (2019). Third State of Water Report for the Arab Region - 2015. Water Resource Management Program - CEDARE & Arab Water Council; Arab Organization for Agricultural Development. (2017). Arab Food Security Situation Report. League of Arab States.

63. The RESTOR'MED FORESTS Project, Morocco and Lebanon

Location	Talassemtane National Park (Morocco), Bentael Nature Reserve and Menjez Forest (Lebanon).
Existing Ecosystems	Forest ecosystem.
Climate Change Challenges	Increased frequency and severity of wildfires, land degradation and deforestation, loss of biodiversity and native species and ecosystem vulnerability to rising temperatures and prolonged droughts.
NbS Approach	Ecosystem restoration of degraded forest areas, sustainable forest management practices, community-based conservation and climate education and fire risk reduction through natural buffers and firebreaks.

Context

Mediterranean forest ecosystems are facing significant challenges due to climate change, which has exacerbated the vulnerability of these areas to rising temperatures, prolonged droughts, and increasing wildfire risks. These environmental stresses contribute to habitat degradation, loss of biodiversity, and the degradation of vital ecosystem services such as water regulation and carbon sequestration. In both Morocco and Lebanon, the local populations face the dual challenge of managing natural resources sustainably while also dealing with a lack of institutional support, funding, and technical knowledge on effective land and forest management. This is particularly important in biodiversity-rich areas like Talassemtane National Park in Morocco, home to the Moroccan fir (Abies marocana) and other endemic species, as well as the Bentael Nature Reserve and Menjez Forest in Lebanon, which are home to the Mount Tabor oak and numerous rare plant species.

The RESTOR'MED FORESTS project led by the International Association for Mediterranean Forests seeks to address these issues by restoring degraded landscapes, conserving endemic species and promoting sustainable forest management practices. This project not only focuses on reforestation and habitat restoration but also empowers local communities through capacity building and community-based conservation. Local stakeholders, including youth and community members, are engaged in forest restoration activities, which include planting native species and managing ecosystems to enhance their resilience to climate change. The project also highlights the importance of participatory management and climate education, ensuring that communities understand the broader environmental challenges and are equipped to take active roles in conserving these critical landscapes.

Applied NbS Methods

The RESTOR'MED FORESTS project implements a range of NbS aimed at improving forest resilience and mitigating climate impacts. These solutions focus on reforestation, sustainable land management, and community-based ecosystem restoration.

In Morocco, activities include reforesting 15 hectares within the Talassemtane National Park, with the active participation of local communities who are involved in planting native species such as maritime pine (Pinus pinaster). The project also integrates fire risk management by creating firebreaks and increasing the resilience of forests to fire hazards.

In Lebanon, the project's efforts extend to promoting sustainable forest management and restoring key habitats, particularly in the Bentael Nature Reserve and Menjez Forest, where native species like Pinus brutia (Turkish pine) and Quercus spp. (oaks) are being replanted and protected.

Sources

- Fondation Prince Albert II De Monaco. (n.d.). RESTOR-MED Forests: Conservation of Mediterranean Endemic Forests. https://www.fpa2.org/en/projets/restor-med-forests-conservation-of-mediterranean-endemic-forests-00572
- Association Internationale des Forêts Méditerranéennes (AIFM). (n.d.). RESTOR-MED Forests. https://aifm.org/en/our-actions/restormed-forests-en/

Visual by Egyptian Broadcast Systems

64. Improved Resilience to Transboundary Sand and Dust Storms Project, Iraq and Kuwait

Location	Southern Governorates of Iraq: Thi-Qar and Muthana Governorates), Kuwait Cities (the capital city of Kuwait, Ahmadi, and Al-Jahrah)
Existing Ecosystems	Arid and semi-arid ecosystems
Climate Change Challenges	Increased frequency and intensity of SDS, desertification and water scarcity, rising temperatures and prolonged droughts, and impacts on ecosystems and biodiversity.
NbS Approach	Ecosystem restoration in the origin areas of sand and dust storms in Southern Iraq, through interventions, such as clay coverage, solid windbreaks, biological methods and afforestation

Context

The Improved Resilience to Transboundary SDS in Kuwait and Iraq project is addressing the growing environmental challenges posed by the increasing frequency and intensity of SDS in the Arabian Gulf region, particularly in the southern governorates of Iraq (Diwaniya, Nasiriyah, and Muthana) and key cities in Kuwait (including the capital, Ahmadi, and Al-Jahrah).

Over the past two decades, the occurrence of SDS has been exacerbated by desertification, changing land-use patterns, water scarcity, rising temperatures, and prolonged droughts—all intensified by climate change.

These storms significantly disrupt local ecosystems, degrade air quality, and harm human health and infrastructure, while also threatening agricultural production and the livelihoods of communities. The project implemented by UN-Habitat with the support of the Kuwait Fund for Arab Economic Development seeks to mitigate the adverse impacts of SDS on human settlements, particularly in southern Iraq and Kuwait, and aims to protect vulnerable populations from the direct and indirect effects of these events.

Applied NbS Methods

The project implements comprehensive resilience strategies to restore affected ecosystems and improve the resilience of local communities to the challenge of SDS. A key aspect of the project is the development of an SDS Prevention Plan, which will guide mitigation measures and land-use practices to reduce the factors contributing to SDS. This plan, alongside capacity-building and knowledge-sharing activities, will enable local authorities and communities to better manage land, restore ecosystems, and prevent the worsening of SDS.

The implemented NbS approaches in the project include:

1 **Afforestation:**
One of the key NbS interventions is the restoration of vegetative cover through afforestation with native tree species. This helps restore ecosystems, reduce soil erosion, and prevent dust from becoming airborne during storms.

2 **Biological Methods:**
The project employs biological methods, such as planting drought-resistant plants and using natural resources to stabilize soil and protect land from erosion. These measures promote sustainable land-use practices and improve land productivity.

3 **Solid Windbreaks:**
The creation of sand barriers serves as a protective measure, preventing the spread of sand and dust into populated and agricultural areas. These barriers can also provide a buffer against wind, reducing the impact of SDS.

Figure 77 Map of the intervention area in Southern Iraq

Note. Priority Area (1) in Muthana Governorate; Priority Area (2) in Thi-Qar Governorate. Source: UN-Habitat Iraq

Sources

- UN-Habitat. (2024, January). Improved Resilience to Transboundary Sand and Dust Storms in Kuwait and Iraq.

65. Perma Atlas, Morocco:
Greening of Mountain Slopes

Location	High Atlas region of central Morocco
Existing Ecosystems	Mountains, forest, inland water and cultivated ecosystems
Climate Change Challenges	Loss of fertile topsoil, flooding and landslides
NbS Approach	Permaculture practices, gabions and swales, horticultural practices

Context

Perma Atlas is dedicated to restoring the High Atlas region of central Morocco through the implementation of permaculture practices, aimed at improving the ecosystem and fostering local community resilience and livelihoods. Located in the highest part of the Atlas mountain range, the region is characterized by eroded mountains that are barren and lack vegetation. These conditions hinder the region's ability to capture and retain water, leading to the loss of fertile topsoil.

Applied NbS Methods

In response, Perma Atlas is employing permaculture techniques rooted in ancient Berber traditions to revitalize the landscape. Over the past few years, Perma Atlas has implemented gabions and keyline techniques to regulate flood control, enhance soil fertility, rejuvenate herbs and plants in higher altitude areas, and increase the presence of small wildlife.

These efforts have better protected the village from the impacts of climate change, inspiring renewed confidence in the prospects of restoration and the creation of a habitable environment. Perma Atlas partners with the local Anguelz organization, Future Association for Agricultural Development and Environmental Protection.

After completing the training on the learning site, the participants have constructed gabions on the mountainsides and placed boomerangs, gabions and swales on the plains around Anguelz. This has caused the mountainsides and plains of Anguelz to re-green. In addition, the participants have planted plants that they have taken cuttings from during the training on the learning site. The slopes, the underlying fields and the village are now much better protected against flooding and landslides. After the heavy rainfall in September 2020, not only was the village spared, but springs also emerged. They are still there today. The water continues to infiltrate the soil. Vegetation is growing again around the gabions and contour lines. This is a sign that the groundwater has improved and the soil is becoming

more fertile. Due to the visible results, surrounding villages have also shown their interest in the work of Perma Atlas.

A core goal of Perma Atlas is ecosystem restoration through permaculture techniques, which provide a framework for revitalizing the environment. These techniques incorporate traditional sustainable horticultural practices, many of which are rooted in ancient Berber traditions from the High Atlas. In addition to ecosystem restoration, Perma Atlas is committed to improving food security in collaboration with the local population. Due to climate change and the shift to modern agricultural practices that deplete the soil, many residents no longer grow their own food, resulting in dependence on external food sources. This dependency became particularly evident during the COVID-19 pandemic, which led to food scarcity and higher prices, highlighting the need for self-sufficiency. In partnership with Utrecht University, Perma Atlas is conducting research into sustainable food systems in Anguelz. The goal is to identify methods for restoring soil fertility, enabling residents to become self-sufficient and reduce their reliance on external food supplies.

Perma Atlas also works to build resilient communities by involving and training residents in sustainable practices such as permaculture and food security. The foundation works closely with local communities, aiming to engage as many residents as possible in its activities. By fostering trust and self-reliance, Perma Atlas is helping to create a strong and resilient future for the region.

Sources

- Perma Atlas. (n.d.). Project: Greening mountain slopes. **https://perma-atlas.com/project-vergroenen-van-berghellingen/**
- Casa Aménagement. (n.d.). Development of the Forest of Bouskoura Merchich. **https://www.casa-amenagement.ma/en/nos-projets/foret-de-bouskoura-merchich**

Green mountainscape. Visual by Egyptian Broadcast Systems

66. Generation Green, Morocco:
Olive Tree Programme 2020-2030

Location	Tanger-Tétouan-Al Hoceima region, Morocco
Existing Ecosystems	Cultivated, forest and dryland systems
Climate Change Challenges	Severe droughts
NbS Approach	Olive Tree plantation

Context and Applied NbS Methods

The Generation Green: Olive Tree Programme 2020-2030 is a strategic initiative aimed at planting 200,000 hectares of olive trees in the Tanger-Tétouan-Al Hoceima region by 2030. This program is spearheaded by the Ministry of Agriculture, Maritime Fisheries, Rural Development, and Water and Forests, in collaboration with its Regional Directorate of Agriculture in the region.

The proposed Green Generation Program-for-Results is co-financed by the World Bank and the French Development Agency. It aims to support the Kingdom of Morocco in addressing the economic hardships and job losses resulting from the COVID-19 pandemic while simultaneously mitigating the impacts of severe droughts, such as the one currently affecting the country. At its core, the program seeks to alleviate job losses and improve employment opportunities for the most vulnerable groups, particularly in rural areas.

In addition to its immediate focus on economic recovery, the GGS also accelerates the transition towards more climate-resilient agriculture, building upon the foundations laid by the Green Morocco Plan (Plan Maroc Vert, PMV). This strategic shift aligns with the long-term objectives of addressing recurring droughts and other structural challenges in the agricultural sector, positioning Morocco for a more sustainable and resilient future.

The primary goal of the Olive Cultivation Program is to enhance the productivity, sustainability, and competitiveness of olive cultivation in response to the global challenges posed by climate change.

Sources

- International Bank for Reconstruction and Development. (2020, November 20). Morocco Green Generation Program-for-Results. The World Bank. https://documents1.worldbank.org/curated/en/245801608346893390/pdf/Morocco-Green-Generation-Program-for-Results-Project.pdf

67. The Conservation of Agro-biodiversity, Morocco

Location	Souss-Massa-Draa Region, Morocco
Existing Ecosystems	Dryland, forest and cultivated systems
Climate Change Challenges	Loss and degradation of the Argan ecosystem
NbS Approach	Organic, sustainable, and biodiversity-friendly production practices

Context

As part of the collaboration between the Kingdom of Morocco and the United Nations Development Programme (UNDP), the project titled Circular Economy Approach for the Conservation of Agro-biodiversity in the Souss-Massa-Draa Region was developed with the aim of conserving agro-biodiversity in the Souss Massa Draa region. The long-term goal of the project is to introduce Payment for Ecosystem Services (PES) as an innovative mechanism to reverse the loss and degradation of the Argan ecosystem. This will be achieved in conjunction with the valorization, including labeling and marketing, of two key local products from this ecosystem: Argan oil and honey.

Applied NbS Methods

The project is structured around four interconnected components. Component One focuses on creating an enabling environment for the introduction of PES in Morocco. This involves addressing the necessary institutional, political, and legal changes to establish and pilot this mechanism in the Souss Massa Draa region. Component Two aims to strengthen technical capacities for the implementation of PES models in the region, laying the groundwork for national replication of PES concepts and tools. This will be achieved through the dissemination of lessons learned and the exchange of experiences with other projects and programs. Component Three will promote organic, sustainable, and biodiversity-friendly production practices through a labeling and marketing scheme tailored to products from the Argan ecosystem. Building on the progress of the first three components, Component Four will initiate a pilot PES-type investment, designed to promote, conserve, and sustainably exploit the biodiversity and associated ecosystem services of the Argan ecosystem.

In the initial months following the launch of the project, significant progress has been made. The Project Management Unit has been established, and operational resources have been set up. Additionally, a working group has been initiated to drive the project forward.

Sources

- United Nations Development Programme. (n.d.). Une approche d'économie circulaire pour la conservation de l'agro-biodiversité dans la région du Souss-Massa-Drâa au Maroc (EC-SMD). **https://www.undp.org/fr/morocco/projets/une-approche-deconomie-circulaire-pour-la-conservation-de-lagro-biodiversite-dans-la-region-du-souss-massa-draa-au-maroc-ec-smd**
- United Nations Development Programme. (n.d.). Project 00080094: Circular economy for agro-biodiversity conservation in Souss-Massa, Morocco. **https://open.undp.org/projects/00080094**

Visual by Egyptian Broadcast Systems

68. Man-Made Forests at Al-Jabal Al-Akhdar, Libya

Location	Al-Jabal Al-Akhdar, Libya
Existing Ecosystems	Forest
Climate Change Challenges	Flashfloods, wildfires, increasing temperatures
NbS Approach	Reforestation

Context and Applied NbS Methods

Al-Jabal Al-Akhdar, translating to "The Green Mountain," is a green plateau in the northeast of Libya, stretching approximately 350 kilometers along the Mediterranean coast between the cities of Benghazi and Derna. Covering about 943,000 hectares (1% of Libya's total land area, nearly half of which is an evergreen natural forest) this region stands out in a country predominantly characterized by desert landscapes. Al-Jabal Al-Akhdar is home to 70% of Libya's plant species and contains significant archaeological sites, underscoring its ecological and cultural importance. Unfortunately, some areas of this forest have also experienced degradation and deforestation. According to the head of media bureau at the government's center for agricultural studies, Al-Jabal Al-Akhdar lost 14,000 hectares of forests between 2005 and 2019. Since the 2011 uprising, the country's political instability has been worsening, which caused the rate of forest loss to accelerate as people embarked on clear-cutting and unplanned construction.

Deforestation has significantly contributed to the flashfloods experienced by the local communities as deforested land loses its ability to absorb rainwater. Consequently, water generated by heavy rains regularly floods residential areas. The loss of green cover has also contributed to the increase in ambient temperatures felt by the region's inhabitants. Moreover, higher temperatures have also led to wildfires, which started in July 2021. Although tree cutting and burning is penalized by the Libyan law, law enforcement officers struggle to curb violations as violators are usually heavily armed. Moreover, the penalty does not match the level of destruction caused by these violators.

In response to this destruction and its impacts, a series of reforestation campaigns was launched by civil society organizations in 2018 to protect arable land, buildings, roads, and houses. The campaigns included the planting of more than 4 million seedlings as of 2021 and awareness raising workshops at schools. The workshops aimed to engage more people in conservation efforts through raising awareness about the impacts of tree cutting and teaching students how to plant and preserve

seedlings. While these reforestation efforts are commendable, the pace of reforestation still cannot catch up with the rate of damage and more efforts are needed to bring back the forests of Al-Jabal Al-Akhdar.

Figure 78 Al Jabal Al Akhdar Plan

Note. Indicated the 5 study sites selected for investigation. From Mohamed, O.A.-F., Ibrahim, E.K., Ahmed, M.E.-B., Hosney, A.A.-G., Ahmed, A.A.E.-S. (2019, June). Evaluation of Some Man-Made Forests at Al-Jabal Al-Akhdar in Libya. Alexandria Journal of Agricultural Sciences 64, 173–194. https://doi.org/10.21608/alexja.2019.70132

Sources

- Hendia Alashepy. (2021, July 20). Libya: The fight to save a forest surrounded by desert. DW News. https://www.dw.com/en/libyas-battle-to-protect-its-endangered-forests/a-58205945
- Mohamed, O.A.-F., Ibrahim, E.K., Ahmed, M.E.-B., Hosney, A.A.-G., Ahmed, A.A.E.-S. (2019, June). Evaluation of Some Man-Made Forests at Al-Jabal Al-Akhdar in Libya. Alexandria Journal of Agricultural Sciences 64, 173–194. https://doi.org/10.21608/alexja.2019.70132

69. The Afforestation, Reforestation and Revegetation (ARR) Project, Libya

Location	Tripoli, Libya
Existing Ecosystems	Forest, seasonal wadi, and open green spaces
Climate Change Challenges	Desertification, declining rainfall, and Extreme Weather Events such as sand and dust storms
NbS Approach	Afforestation using water-saving techniques

Context and Applied NbS Methods

In a significant step towards advancing environmental preservation, combating desertification, and supporting Climate Action and Life on Land (aligned with SDGs 13 and 15), Oilinvest and the Public General Services Company-Tripoli launched an integrated reforestation and agroforestation project in Tripoli. This initiative aims to address pressing environmental challenges while promoting sustainable development in Libya. The Afforestation, Reforestation, and Revegetation (ARR) project demonstrates a shared commitment to reducing carbon emissions, mitigating desertification, and conserving Libya's natural resources.

Oilinvest and the Public General Services Company signed a strategic agreement to plant up to one million trees across 1,450 hectares within the deteriorated Wildlife Park Tripoli site. This agreement outlines the framework for project implementation and management, reinforcing Libya's commitment to reducing greenhouse gas emissions and promoting sustainable land use. The ARR project will commence with the reforestation of an initial 450 hectares during the first phase. This phase will include the installation of a drip irrigation system and the establishment of an in-house tree seedling nursery. Subsequent phases will expand the project to cover the remaining 1,000 hectares.

Once fully implemented, the project is expected to achieve significant environmental outcomes. The one million trees that will be planted are estimated to absorb over 10 million tons of CO2 equivalent annually once fully grown. This will contribute substantially to Libya's climate action goals and the broader Mediterranean region's environmental sustainability.

Sources

- Oilinvest. (2024, April 17). Oilinvest (Netherlands) B.V. and the Libyan Public General Services of Tripoli forge a strategic collaboration to implement a nature-based carbon sequestration ARR project in Libya. Oilinvest. https://www.oilinvest.com/oilinvest-netherlands-b-v-and-the-libyan-public-general-services-of-tripoli-forge-a-strategic-collaboration-to-implement-a-nature-based-carbon-sequestration-arr-project-in-libya/

70. Ancient Irrigated Terraces, Palestine

Location	Battir, Bethlehem, Palestine
Existing Ecosystems	Hillside agricultural land; mountainous ecosystem
Climate Change Challenges	Water scarcity, prolonged drought periods, increased rainfall variability and increased temperatures
Complementary NbS Type	Water Management and Resilience
NbS Approach	Rainwater harvesting and management for agriculture

Context and Applied NbS Methods

Terracing, a traditional agricultural practice, transforms steep hillsides into flat, arable areas surrounded by stone walls known as sanasel. In Battir, these terraces play a crucial role in reducing water runoff and preventing soil erosion. They also define the distinctive landscape and serve as boundaries for land ownership. However, the region is primarily characterized by smallholdings due to inheritance-based land fragmentation.

Terraces in Battir are classified based on their irrigation methods:

- Downstream Terraces (al-jenan or "paradise"): These terraces are used for irrigated agriculture and are divided into smaller plots called masateb. They are planted with fruits, vegetables (notably the Battiri eggplant), and aromatic herbs. Their proximity to inhabited areas is essential for farmers, as water-dependent crops require intensive care.

  Upstream Terraces (al-karrm or "farms"): Due to their upstream location, these terraces rely on rainfed farming. They are subdivided into plots called habalat and are used to grow crops that do not require regular care such as olives, figs, and grapevines.

The irrigation system in Battir, which was developed during Roman times, has been preserved in its traditional form.

It consists of two primary components

1. **Physical Infrastructure:**
   The irrigation system begins with a spring that feeds into a central canal, directing water to a Roman-era pool where it is collected. From the pool, a network of open canals distributes water to the terraces. At the spring, water forms a small waterfall (serdab al-'ein), the strength of which reflects the quality of the rainy season and the replenishment of groundwater.

2. **Social Distribution System or *Al-Ma'dood (the counted system in English)*:**
   The distribution of water is managed through a traditional system, which operates at two levels:

- **Family Allocation:** Water is divided among Battir's eight major families, with each family entitled to collect and use spring water for one day in an eight-day cycle.
- **Intra-Family Allocation:** Within each family, water is further portioned out based on individual land ownership.

Water collection begins at night when it flows from ***'ein al-balad*** (spring of the village in English) into the pool. In the morning, a family representative measures the water level using ***al-ma'dood***, which is a wooden stick marked with thorns to indicate water levels and portions. These portions are allocated in time units rather than specific water quantities. The time between sunrise and sunset is divided into units proportional to each family member's land area.

When it is a farmer's turn, they open the pool's outlet to release water into the mashakib—a network of open canals reaching all terraces. The farmer directs water flow by blocking and unblocking canal junctions using soil or other materials. At sunset, the outlet is closed by a representative of the next family to allow water collection for the following day.

This intricate system not only sustains Battir's agricultural practices but also reflects a deep integration of physical infrastructure and social cooperation, ensuring equitable water distribution among the community.

Figure 79 Terraces in Battir Valley, Palestine

Note. From Desclaux-Salachas, J. (2024). BIBLIOGRAPHY — INSTITUTIONAL CARTOGRAPHY & BATTIR, village of Palestine. Publications since 2012: Conferences, Papers, Exhibitions — Links to Web Sites & Blogs by Jasmine Desclaux-Salachas, cartographer -les Cafés-cartographiques. Jasmine Desclaux-Salachas. https://doi.org/10.5194/ICA-PROC-4-27-2021

Sources

- Nasser, K.D. (2024). Spring-based irrigation in Battir, Palestine: A locus of social agency in the face of hydro-hegemony. Water Alternatives 17(1): 20-45 https://www.water-alternatives.org/index.php/alldoc/articles/vol17/v17issue1/735-a17-1-2/file

71. Microcatchment Rainwater Harvesting, Palestine

Location	West Bank, Palestine
Existing Ecosystems	Drylands
Climate Change Challenges	Droughts and increasing temperatures
Complementary NbS Type	Water Management and Resilience
NbS Approach	Rainwater harvesting through microcatchments

Context and Applied NbS Methods

In Palestine, olive trees are traditionally cultivated in rainfed, undulating landscapes where the annual rainfall averages between 400 and 700 mm. Although drought-resilient, these trees are planted in degraded and steeply sloping areas, where the infiltration and storage of water are limited. A significant portion of rainfall becomes surface runoff, which accelerates land degradation by causing erosion and removing fertile topsoil, ultimately reducing soil health and productivity.

Recognizing these challenges, the International Center of Agricultural Research in Dry Areas (ICARDA) and others introduced microcatchment water harvesting structures around rainfed olive trees in degraded and marginal drylands of Palestine. This method aims to enhance soil moisture by capturing runoff and improving infiltration, thereby increasing yields and reducing the potential for land degradation caused by surface runoff. This intervention supports local land users and owners, who are often marginalized due to limited access to off-farm employment and financial resources for farm investments. These farmers are also directly affected by climate change, experiencing frequent droughts that contribute to declining yields and reduced farm income.

Depending on the soil conditions, topography, and local climate, olive trees are generally spaced 5 to10 meters apart to minimize competition for water. First, the land is surveyed before constructing the microcatchment water harvesting structures, which are technically known as "semi-circular bunds." These structures are placed about 0.5 meters downslope from each olive tree and form a semi-circle with a diameter of approximately 4 meters. They are built using a stone foundation topped with a compacted soil layer, with heights ranging from 0.3 to 1.2 meters. The process begins with arranging and fixing stones in a semi-circular shape.

Next, the soil within the structure is leveled slightly. More stones are then added to increase the bunds' height, and finally, excavated soil and surrounding soil are compacted over the stones. The estimated cost of constructing these microcatchments is

about 7 USD/m of bund, resulting in a total cost of roughly 7000 USD/hectare.

The water harvesting system implemented in highly sloping areas is estimated to last 15 years, with annual maintenance costs of approximately 3 USD/tree or 300 USD/hectare. Lack of maintenance will shorten the system's lifespan. Given its ability to increase olive yields and consequently income, land users value this technology. They observe that maintaining topsoil in place and improving soil moisture positively impacts their harvests. However, they also acknowledge that implementation and maintenance require additional labor. Despite this, the low cost of the system, due to the use of locally available materials, is seen as a benefit.

This case study is extracted from the project "Testing and Out-scaling in situ Water Harvesting Technologies in Palestine" led by ICARDA in partnership with the Palestinian Ministry of Agriculture, the Applied Research Institute Jerusalem, and the National Agricultural Research Centre in Palestine. This project is part of the FAO led regional project entitled "Implementing the 2030 Agenda for water efficiency/productivity and water sustainability in NENA countries", under the Regional Water Scarcity Initiative. The project is funded by the Swedish International Development Cooperation Agency.

Figure 80 Water Harvesting Structures - Semi-circular Bunds

Note. Water harvesting structures (semi-circular bunds) implemented at the Faqua'a site in Palestine using soil and stones (Left) and soil only (Right) Photo: ARIJ, 2021. From WOCAT. (2022, December 9). Rainwater Harvesting for Olive Production [Palestine, State of]. WOCAT SLM Database. https://qcat.wocat.net/en/wocat/technologies/view/technologies_6437/

Sources

- International Center for Agricultural Research in the Dry Areas (ICARDA). (n.d.). Testing and out-scaling in-situ water harvesting approaches in Palestine. https://icarda.org/research/projects/testing-and-out-scaling-situ-water-harvesting-approaches-palestine
- Verbist, J. (Compiler), Critchley, W., & Mekdaschi Studer, R. (Reviewers). (2023). Rainwater harvesting for olive production [Palestine, State of]. World Overview of Conservation Approaches and Technologies (WOCAT). https://qcat.wocat.net/en/wocat/technologies/view/technologies_6437/
- Dhehibi, B., Haddad, M., Alimari, A., Shadeed, S., Strohmeier, S., Nofal, I., Sayeh, A., AbuAlhaija, I., Besharat, M., Ghenma, I., & Nangia, V. (2023). Potential of water harvesting as a strategic tool for resilience, sustainable livelihoods, and drought mitigation in the olive farming system in Palestine. Beirut, Lebanon: International Center for Agricultural Research in the Dry Areas (ICARDA). https://mel.cgiar.org/reporting/downloadmel-space/hash/18e6fc8bbdbd63efda4d7514ea146efa/v/180777a453068eee988ab7d7f541d2c4

72. The Miyawaki Forest Program, Jordan

Location	Across Jordan
Existing Ecosystems	Urban and cultivated systems
Climate Change Challenges	Urban heat island effects, Water scarcity
NbS Approach	Urban Forests, Greywater reuse system

Context

The Miyawaki Forest Program (to launch in 2025) is designed to establish dense, biodiverse forests using the Miyawaki method and implement greywater reuse systems in urban and suburban locations across Jordan. This initiative seeks to enhance green cover, mitigate urban heat island effects, improve biodiversity, and promote sustainable water use, addressing Jordan's limited water resources.

Applied NbS Methods

To realize its goals, the program identifies suitable urban and suburban sites for forest creation, ensuring safety, ecological suitability, and visibility to inspire replication. Site preparation and tree planting activities are carried out in collaboration with local stakeholders, including municipalities and community groups. Greywater reuse systems are integrated into public buildings to demonstrate sustainable water management practices.

The program also includes a robust monitoring framework to assess environmental impacts, such as tree growth rates, biodiversity enhancements and water savings from greywater reuse. Educational campaigns and capacity-building initiatives raise awareness about native species, biodiversity, and ecological restoration, empowering communities to actively participate in ecological efforts.

Sources

- Climate Action NGO in Jordan. (n.d.). Miyawaki Forest Method and Gray Water Reuse in Jordan. https://climateaction-now.org/miyawaki-forest-method-and-gray-water-reuse-in-jordan/

73. The Kuwait Environmental Remediation Program, Kuwait

Location	Kuwait
Existing Ecosystems	Arid and rangelands
Climate Change Challenges	Ecological degradation, desertification
Complementary NbS Type	Coastal and Marine Ecosystem Restoration
NbS Approach	Remediation and revegetation and restoration of an artificial reef

Context

Land Degradation and Ecological Challenges in Kuwait

Over the past six decades, Kuwait's landscape has undergone significant transformations due to rapid urbanization, leading to the loss of ecologically productive land.

Rangelands, once flourishing ecosystems, have experienced severe degradation caused by overgrazing, desertification, and environmental destruction—most notably as a result of the 1990 Iraqi invasion. During the conflict, more than 700 oil wells were detonated, contaminating the soil and further accelerating ecosystem decline. The cumulative impact of these disturbances has left vast areas infertile, necessitating targeted restoration efforts to regenerate vegetation and re-establish ecological balance.

The environmental devastation impacted both terrestrial and marine wildlife, with long-term consequences that remained uncertain for years. While soil remediation projects have been ongoing to address land contamination, Kuwait's coral reefs continue to struggle, particularly due to coral bleaching and habitat degradation. In response to these challenges, efforts have also been made to rehabilitate marine ecosystems and restore biodiversity.

Applied NbS Methods

1. Re-vegetation

To address these challenges, the Kuwait Oil Company (KOC) launched large-scale remediation and revegetation projects under the Kuwait Environmental Remediation Program. These efforts, implemented across Southeast Kuwait and North Kuwait oil fields, are overseen by the Kuwait National Focal Point and funded by the United Nations Compensation Commission (UNCC) as part of broader recovery initiatives following the Gulf War.

The revegetation efforts span approximately 42 km² of land managed by KOC, carefully selected based

on UNCC guidelines to minimize conflicts with ongoing oilfield operations and ensure long-term ecological restoration. The projects aim at combating sand encroachment, mitigating dust storms in affected oil fields, and restoring native vegetation to pre-invasion levels.

To achieve these objectives, the program plans to introduce 9.5 million plants representing 12 native species, utilizing modern remediation techniques that accelerate vegetation recovery. The large-scale cultivation of native perennial plant species which has proven technically feasible with minimal infrastructure investment is integral to the approach of the program. These plants restore ecosystem stability and generate substantial quantities of seeds within a year, aiding broader remediation efforts. Additionally, native perennial grasses serve as a sustainable source of fodder for livestock and require significantly less irrigation than conventional forage crops.

2. Restoration of an Artificial Reef

To revitalize Kuwait's marine habitats, the KOC partnered with the Kuwait Institute for Scientific Research (KISR) to launch the Marine Colony Project, aimed at enhancing fish populations, rehabilitating coral reef habitats, and promoting biodiversity conservation in Kuwait's waters. Within the scope of the project, an artificial reef was built in 2005, approximately 4.3 nautical miles southeast of Al-Ahmadi Port. Spanning 48,500 m², the reef consists of 1,000 reef balls strategically placed in clusters at depths of 7 to 9 meters.

To evaluate the reef's effectiveness, a joint diving team from KOC and KISR conducted seasonal ecological assessments using advanced monitoring techniques. Their research confirmed that the reef ball clusters significantly boosted coral habitats and biodiversity, demonstrating the potential for artificial reefs to contribute to marine ecosystem recovery. These insights also support broader restoration projects, including initiatives to rehabilitate the degraded coral reefs at Kubbar Island through innovative research and design strategies.

In addition to its ecological impact, the Marine Colony Project also focused on raising awareness about Kuwait's marine environment. KOC launched community outreach activities that included school awareness sessions, beach clean-up campaigns, and recycling initiatives in Ahmadi. Through these efforts, the project reinforces environmental responsibility, encouraging the public to participate in conservation activities that protect Kuwait's natural resources.

Integrating scientific research, ecological

Figure 81 Native Plants Revegetation in Kuwait Before and After

Note. From Kaitharath, J. and Omar, S. (2023, March 7). Revegetating Kuwait's Damaged Natural Ecosystem with Native Plants. SBB 6. https://doi.org/10.31031/SBB.2023.06.000628

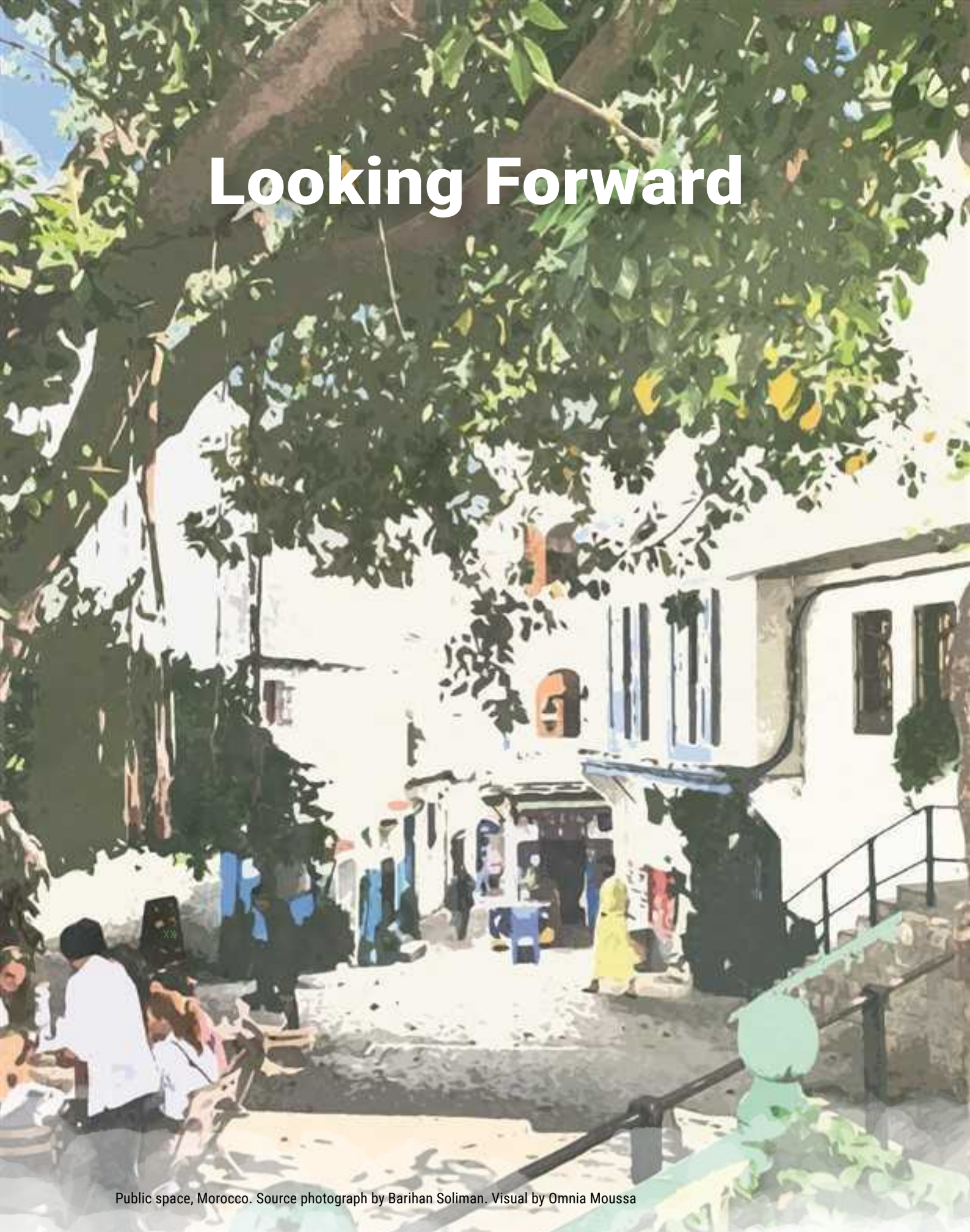
restoration, and community engagement, the Marine Colony Project successfully supports marine biodiversity, combats coral reef degradation, and fosters environmental stewardship. As Kuwait continues its restoration efforts, this initiative stands as a valuable model for marine conservation.

Sources

- Kaitharath, J. and Omar, S. (2023, March 7). Revegetating Kuwait's Damaged Natural Ecosystem with Native Plants. SBB 6. https://doi.org/10.31031/SBB.2023.06.000628
- Al-Barood, A., Al-Kandari, H. and Vedhapuri, S. (2023). Kuwait Environmental Remediation Program (KERP): Criteria for Site Selection and Expected Benefits of The Revegetation Projects. Advances in Ecological and Environmental Research (ISSN 2517-9454, USA) Vol. 8, Issue 09, pp. 19-26. Science Signpost Publishing. https://www.ss-pub.org/wp-content/uploads/2023/09/AEER2023071201.pdf

Visual by Egyptian Broadcast Systems

Looking Forward



Public space, Morocco. Source photograph by Barihan Soliman. Visual by Omnia Moussa

Looking Forward

Long before NbS was introduced into modern terminology, the Arab region has had a rich legacy of techniques like qunuwāt (underground channels), fuqqārāt (open ditches), rainwater harvesting, and terraced farming[9]. Today, the region is emerging as a hub for innovative, large-scale NbS initiatives with global relevance. A range of knowledge, policy and financing measures are available to support NbS investments.

Knowledge Generation, Technological Advancements, and Policy Support

Given the emergent status of NbS in the region, several organizations are working on improving the knowledge base and supporting NbS approaches in the Arab region.

For example, platforms like Climate Investment Funds (CIF) Nature, People, Climate (NPC) Learning Platform[10] are supporting the acceleration of the exchange of knowledge and best practices on NbS globally, including in the Arab region. MDBs, such as the World Bank Group, are supporting knowledge generation at a global level on NbS for urban resilience, cost-benefit analysis of NbS, integrating gender and social inclusion in NbS, and private sector opportunities for NbS[11]. The Trees in Dry Cities Coalition[12], a United Nations initiative, champions the power of urban trees and nature as a nature-based solution for cities and towns in drylands. The Coalition promotes knowledge sharing, awareness raising, and pilot programs thereby influencing policy via the provision of data, best practices and joint research.

Advancements in technologies to support NbS will also play a critical role, particularly at the local level, as outlined in a 2024 affordable and transferable green and climate-smart mapping exercise conducted by FAO, IFAD and IsDB.[13] The assessment, which included case studies from Egypt, Jordan, Morocco, Palestine, and Tunisia, included green and climate-smart technologies such as agrivoltaics (dual solar and smallholder farm use), smart irrigation systems, waste reuse and recycling, geothermal greenhouses, renewable energy, green fintech innovations, and others.

Region-specific initiatives, such as the Al Murunah[14] project by the International Water Management Institute (IWMI) is enhancing water security by implementing NbS in agriculture and water management practices across pilot sites in Egypt, Jordan, Lebanon, and the Occupied Palestinian Territories. Learnings gained from these pilot activities may ultimately be scaled up to influence policy, expand their reach, and embed lasting change within communities.

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9 https://www.iwmi.org/blogs/al-murunah-project-expands-nature-based-solutions/#:~:text=For%20millennia%2C%20farmers%20in%20the,%2C%20social%2C%20and%20environmental%20viability.

10 Climate Investment Funds, January 2024, Nature-based solutions: A learning platform to support country-led climate ambitions, https://www.cif.org/news/nature-based-solutions-learning-platform-support-country-led-climate-ambitions#:~:text=This%20is%20how%20Rodrigo%20Fincheira,for%20knowledge%20exchanges%20on%20NbS.

11 World Bank Group, 11th July 2025, Mobilizing Nature-Based Solutions for Disaster and Climate Resilience, https://www.worldbank.org/en/results/2025/07/10/mobilizing-nature-based-solutions-nbs-for-disaster-and-climate-resilience.

12 Trees in Dry Cities Coalition, https://unece.org/forests/trees-dry-cities-coalition.

13 FAO, IFAD and IsDB. 2024. Mapping affordable and transferrable climate-smart technologies for smallholder farmers. Cairo. https://doi.org/10.4060/cd2799en.

14 International Water Management Institute (IWMI), April 2025, IWMI's Al Murunah project scales nature-based solutions to achieve water-security in the MENA region, https://www.iwmi.org/blogs/al-murunah-project-expands-nature-based-solutions/#:~:text=Hosni%20Azzam%2C%20Deputy%20Minister%20of,resilience%20across%20the%20MENA%20region

Such initiatives to enhance knowledge and support policy reform ultimately must be connected to broader Rio Convention Framework goals and national implementation mechanisms (e.g. NBSAPs, NDCs, NAPs, as outlined in the introduction). As an example, Box 1 outlines cases of Arab countries developing and enhancing their NBSAPs, NDCs, and NAPs (see Box 1).

Box 1 – Examples of Select Arab NBSAPs, NDCs & NAPs

Many countries in MENA are enhancing their NBSAPs. Some examples of the focus of NBSAPs in the region include:

Jordan's NBSAP outlines a framework for conserving biodiversity and sustainably using natural resources, with a focus on in-situ conservation, understanding ecosystems, and protecting natural resources. The NBSAP also addresses cross-cutting issues like knowledge management, technical training, and local community empowerment. The NBSAP addresses the need for resource mobilization to support biodiversity conservation efforts.[15]

Egypt's NBSAP has six main goals, including sustainable management of natural resources, development of scientific and technological capabilities in biodiversity conservation, mobilization of national resources, promotion of public participation, and establishment of legal and economic incentives for conservation. The NBSAP includes a national action plan with 11 programs categorized into 1) enabling and supporting, 2)applied, and 3) Research and monitoring projects. A National Biodiversity Unit has established a biodiversity database to support monitoring efforts. To date, Egypt has made progress in establishing protected areas and building capacity in nature conservation. There is an opportunity to strengthen the mainstreaming of biodiversity considerations into various sectors and policies, including the development of legal instruments and economic incentives.[16]

Morocco's NBSAP aims to make biodiversity a pillar of sustainable development, ensuring societal well-being and the sustainable use of natural resources. It focuses on conserving, restoring, valuing, and sustainably managing biological diversity and the ecosystem services it provides. It also emphasizes strengthening biodiversity knowledge, inter-institutional coordination, and international cooperation. Morocco recognizes the importance of cross-cutting issues like climate change and gender in biodiversity conservation, integrating them into the NBSAP. The NBSAP emphasizes the need for greater collaboration and involvement of the private sector in biodiversity conservation and sustainable use. Morocco actively revises its NBSAP through utilizing an annual quick assessment process to track implementation progress and adapt the NBSAP as needed. [17]

Iraq's NDC, in addition to mitigation and adaptation measures, acknowledges the potential of NbS, particularly in the context of water resources, agriculture, and ecosystem protection. One example is a project in Basra Marshes that aims to enhance climate resilience through NbS, the Water-Energy-Food-Ecosystem (WEFE) Nexus approach, and sustainable land management.[18]

United Arab Emirates' NDC includes economy-wide mitigation and adaptation measures, including an explicit role for NbS. NbS include blue economy and mangrove ecosystem support, including coastal protection against rising sea levels and storm surges, as well as carbon sequestration. The target for mangrove restoration includes

planting 100 million mangroves by 2030. Mangrove restoration can also have positive tourism. The UAE emphasized the importance of NbS in climate action and hosted initiatives like the Sustainable Blue Economy guidelines at COP28 in Dubai.[19]

Lebanon's NAP, launched in 2003, is a comprehensive framework to combat desertification, land degradation, and drought. The NAP emphasizes sustainable land management, aligns with SDG 15.3 on land degradation neutrality (LDN), and integrates participatory, bottom-up approaches involving local communities. Lebanon has established an institutional framework to mainstream UNCCD principles into national development. The NAP also supports decentralization and empowering local authorities in natural resource management.[14]

[15] Ministry of Environment, Jordan. (2015). National Biodiversity Strategy and Action Plan. Convention on Biological Diversity. **https://www.cbd.int/doc/world/jo/jo-nbsap-v2-en.pdf**

[16] Ministry of Environment, Egypt. (2015). National Biodiversity Strategy and Action Plan. Convention on Biological Diversity. **https://www.cbd.int/doc/world/eg/eg-nbsap-v2-en.pdf**

[17] Haut Commissariat aux Eaux et Forêts et à la Lutte Contre la Désertification. (2016). Stratégie Nationale de la Biodiversité et Plan d'Action [National Biodiversity Strategy and Action Plan]. Convention on Biological Diversity. **https://www.cbd.int/doc/world/ma/ma-nbsap-v3-fr.pdf**

[18] Government of Iraq. (2021). Nationally Determined Contribution (NDC). United Nations Framework Convention on Climate Change (UNFCCC). **https://unfccc.int/documents/497569**

[19] Government of the United Arab Emirates. (2024). Third Nationally Determined Contribution (NDC). United Nations Framework Convention on Climate Change (UNFCCC). **https://unfccc.int/sites/default/files/2024-11/UAE-NDC3.0.pdf**

[20] Government of Lebanon. (2023). National Adaptation Plan Progress Report. United Nations Framework Convention on Climate Change (UNFCCC). **https://unfccc.int/sites/default/files/resource/NAP-progress-publication-2023.pdf**

Regional and Global Initiatives

Beyond local and national-level NbS actions, the Arab region is demonstrating regional and global leadership on NbS.

In recent years, the region has hosted major Conferences of the Parties (COPs). COP27 of the UNFCCC in Sharm El-Sheikh, Egypt (2022) elevated NbS on the global climate agenda, including through the launch of the Enhancing Nature-based Solutions for an Accelerated Climate Transformation (ENACT) initiative to accelerate and coordinate NbS action. This momentum carried into COP28 of the UNFCCC in Dubai, United Arab Emirates (2023), and COP16 of the UNCCD in Riyadh, Kingdom of Saudi Arabia (2024). Both COP28 and COP16 placed significant emphasis on NbS, highlighting their central role in climate change mitigation and adaptation, as well as in efforts to combat desertification, drought, and land degradation (see Box 2).

Box 2– Arab region hosts important COPs for NbS

COP28 in Dubai, UAE included a focus on NBS, such as:

- The outcome of the global stocktake at COP28 formally acknowledged the importance of nature and NbS in mitigating climate change and protecting vulnerable communities.
- NbS was presented as part of a suite of strategies to tackle climate change, alongside transitioning to renewable energy and reducing energy consumption. COP28 discussions emphasized the immediate positive impacts, scalability, cost-effectiveness, and potential for job creation associated with NbS.
- The decision on the Global Goal on Adaptation, established under the Paris Agreement, included references to ecosystem-based approaches and NbS.
- Challenges for NbS, which include insufficient financial investment and a lack of consistent understanding across sectors regarding what qualifies as NbS. A call to action included a need to champion high integrity, properly financed NbS to meet the urgent needs of climate action at scale.
- COP28 is regarded as the largest UNFCCC COP to date.

COP16 in Riyadh, KSA had the theme of "Our Land. Our Future", including an NbS focus:

- A key focus was on NbS for drought, including recognition of the importance of community engagement, policy changes, and access to finance for successful implementation.
- The Riyadh Global Drought Resilience Partnership (RGDRP) was launched at COP16[21], which includes support for 74 of the world's most drought-vulnerable countries, and is expected to strongly integrate NbS. The RGDRP is proposed to be the world's leading drought resilience building initiative.
- The conference aimed to move beyond pilot projects and scale up NbS adoption for effective action against drought and land degradation.
- The conference also saw the launch of the Business 4 Land (B4L) Call to Action, encouraging companies to adopt sustainable practices.
- COP16 was the largest UN land conference to date and the first UNCCD COP held in the Arab region

In 2025, UAE hosted the IUCN Congress in Abu Dhabi, with Powering Transformative Conservation. The congress focused on accelerating conservation action through five interconnected themes: scaling up resilient conservation action, reducing climate overshoot risks, delivering on equity, transitioning to nature-positive economies and societies, and using disruptive innovation and leadership for conservation.

Beyond an increasing advocacy role for the Arab region on NbS in international fora, several large-scale nature-based initiatives are emerging, and are expected to support local level actions. These initiatives include Africa's Great Green Wall, the Nature-based Solutions for Climate, Biodiversity, and People, and the Middle East Green Initiative (see Box 3).

[21] https://www.unccd.int/sites/default/files/2023-12/TNC%20UNCCD%20NbS%20and%20Drought%20Technical%20Brief_v3.pdf.

Box 3 – NbS initiatives relevant for the Arab region

The Great Green Wall is an African-led initiative to combat desertification and land degradation in the Sahel region, including extension into some Arab countries. It aims to restore 100 million hectares of degraded land, create 10 million green jobs, and sequester 250 million tons of carbon by 2030. Stretching 8,000 km from Senegal to Djibouti, it's a mosaic of green and productive landscapes designed to improve livelihoods and foster environmental sustainability.

The UAE's Nature-based Solutions for Climate, Biodiversity, and People[22] initiative aims to enhance the resilience of blue carbon ecosystems—mangroves, seagrasses, and saltmarshes—delivering climate mitigation, biodiversity gains, and socio-economic benefits. Key goals include restoring coastal carbon sinks, reducing emissions, integrating climate-nature policies, unlocking ecotourism and food innovation, and mobilizing blended finance. Funded by HSBC and led by Ministry of Climate Change and Environment, Ministry of Economy, Environment Agency – Abu Dhabi, Umm Al Quwain, Emirates Nature-WWF, and the International Center for Biosaline Agriculture, the project is part of HSBC's global Climate Solutions Partnership with the World Resources Institute and the World Wide Fund for Nature. Aligned with the IUCN Global Standard, it adopts a seascape-level approach to demonstrate commercial viability, drive entrepreneurship, and attract investment—anchored in science, policy reform, and public engagement.

Building upon its Saudi Green Initiative (SGI)[23] , which is a national strategy to combat climate change, enhance quality of life, and safeguard the environment for future generations, KSA launched the Middle East Green Initiative (MGI) in 2021. MGI aims to drive regional climate action and support global goals by planting 50 billion trees (~5% of the global afforestation goal) and cutting 670 million tons of CO_2 emissions (10% of global contributions at launch). It also promotes regional cooperation, economic diversification, and private sector investment. Backed by a dedicated Secretariat and up to US$2.5 billion commitment, MGI now has 30 endorsing countries across the Arab region, Africa, and Central Asia. MGI is proposed as the world's largest reforestation program.

Financing and Empowerment Opportunities for NbS

To achieve biodiversity, climate and land degradation targets, it is estimated that investments need to more than double current levels to $384bn per year by 2025 and $484bn per year by 2030[24].

This is aligned with Target 19 of the Global Biodiversity Framework, which specifically aims to mobilize at least US$200 billion annually towards biodiversity conservation[25]. A combination of public, private, domestic and international finance sources will be required to achieve these targets, including provision of support for NbS.

[22] Sources: (i) HSBC, 25 March 2024, Unlocking Nature-based Solutions for Climate Resilience in the MENA Region, **https://www.about.hsbc.ae/news-and-media/unlocking-nature-based-solutions-for-climate-resilience-in-the-mena-region** & (ii) The NbS Project in the UAE, **https://naturebasedsolutions.ae/**

[23] Saudi Green Initiative website, **https://www.sgi.gov.sa/.**

[24] United Nations Environment Program (UNEP), 2022 State of Finance for Nature.

[25] Target 19, Global Biodiversity Framework, **https://www.cbd.int/gbf/targets/19/.**

While NbS is generally considered a cost-effective option, including for emerging areas such as mitigating disaster hazards[26], several challenges remain for NbS financing.

Such challenges include:

1. NbS remains a relatively novel concept for many stakeholders, where an agreed / standardized taxonomy may benefit interested parties;
2. The multiplicity of NbS benefits can be difficult to capture in traditional valuation and accounting methods;
3. Quantifying and disseminating NbS results and return on investment can be complex; and
4. Coordination on NbS between public and private financiers requires strengthening to overcome potentially longer investment times and perceived/actual risks[27].

Despite these challenges, there are multiple sources of public and private finance, and financiers that are increasingly engaging in NbS support[28].

Examples of public sources of finance which could support NbS include national budgets and international concessional grants and loans. Where public finance is limited, engaging the private sector through blended financing presents an opportunity, including a shift towards outcome- and impact-based financing, such as results-based models and public-private partnerships.

Private philanthropic finance rojects that may not immediately attract commercial investment due to perceived high risk or long-term returns. This support can help de-risk projects, making them more attractive to other investors and enabling the scaling up of NbS initiatives that address climate change, biodiversity loss, and other societal challenges. Additionally, innovative financing vehicles, such as thematic bonds, debt swaps, and private equity vehicles, may help to crowd-in private sector investment for NbS. Households, which are often overlooked as private investors, may also contribute to local-level NbS measures.

Islamic Finance, with its ethical and sustainable core principles, aligns closely with NbS and may also serve Arab communities not utilizing conventional financing modalities. For example, Green and Sustainability Sukuk, the Islamic equivalent of green and sustainability bonds, can support NbS investments.

Box 4 outlines examples emerging NbS financing modalities, including green thematic bonds, green lines of finance (green loans), and locally relevant innovative approaches such as crowdfunding and green microfinance.

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[25] Vicarelli, M. et al., October 2024, On the cost-effectiveness of Nature-based Solutions for reducing disaster risk, Science of The Total Environment, Vol. 947, 174524, **https://doi.org/10.1016/j.scitotenv.2024.174524.**

[26] (i) World Resources Institute, November 2022, 5 Barriers That Hinder Green Financing, López Portillo Purata, V., Gómez, S. & Eunice Rodríguez, S., **https://www.wri.org/update/5-barriers-hinder-green-financing.** (ii) Toxopeus, H. & Polzin, F., 2021, Reviewing financing barriers and strategies for urban nature-based solutions J. Environ. Manage., 289, Article 112371, 10.1016/j.jenvman.2021.112371.

[27] IsDB, December 2024, An Innovative Finance Framework for Sustainable Drylands Development, **https://www.isdb.org/sites/default/files/media/documents/2024-12/IsDB%20-%20An%20Innovative%20Finance%20Framework%20for%20Sustainable%20Drylands%20Development%20-%2001-12-2024%20-%20Final%20%282%29.pdf.**

[27] Sources: (i) IsDB, November 2024, An Innovative Finance Framework for Sustainable Dryland Development, https://www.isdb.org/sites/default/files/media/documents/2024-12/IsDB%20-%20An%20Innovative%20Finance%20Framework%20for%20Sustainable%20Drylands%20Development%20-%2001-12-2024%20-%20Final%20%282%29.pdf; & (ii) Narayanan, N., October 2024, Middle East's green bond issuances reach $16.7bn for 2024: S&P Global, https://www.arabnews.com/node/2575501/business-economy; (iii) Sustainalytics, Commundo, Nordico websites; (iv) Tadamon Community, https://tadamon.community/.**fault/files/media/documents/2024-12/IsDB%20-%20An%20Innovative%20Finance%20Framework%20for%20Sustainable%20Drylands%20Development%20-%2001-12-2024%20-%20Final%20%282%29.pdf.**

Box 4 – Financing NbS[28]

Green thematic bonds – Countries with manageable debt and market access can leverage thematic bonds, such as green, restoration, or resilience bonds, to issue new debt or refinance existing obligations, aligning proceeds with sustainability goals. Those with stronger debt positions may also use performance bonds or new loans to prepay debt and fund climate initiatives.

In 2023, global sustainable bond issuance topped USD 1 trillion, led by green bonds. Performance bonds offer flexibility, provided that climate and nature-related KPIs drawn from national plans like NDCs or biodiversity strategies are met.

Thematic bonds are gaining traction as long-term tools for conservation and sustainable development, with emerging instruments like restoration, landscape, and resilience bonds targeting specific outcomes.

In 2024, green bond issuance in the Middle East reached USD 16.7 billion. Green sukuk - Shariah-compliant sustainable debt - are also rising as regional markets embrace sustainable finance.

Green loans offered by public and private lenders enable borrowers to use the proceeds to exclusively fund projects that help to drive the green transition, such as NbS, ecosystem restoration, or emissions reduction. To qualify, projects must meet strict environmental criteria ensuring measurable impact. These loans are available to individuals and businesses through banks and other financial institutions, with options ranging from sector-specific (e.g., agriculture) to broader eligibility.

According to the Green Loan Principles, coordinated by International Capital Market Association, green loans must exclusively fund environmentally beneficial activities. Unlike green bonds, which raise capital from investors, loans are financed directly by lenders.

Technologies like drones and satellites enhance the effectiveness of green loan-funded projects by enabling high-resolution monitoring and improved land management.

Platforms supporting local green financing – Financing platforms such as microfinance and crowdfunding offer potential opportunities to mobilize green finance on a local scale.

Green microfinance can be a tool to integrate the principles of environmental sustainability to promote ecologically sound practices in financial and social aspects of microfinance. Microfinance may offer an avenue to both empower women and youth (via increased access to finance) and support NbS initiatives.

Crowdfunding typically raises small amounts of finance from large numbers of people, typically via the internet. TADAMON, launched by the Islamic Development Bank and the United Nations Development Program, is a community and a crowdfunding platform for Civil Society Organizations in 57 Organization of Islamic Cooperation Member Countries. TADAMON aims to empower non-governmental organizations to improve the socioeconomic well-being of the hard-to-reach communities through education, job creation, building resilience, and community livelihood development. TADAMON supports green activities, including climate change, energy and environment, water and sanitation, disaster and risk management, community development and resilience, among other focus areas.

[28] Sources: (i) IsDB, November 2024, An Innovative Finance Framework for Sustainable Dryland Development, **https://www.isdb.org/sites/default/files/media/documents/2024-12/IsDB%20-%20An%20Innovative%20Finance%20Framework%20for%20Sustainable%20Drylands%20Development%20-%2001-12-2024%20-%20Final%20%282%29.pdf;** & (ii) Narayanan, N., October 2024, Middle East's green bond issuances reach $16.7bn for 2024: S&P Global, **https://www.arabnews.com/node/2575501/business-economy**; (iii) Sustainalytics, Commundo, Nordico websites; (iv) Tadamon Community, **https://tadamon.community/.**

Beyond financing and economic considerations, the localized nature of many NbS activities emphasizes the critical role of local and indigenous communities in ecosystem stewardship, highlighting the importance of inclusive decision-making processes. By adopting participatory approaches, NbS policies can more effectively reflect the needs and preferences of marginalized groups, ensuring equitable distribution of benefits across socio-economic boundaries.[29]

Box 5 – Useful Resources from UN-Habitat and IsDB: Scaling NbS for Urban Futures

UN-Habitat views Nature-based Solutions (NbS) as a pathway to advance the SDGs and realize its 2026–2029 Strategic Plan, endorsed by Member States at the UN Habitat Assembly in 2025. NbS are promoted as an integrated urban planning approach that addresses climate and environmental challenges while delivering socio-economic co-benefits and inclusive prosperity.

Within the environment and climate action area, NbS are promoted as an integrated urban planning and management approach that addresses challenges such as urban heat, flood risk, biodiversity loss, and human well-being, while also creating socio-economic co-benefits. Their potential is further amplified when applied across other impact areas, for example by enhancing disaster preparedness and recovery, or by fostering social inclusion through green public spaces and sustainable livelihoods.

UN-Habitat applies a holistic, evidence-based methodology to ensure NbS interventions respond to real needs and contribute to broader resilience. Tools such as spatial profiling, climate modeling, and participatory validation guide interventions, while knowledge-sharing platforms, geospatial analytics, and capacity-building activities empower local governments and communities to replicate and scale effective practices.

To support cities and communities, UN-Habitat has developed a wide range of tools, publications, and knowledge products. This publication complements those resources by showcasing case studies and practical experiences, while the listed materials at the end of this box provide further guidance for scaling NbS across diverse urban contexts.

- Multilayered Vulnerability Assessment Handbook - Resilience planning for urban, biodiversity and climate action
- Hotstop Stoplight Tool
- White Paper on Cities and Nature
- Managing Urban-Rural Linkages for Nature
- PRIMER ON URBAN-RURAL LINKAGES AND LAND
- The Critical Role of Nature-based Solutions for Enhancing Climate Resilience in Informal Areas: An Urban Supplement to the UNFCCC Technical Guidelines on National Adaptation Plans
- Strategy Paper on Nature-based Solutions to Build Climate Resilience in Informal Areas
- Guidelines for Urban Ecosystem-based Adaptation in the Arab Region

[29] Vicarelli, M. et al., October 2024, On the cost-effectiveness of Nature-based Solutions for reducing disaster risk, Science of The Total Environment, Vol. 947, 174524, **https://doi.org/10.1016/j.scitotenv.2024.174524.**

IsDB is progressively strengthening its support to Member Countries on NbS by leveraging both its engagement in global MDB collaboration and its operational instruments. Through its participation in MDB joint initiatives, IsDB is contributing to the development of emerging global standards, frameworks, and metrics for nature finance – ensuring that Member Countries benefit from harmonized approaches and improved access to international climate and biodiversity finance.

At the institutional level, IsDB is gradually integrating NbS into its financing architecture and capital market instrument offerings. For example, the Sustainable Finance Framework (updated July 2025) provides a platform for scaling investments in green and resilient development, including NbS, through the issuance of Green and Sustainability Sukuk. To date, the Bank has mobilized approximately USD 6 billion, demonstrating its capacity to crowd in capital for climate and nature-positive investments and supporting Member Countries in accessing innovative financing solutions.

IsDB's knowledge base continues to grow through a range of products, developed both independently and in collaboration with MDB partners. These include flagship contributions on NbS for adaptation, nature-positive finance tracking, drylands transition, results-based metrics for nature investments, and supporting green Islamic finance. Collectively, these outputs position IsDB to help translate global NbS agendas into practical guidance, investment pipelines, and scalable financing mechanisms, particularly in climate-vulnerable regions such as dryland OIC Member Countries.

Key IsDB-supported outputs include:

- Guidance on the use of Nature-Based Solutions for Climate Change Adaptation (2022)
- MDB Common Principles for Tracking Nature-Positive Finance (2023)
- An Innovative Finance Framework for Sustainable Drylands Development (2024)
- A Just Land Transition for Drylands (2024)
- IsDB Sustainable Finance Framework (2025)
- MDB Common Nature Finance Taxonomy (2025)
- MDB Common Principles for Tracking Nature Finance (2025)
- Financing Nature: A Practitioner's Guide to Results Metrics for Nature Investments (2025)
- Islamic Finance and Climate Agenda: From Green Sukuk Innovation to Greener Halal Value Chains (2025)

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