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Sustainable Agriculture in Arid Countries

The Al-Attiyah Foundation

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MENA holds 1% of global freshwater yet sustains 6% of the global population, with most of the world's water-stressed countries located in the region. This scarcity leads to significant crop yield losses, forcing governments and enterprises to reconcile food security with aquifer depletion and energy-intensive irrigation costs that threaten fiscal sustainability. Precision irrigation, controlled-environment systems and solar-powered water solutions are scaling, supported by national strategies, regional cooperation and expanding sustainable finance. Yet adoption remains uneven due to high upfront costs, capacity gaps and fragmented supply chains dominated by small farms. What are the main challenges facing agriculture in arid regions? What solutions and innovations can make agriculture more sustainable in these environments? What role does regional and corporate cooperation play in strengthening agricultural resilience?

SUSTAINABILITY RESEARCH PAPER

This research paper is part of a 12-month series published by the Al-Attiyah Foundation every year. Each in-depth research paper focuses on a current sustainability topic that is of interest to the Foundation's members and partners. The 12 technical papers are distributed to members, partners, and universities, as well as made available on the Foundation's website.

EXECUTIVE SUMMARY

- Water scarcity is the defining constraint on agriculture in the arid Middle East and North Africa (MENA), compounded by climate change that intensifies droughts, depletes groundwater and disrupts rainfall, driving yield losses and planning uncertainty.
- Projections indicate significant productivity declines if warming trends persist, underscoring the urgent need for climate adaptation across food systems.
- Technology solutions such as precision irrigation using Internet of Things (IoT) sensors, satellite monitoring and vertical farming with hydroponics offer significant water savings, commercial scalability and a promising pathway for the future of agriculture in arid regions. However, diffusion beyond high-value crops remains limited.
- National food-security strategies prioritise irrigation modernisation, subsidy reform and crop diversification, while regional water diplomacy strengthens cooperation on desalination, wastewater reuse and flood management.
- Green finance is accelerating through sovereign bonds and blended-finance platforms. Blended finance, a strategic use of development finance and philanthropic funds to mobilise private capital, is particularly crucial in the context of sustainable agriculture in arid regions, where upfront costs are a significant barrier to adoption.
- Corporate water stewardship, which involves the sustainable use of water resources by companies, is expanding. Complemented by public-private partnerships that de-risk investment and promote technology transfer, they can help ensure that water resources are used efficiently and responsibly.
- High upfront costs, capacity gaps and fragmented supply chains dominated by small farms constrain adoption and limit scale. Coordinated measures – concessional finance, volumetric water pricing and equipment-leasing models – are critical to unlock proven interventions.
- Sustainable agriculture transformation requires integrated approaches that treat water efficiency, climate resilience and food security as interdependent priorities. This approach aligns policy design, investment mobilisation and institutional capacity to safeguard livelihoods under accelerating climate pressures.

Water scarcity is the primary risk to agriculture in arid MENA. World Bank analysis shows a 20% freshwater reduction could cut GDP by up to 10% in six countries.[1] Climate-induced water scarcity has depressed crop yields by 10–30% over two decades. Traditional irrigation remains highly inefficient, consuming multiples of strict crop requirements and losing significant volumes through leakage and evaporation.

Recent crises underscore the severity of the problem. Syria's worst drought in six decades devastated rain-fed wheat, leaving millions food insecure. Groundwater depletion is accelerating beyond its replenishment rate; Jordan faces severe basin depletion and projected annual deficits exceeding one billion cubic metres by mid-century. Gulf states rely almost entirely on desalinated water for agriculture and municipal supply, establishing a reliance on energy-intensive processes that raise operational costs and link food security to fuel markets.[2]

Per capita water availability in MENA is less than 10% of the global average. Nevertheless, rapid population growth, urbanisation and high import dependency are a source of structural vulnerability. Labour demand could plausibly contract by double digits under baseline water scarcity scenarios, risking rural livelihood collapse and internal displacement.[1]

Against this backdrop, governance challenges compound the level of exposure. Transboundary water-sharing remains contested, with upstream extraction and infrastructure damage limiting predictable allocation. Soil salinisation from inefficient irrigation has degraded one-fifth of irrigated land, while carbon depletion reduces fertility and resilience to recurrent drought cycles.[3] Multilateral capacity-building initiatives aim to integrate remote-sensing data and water productivity metrics into allocation frameworks.

However, gaps persist where policy fails to connect with field-level adoption of precision irrigation and "deficit scheduling" (the intentional application of less water than crops require for their full yield potential). Climate variability adds further uncertainty, as shorter winters reduce replenishment and heighten irrigation demand precisely when renewable freshwater contracts.[4]

Figure 1: Infographic Evidencing Low Water Use in MENA

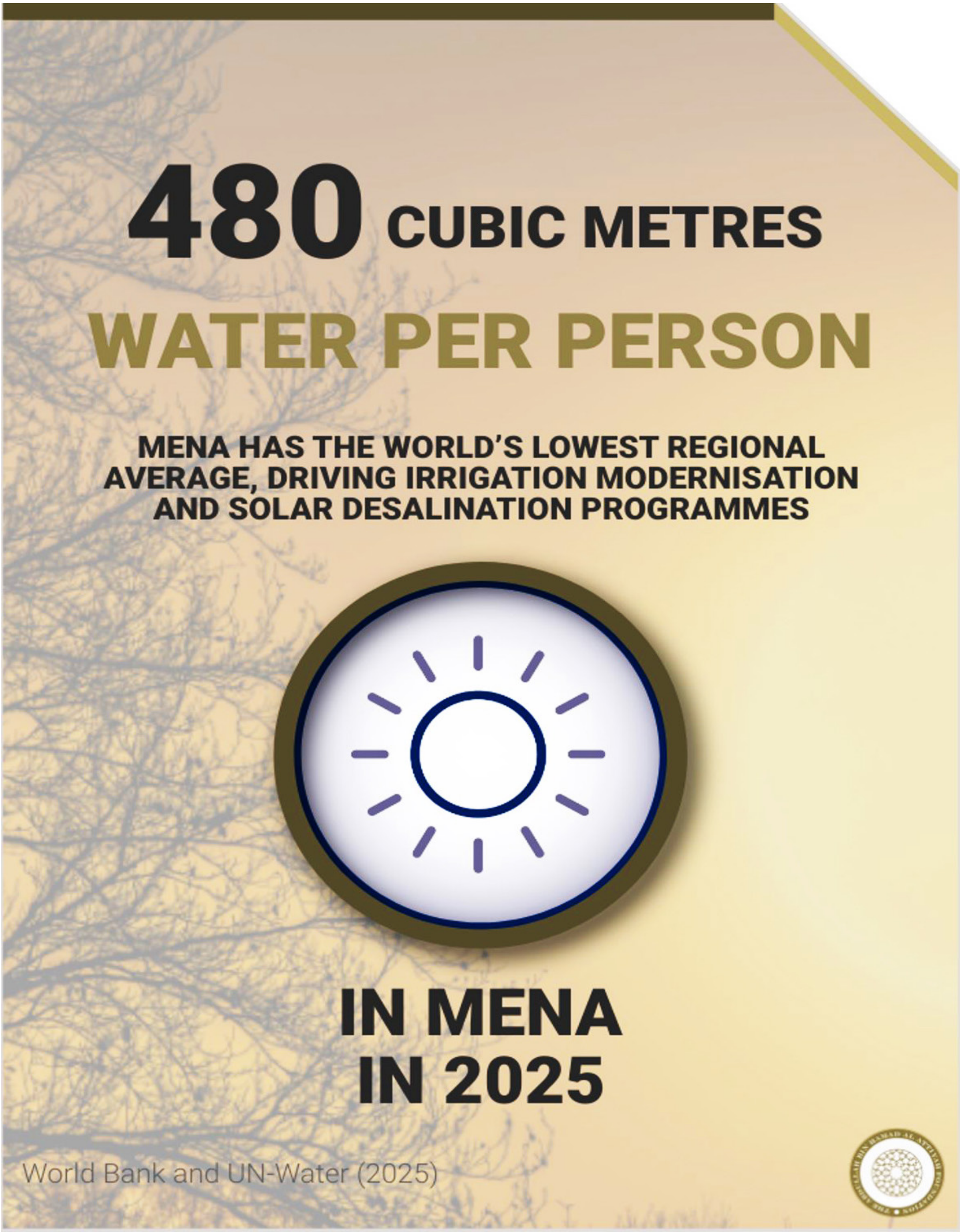


Table 1: Corporate, Role-specific Insights on the Impact of Water Scarcity

ROLE SPECIFIC INSIGHTS

Operations

Deploy precision irrigation and leakage controls to raise water productivity in arid farms

Procurement

Source efficient irrigation hardware under sustainable procurement standards to curb evapotranspiration (ET) losses

Sustainability

Disclose water allocation, deficit scheduling and desertification risks aligned to ISSB and GRI

Source: Al-Attiyah Foundation

07 TECHNOLOGY ECONOMICS AND INVESTMENT RETURNS

Desalination and precision agriculture economics have improved sharply. Reverse osmosis (RO) costs have fallen below US$1 per cubic metre for large plants, while renewable energy integration has cut operating costs significantly.[5] These advances enhance the feasibility for water-scarce economies where energy intensity has historically constrained supply solutions.

Precision agriculture technologies deliver measurable productivity gains, with yield improvements of 20–30% and water savings of up to 40% per hectare through optimised planting, targeted inputs and AI-driven irrigation scheduling.[6] Controlled-environment systems complement these benefits, supporting resource efficiency and year-round production.

“AgriTech” venture funding in MENA expanded in 2024 despite broader capital softening, reflecting government prioritisation of food security under various “Vision 2030” programmes (as exemplified in Saudi Arabia, Egypt and Qatar) and similar strategies among other national governments. The growth of AgriTech investment in recent years underscores investor confidence in technologies that address import dependency and climate risk.[7]

Return on investment for precision systems has proven to be competitive: drip irrigation typically achieves short-term payback, while satellite-based crop monitoring platforms deliver cost savings and real-time analytics at a fraction of traditional sensor deployment costs.[8] Water productivity gains of 15–20% are common where zone-based irrigation integrates remote sensing and hyperlocal weather data. Blockchain-enabled traceability is emerging as a global standard for supply-chain transparency, with associated market valuations projected to quadruple by 2029, driven by compliance and fraud-prevention imperatives.

Despite these advances, adoption barriers persist. Initial capital requirements for sensors, automation and data infrastructure remain prohibitive for resource-constrained operators, with costs varying by crop and system sophistication. Scaling solutions will require targeted subsidies, blended finance and equipment-leasing models to overcome structural constraints and enable widespread uptake in resource-limited settings.

Table 2: Summary of Livelihood Risks and Policy Responses in Arid Countries

Livelihood risks

Potential policy mitigations

Risk	Control	Policy linkage
Rural income shock	Shock-responsive transfers	Social protection
Rapid internal migration	Cash transfers	Labour market plan
Food insecurity	Seed kit distribution	Nutrition strategy
Farm input inflation	Irrigation vouchers	Subsidy reform

Source: Research from various sources by Al-Attiyah Foundation

Smallholders in arid regions invest large shares of annual income in adaptation—collectively exceeding multilateral pledges like the Adaptation Fund. However, despite their role in supplying one-third of global food, they receive less than 1% of global climate finance.[9] This structural gap between household-level investment and institutional support constrains resilience in resource-limited settings.[10]

Water scarcity-driven disruption has accelerated internal labour migration across the MENA region. Consecutive droughts have displaced rural populations to urban and peri-urban centres, heightening competition for resources and infrastructure. Syria's prolonged drought contributed to agricultural collapse and the displacement of over a million people, while Iraq recorded similar rural-to-urban movements during peak water stress.

Migration patterns for climate-induced movement remain largely domestic or regional, with Jordan and Egypt absorbing significant flows and Gulf states attracting labour migration rather than generating large-scale outflows to Europe.

Beyond mobility, water scarcity undermines both the quantity and quality of crops, directly impacting food security. When water is limited, plants produce lower yields and lose key nutrients, while plants suffer cellular stress. Although some crop types can slightly adapt by strengthening natural defences under moderate water stress, persistent shortages degrade plant health, reduce productivity and lessen nutritional value. For farmers, fluctuating water availability and prices add to the threats of soil deterioration and pest problems, compounding operational risk and deepening exposure to livelihood shocks.[11]

09 RISK FRAMEWORKS AND OPERATIONAL RESILIENCE

Enterprise risk management (ERM) frameworks for arid MENA agriculture are becoming increasingly mandatory, with climate disclosure rules, investor stress testing and water volatility now requiring formal scenario planning aligned with ISO 31000. A 2024 UN Environment Programme (UNEP) Finance Initiative survey found that 72% of bank respondents in MENA identified agriculture as the most affected sector by climate change, reflecting sector-wide recognition of material risk exposure. Effective ERM systems must now integrate physical climate risks, transition risks from policy and technology changes and operational risks from resource scarcity into board-level governance and strategic planning processes aligned with ISO 31000 enterprise risk management standards.[13]

Agricultural operators must model physical risks, including drought frequency, extreme heat events, precipitation variability and water allocation constraints. Transition risks encompass carbon pricing impacts on energy-intensive desalination, regulatory restrictions on groundwater extraction, technological obsolescence of conventional irrigation systems and market shifts toward sustainable products. The International Sustainability Standards Board (ISSB) IFRS S2 Climate-related Disclosures standard mandates disclosure of climate scenarios used, key assumptions, including climate policies, macroeconomic trends, national variables such as local weather patterns and water resource availability, energy usage and technology developments. Entities should specify time horizons, operational scope, and reporting periods to ensure comparability and facilitate audit verification.

Governance structures have adapted to accommodate climate risk oversight. Leading agricultural enterprises in MENA have established board-level sustainability committees with explicit responsibility for climate risk and opportunity management, supported by executive management structures that integrate climate considerations into capital allocation, operational planning and performance evaluation. Qatar has deployed the HAIAT precision agriculture project, demonstrating governance-driven adoption of AI for crop monitoring, resource optimisation and climate adaptation. The system uses satellite imagery, sensor networks and predictive analytics to enable real-time decision-making on irrigation, fertilisation and pest control, translating governance frameworks into operational capabilities.[14]

Data disclosure gaps constrain effective risk management. Agricultural operations in MENA face challenges in establishing baseline water footprints, tracking Scope 3 emissions across supply chains, quantifying crop yield sensitivities to temperature and precipitation variability and verifying adaptation investment effectiveness. The water footprint across agricultural supply chains can exceed direct operational use by a factor of 100, requiring comprehensive value chain mapping to achieve disclosure completeness. Companies face a distinct challenge to evaluate the materiality of water security risk across operations and supply chains, assess customer vulnerability to price shocks from resource scarcity, investigate regulatory intentions of governments facing water insecurity and model impacts on operations and investment.[14]

Table 3: Overview of Financial Instruments for Risk Mitigation in Agriculture

Financing instruments for agricultural risk

Frequency–severity categories and example cases

Instrument	Type of risk	Use case	Key metric
Parametric insurance (micro-cover)	High frequency, low severity	Seasonal shortfall	Payout timeliness
Sovereign risk pool	Medium frequency, medium severity	Regional drought	Basis risk incidence
Catastrophe bond	Low frequency, high severity	Extreme tail event	Settlement speed
Blended finance	Non-event adaptation	Capex for resilience	Capital deployed to smallholders

Source: Al-Attiyah Foundation

MENA adaptation finance remains severely inadequate. In the region, small-scale agrifood systems received only US$4.5 billion globally in 2019-2020 but requires US$415 billion for agricultural resilience. Historically, MENA has been among the smallest regional recipients of climate finance worldwide, despite ranking among the most vulnerable. The World Bank is on track to achieve a US$10 billion target for 2021-2025, but this falls far short of regional requirements. The protection gap—the difference between climate-related losses and insured recovery capacity—exposes agricultural operators and dependent communities to unmitigated shocks that erode productive assets and push vulnerable households into poverty traps.[16]

Parametric insurance has emerged as a viable risk transfer mechanism for climate-vulnerable agriculture, as evidenced by the US$7.9 million Syria drought payout in June 2025. The policy, funded by Humanity Insured in partnership with the World Food Programme (WFP), Global Shield Financing Facility, Allianz and supported by United Kingdom and German government contributions, provided immediate relief to nearly 120,000 people following one of the worst droughts in 50 years. Triggered by satellite-monitored rainfall and vegetation data, the parametric structure enabled rapid deployment of food assistance and essential supplies without the delays inherent in traditional insurance claim processes.

This payout represents the first activation of a national-level drought insurance policy in a conflict-affected country, demonstrating technical feasibility despite challenging operating conditions.

Capital structuring through blended finance has proven essential for mobilising private investment into climate-smart agriculture in resource-constrained environments. The Acumen Resilient Agriculture Fund (ARAF) closed at US$58 million in 2021, becoming the world's first equity fund designed to build climate resilience for small-scale farmers in Africa through equity and quasi-equity investments in agribusinesses. The Green Climate Fund (GCF) partnered with ARAF to provide a US$23 million investment in a first-loss layer, de-risking the structure for private sector investors.[17]

First-loss capital absorbs initial losses up to a defined threshold before senior investors face exposure, reducing risk-adjusted return requirements and enabling broader participation in sectors perceived as high-risk. It also addresses the mismatch between patient capital requirements and conventional investment horizons.

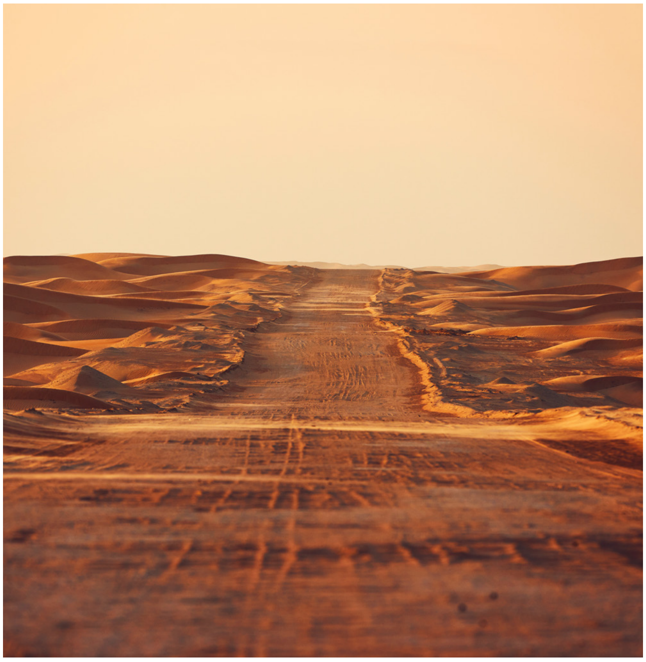
Coverage gaps persist despite these innovations. Only a fraction of climate-vulnerable agricultural operations in MENA access parametric insurance or blended finance vehicles, reflecting cost barriers, limited technical capacity, regulatory hesitancy to endorse climate risk transfer mechanisms and fragmented data infrastructure for index construction. Effective financial protection requires integration across instruments: parametric insurance for frequent, moderate shocks; risk pools for correlated regional events; catastrophe bonds for extreme tail risks; and blended finance structures for adaptation capital expenditure.[18]

Institutional investment in dryland technologies accelerated in 2025. The International Center for Agricultural Research in the Dry Areas (ICARDA), under the Consortium of International Agricultural Research Centers (CGIAR) global research partnership, launched the Integrated Desert Farming Innovation Program (IDFIP) with a target of mobilising US$20 million by end-2025. The initiative addresses water scarcity, land degradation and food insecurity by bundling hydroponics, aquaponics, controlled-environment agriculture and solar-powered irrigation into scalable models for deployment. Field pilots in Egypt, Jordan, Morocco and the Arabian Gulf have validated performance improvements under extreme heat and water stress, achieving 30–50% water savings compared with conventional irrigation and yield improvements of 20–40% for protected cultivation of vegetables and leafy greens.[19]

Meanwhile, drought-tolerant crops are being developed much faster based on new genetic technologies like advanced gene editing and targeted selection tools, coordinated globally through the CGIAR and similar networks. Recent research identified key genetic markers that boost yield stability, root growth and water efficiency, helping breeders cut development times for new wheat varieties from over a decade to just 6–8 years. Maize breeding programmes now incorporate traits that allow plants to maintain photosynthesis and cope with water shortage, delivering yield improvements of 15-25% over older types. Despite these advances, MENA farmers still face delays in accessing improved seeds due to slow regulatory approval and limited seed production capacity in public systems.[20]

Regenerative agriculture practices are gaining traction as ecosystem-based adaptation strategies that restore soil health and enhance water retention. Case studies from the UAE and Morocco demonstrate successful integration of no-till farming, cover cropping and biochar-based materials. Conservation agriculture reduces soil erosion by 60-70% compared with conventional tillage. Also, it increases organic carbon sequestration significantly, improving drought resilience through enhanced infiltration and reduced evapotranspiration (water loss from soil and plants).

Agroforestry systems that combine drought-tolerant trees such as Acacia, Prosopis and date palm with cereal and legume intercrops can meaningfully reduce evaporative water loss from fields and provide farmers with a broader range of income sources. However, these benefits are tempered by higher initial labour demands, a lack of targeted technical advisory services and the absence of financial mechanisms—like carbon credits or water stewardship payments—to help farmers recover the costs of transition.



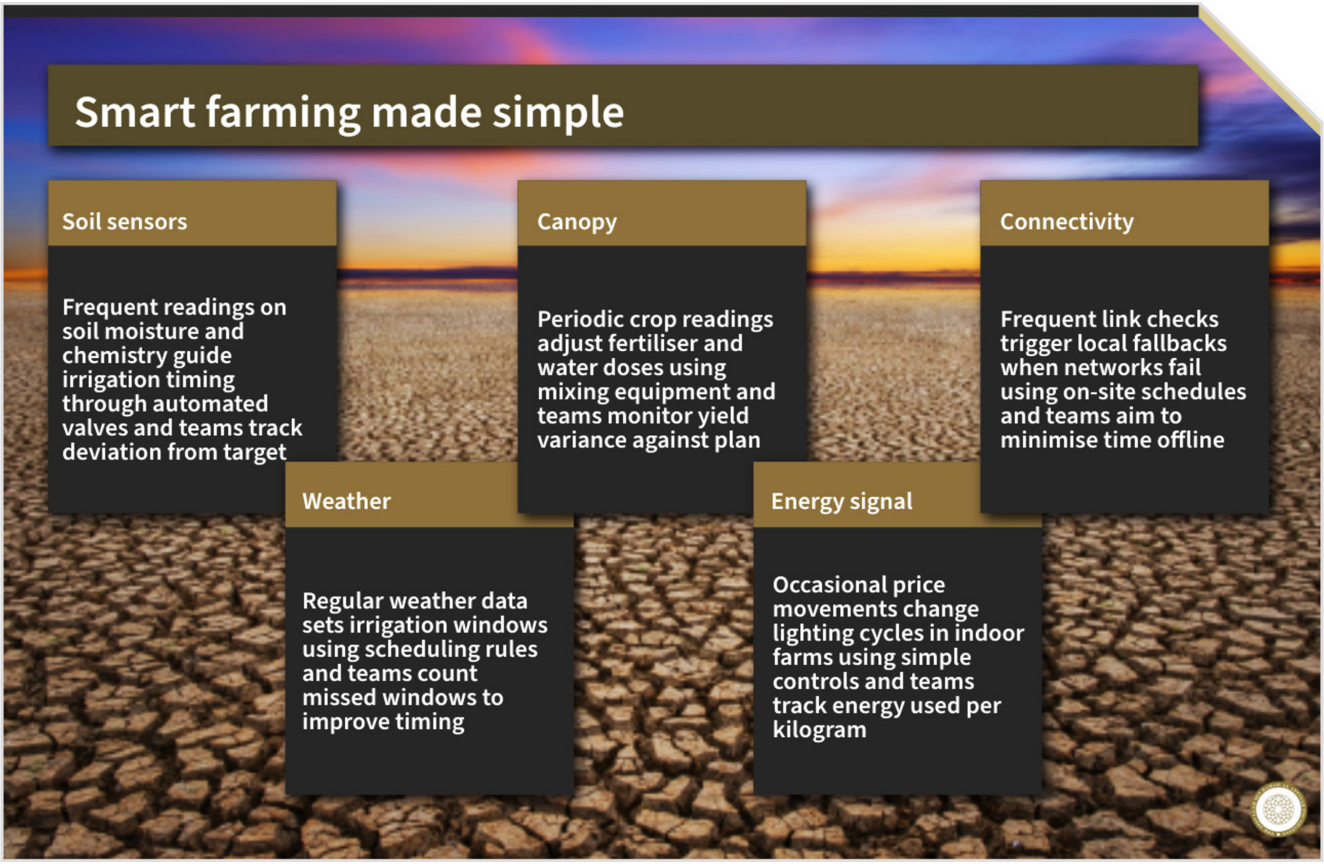
Internet of Things (IoT) sensor networks have expanded rapidly across MENA agricultural operations in 2025. Growth is driven by smart sensor deployments for soil moisture monitoring, crop health assessment and automated irrigation control. In the UAE, adoption has accelerated through government-backed digital transformation initiatives, with the density of sensors, a key metric, reaching 15-25 units per hectare in commercial greenhouses and 5-10 units per hectare in open-field high-value crops.

Precision agriculture platforms integrate real-time data streams from soil sensors (moisture, pH, electrical conductivity), weather stations (temperature, humidity, wind speed) and crop canopy sensors (chlorophyll content, leaf area index) to optimise fertigation schedules. These systems typically reduce water use while adhering to yield targets.

However, despite demonstrated returns–often within two to three growing seasons–implementation challenges persist, including connectivity gaps in remote zones with low 4G/5G coverage, high initial capital expenditures and technical capacity constraints that limit the adoption of eligible farms.

Vertical farming systems are highly water-efficient, using closed-loop hydroponic and aeroponic designs to recirculate nutrients and cut freshwater usage by as much as 95% compared with conventional field farming, while eliminating environmental runoff. Advanced LED lighting for plant growth reduces energy use by 30-40% versus preceding technologies, delivering year-round yields.

Figure 2: Summary of Water-related Technological Advances in Farming



In Saudi Arabia and the UAE, pairing vertical farms with rooftop solar and battery storage has reduced operational carbon emissions by up to 70%, helped by high local solar productivity. Despite these gains, profitability is hindered by high capital costs (US$1,500–2,500 per square metre) and energy prices, meaning that vertical farms must price their produce 20-30% more than traditional crops to breakeven.[21]

Precision platforms are now market-ready as critical decision-support tools for large-scale enterprises. However, in parallel, cybersecurity has emerged as a crucial constraint on technology adoption. Connected agricultural systems create attack surfaces through IoT devices, cloud platforms, automation controllers and data management systems.

A systematic literature review published in 2024 identified authentication weaknesses, insecure communication protocols, inadequate encryption and lack of security updates as primary vulnerabilities in smart agriculture deployments. The agriculture cybersecurity market is projected to grow significantly as operators recognise that compromised irrigation systems, manipulated sensor data or disabled automation can cause crop losses exceeding the value of stolen data. National Institute of Standards and Technology (NIST) cybersecurity frameworks and ISO 27001 standards provide implementation guidance for agricultural operators. Still, adoption remains uneven across MENA.[22]

National food security strategies across MENA increasingly embed climate adaptation priorities into multi-decade policy frameworks. The UAE's National Food Security Strategy 2051 coordinates a plurality of initiatives spanning domestic production, strategic reserves and international partnerships. The strategy targets zero hunger in alignment with Sustainable Development Goal (SDG2) and aspires to global leadership in the Economist's "Global Food Security Index" by diversifying supply chains and reducing import dependency, which currently exceeds 80% for staple commodities. Implementation mechanisms include national gene banks for drought-tolerant crops, sovereign wealth fund allocations to agriculture ventures and bilateral agreements with other countries to secure long-term food supply corridors.[23]

Jordan has advanced water governance reforms under its Water Sector Green Growth National Action Plan 2021-2025, allocating US$153 million to irrigation modernisation, wastewater treatment and institutional capacity building. Policy priorities include phasing out subsidies for water-intensive crops, liberalising trade regimes to enable efficient water allocation and introducing volumetric water pricing to internalise scarcity costs in farming decisions.[24] Jordan's 2024 subsidy reforms cut wheat and barley support by 15-20% annually, redirecting resources toward drip irrigation and services that promote high-value horticulture using significantly less water per unit of revenue.[24]

Transboundary water resource management remains a critical challenge. World Bank analysis projects US$500 billion in investment needs across MENA by 2050 for water infrastructure, desalination and wastewater reuse. Regional cooperation frameworks under the League of

Arab States and the Gulf Cooperation Council (GCC) facilitate technical knowledge exchange and joint procurement for large-scale projects. However, implementation is constrained by competing national priorities and weak enforcement of shared resource agreements.[25]

Morocco's water crisis response during 2024-2025 illustrates governance stress points. Consecutive drought years reduced dam reserves to under 30% capacity, triggering emergency measures including irrigation cuts, agricultural restrictions and urban rationing affecting millions. Policy responses emphasised desalination scale-up (targeting 1.7 billion cubic metres annually by 2030), wastewater reuse (65% by 2027) and basin-level water agencies with enforcement authority and participatory planning involving farmer associations.[25]

Green finance mobilisation through sovereign bonds and climate-tagged lending has expanded, with multilateral lenders (including the European Investment Bank and the Islamic Development Bank) deploying concessional capital for water-efficient agriculture. Nevertheless, political economy constraints persist due to resistance to subsidy reform, fragmented mandates across ministries and limited enforcement capacity where informal water markets and unauthorised wells undermine formal allocation systems.[25]

Corporate agricultural strategies in MENA have aligned with climate resilience, supply chain security and regenerative practices as water scarcity, regulatory pressure and investor expectations converge. Leading corporates integrate precision agriculture, renewable energy and diversified sourcing while meeting disclosure requirements under the Global Reporting Initiative (GRI), the Science-Based Targets initiative (SBTi) and regional sustainability frameworks. Venture capital investment, operational innovation and market repositioning demonstrate a private sector response to structural shifts in food security priorities. Yet, scalability challenges, capital constraints and technical capacity gaps limit transformation pace.

Al Dahra, the UAE's largest agricultural producer, has committed to transitioning 80% of farmland to regenerative practices by 2030 (reaching 35% implementation in 2024). The company's 2024 sustainability report emphasises no-till farming, cover cropping, crop rotation and integrated pest management to enhance soil health, sequester carbon and reduce chemical inputs. The transition is expected to require sustained capital expenditure for equipment, training and certification, with payback periods extending five to ten years depending on baseline soil conditions and crop types.[26]

Supply chain resilience has become a strategic priority for firms in most industries. In the MENA region, import dependence creates vulnerability to geopolitical disruptions, climate shocks in exporting countries and logistics bottlenecks. Gulf Cooperation Council (GCC) countries have pursued sourcing diversification, strategic reserves and domestic production expansion to reduce exposure. However, implementation faces land and water constraints that favour capital-intensive technologies over conventional expansion.

The World Economic Forum (WEF) has highlighted that Gulf nations have adapted supply chain strategies by strengthening regional partnerships, investing in cold storage infrastructure and implementing digital traceability systems to reduce post-harvest losses and improve food safety compliance.[27]

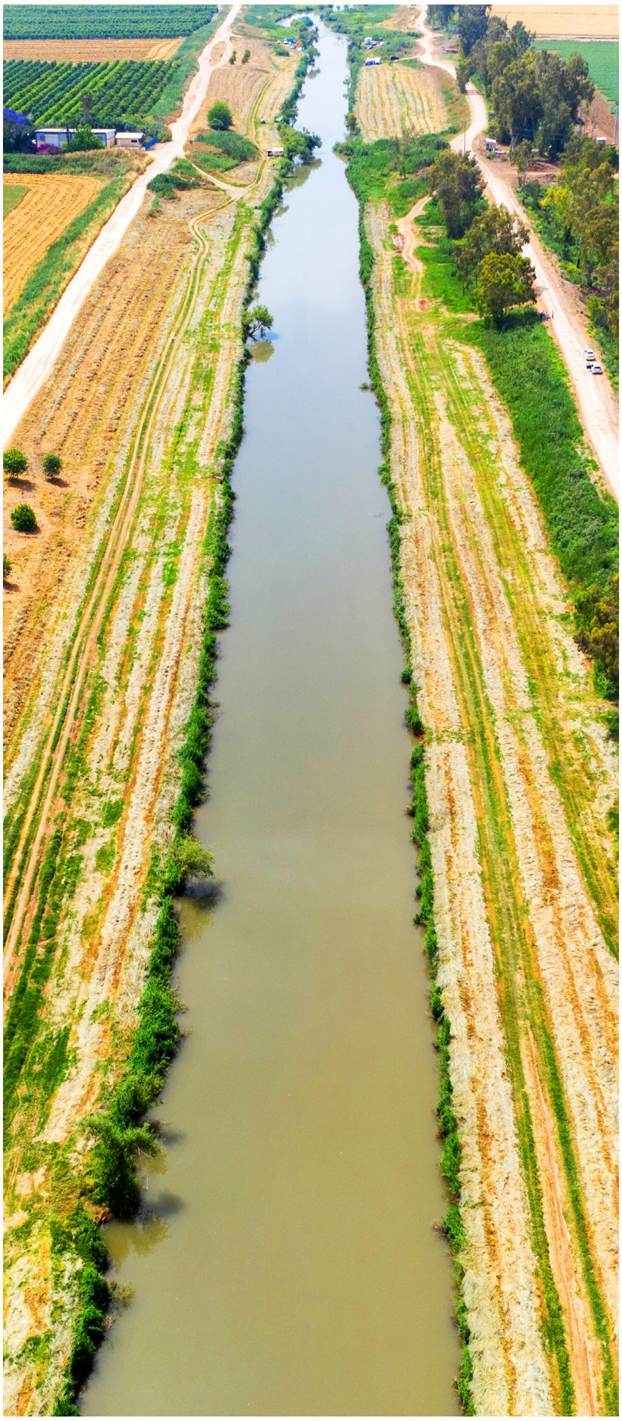
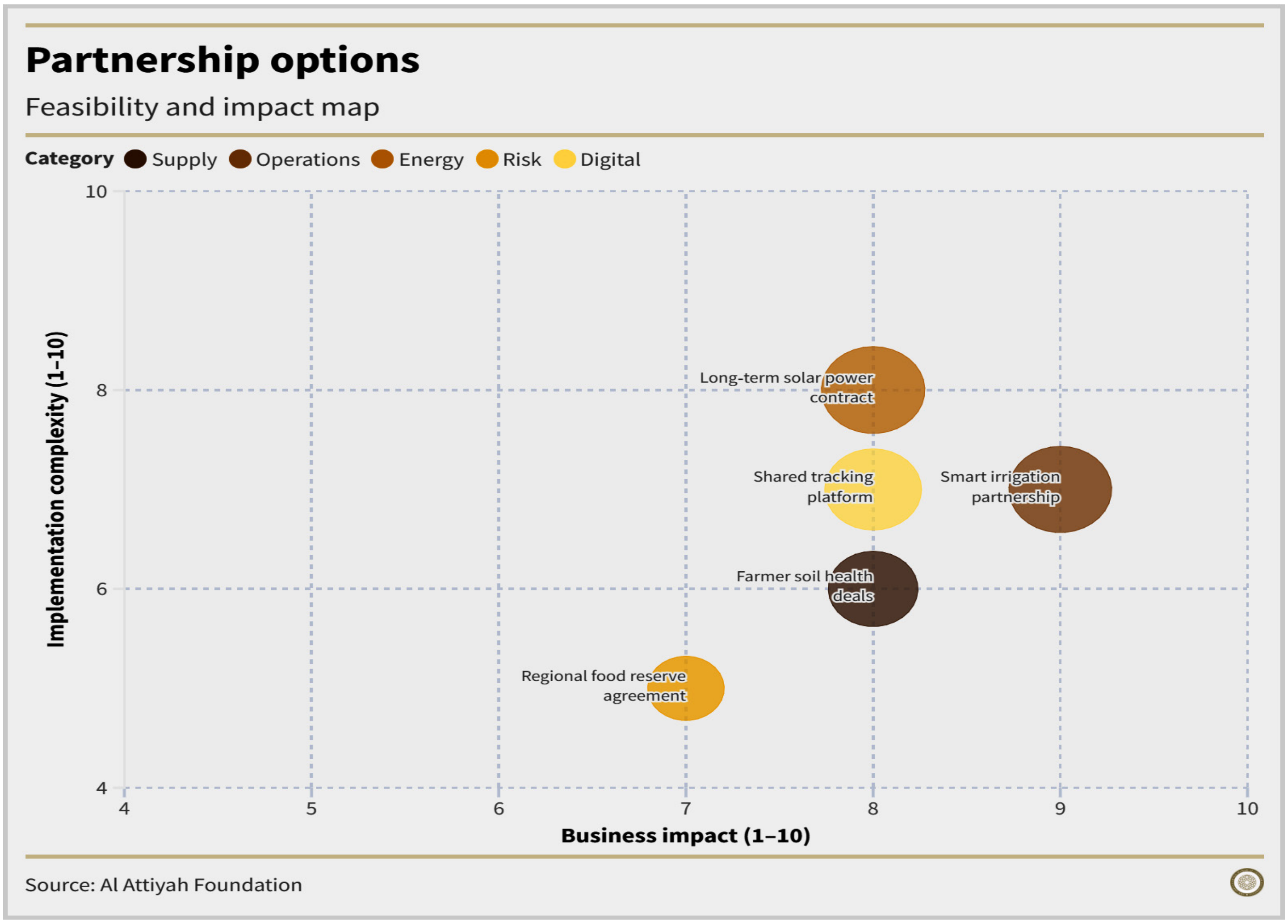


Figure 3: Comparison of Corporate Strategies for Dealing with Water Scarcity



Despite rapidly increasing investment inflows in Agritech ventures in MENA, operational challenges constrain scalability. Water use efficiency improvements require investment in drip irrigation, soil moisture sensors and fertigation systems that smallholders cannot afford without subsidies or concessional finance. Yield per hectare gains from precision agriculture depend on technical expertise for sensor calibration, data interpretation and agronomic decision-making that surpass available labour skills in many MENA markets. Energy intensity reductions through solar integration face upfront capital barriers and grid connection constraints in rural areas, limiting renewable deployment despite favourable economics over equipment lifetimes.

The AgraME 2025 forum, held in Dubai in October 2025, emphasised technology and collaboration as pathways to food resilience, with industry leaders calling for public-private partnerships, knowledge sharing and coordinated investment to accelerate transformation. Revenue growth rates, water use efficiency measured as output per cubic metre, yield per hectare improvements, GHG emissions intensity, regenerative farming as a percentage of cultivated area and supply chain diversification indices provide key performance indicators for corporate performance assessment. These metrics enable investor evaluation, competitive benchmarking and strategic decision-making aligned with GRI, SBTi and regional certification standards.

An illustrative example of practical South-South cooperation between countries facing critical water scarcity is the case of Egypt and Morocco. The countries advanced water diplomacy through bilateral frameworks established in 2023, signing a memorandum of understanding (MoU) on sustainable water resource management during COP28 in Dubai. The agreement covers technical cooperation on desalination plant development, flood risk management systems, dam construction methodologies and agricultural wastewater treatment protocols, with joint technical committees meeting every six months to monitor progress and facilitate technology transfer.

Follow-up talks in March 2024 reaffirmed commitments to share expertise in water harvesting, groundwater exploration and integrated resource management. Morocco provides technical assistance on drip irrigation deployment based on its experience covering 680,000 hectares, while Egypt shares flood management technologies applied along the Nile Delta. Operational South-South cooperation enables countries with similar water scarcity constraints to exchange context-appropriate solutions rather than relying solely on technology transfer from water-abundant regions.

Knowledge exchange has been institutionalised through regional capacity-building programmes. For example, in 2025, Egypt agreed to host the FAO Regional Leadership Academy, a new centre aimed at training current and future leaders from Arab and African countries in sustainable agri-food systems. Technical programmes delivered through the Academy have focused on sustainable intensification, climate-smart agriculture and value chain development, with a strong emphasis on peer-to-peer learning between practitioners from similar climatic zones who share practical implementation experience.

This approach helps accelerate regional innovation by making leadership development and technical knowledge more accessible and grounded in local realities.[28]

Egypt's participation at the October 2025 Food and Agriculture Forum in Rome reinforced calls for expanded South-South platforms connecting MENA expertise with sub-Saharan Africa (SSA). Proposals include regional centres of excellence leveraging Egyptian facilities for drip irrigation testing, date palm breeding and desert agriculture research to support neighbouring countries lacking dedicated capacity. ICARDA's January 2025 blueprint for MENA and SSA drylands resilience advocates systematic knowledge transfer through farmer field schools, demonstration plots and digital extension services, targeting 24 priority countries representing 450 million people.[28]

Multi-billion-dollar development initiatives complement these efforts. The US$10 billion Africa and Middle East Sustainable Agriculture and Food Systems for Economic Development (SAFE) Initiative, launched with the support of the Global Green Growth Institute, aims to scale climate-resilient agriculture, benefiting millions of livelihoods. SAFE mobilises blended finance combining sovereign green bonds, development finance institution capital and commercial investment for irrigation infrastructure, renewable energy integration and cold chain logistics, with a focus on women and youth. Implementation relies on country-specific investment plans, regional coordination for cross-border value chains and private-sector engagement frameworks that de-risk participation through partial credit guarantees covering significant shares of financial exposure. Administrative complexity across national governments with divergent priorities continues to constrain timelines, with initial approvals requiring 18–24 months from concept to financial close.[29]

Across MENA's water-stressed oases, agricultural communities have faced mounting challenges as aquifer levels decline and salinity rises, threatening the viability of traditional farming systems. These fragile ecosystems have become emblematic of the region's water-energy-food nexus risks, where every decision on irrigation infrastructure carries long-term implications for resource security and economic resilience. Within this context, planners have been forced to choose between two starkly different futures: focusing on centralised, fossil-powered irrigation or transitioning to decentralised solar desalination paired with drought- and salt-tolerant crops.

Evidence from oasis-based pilots in Morocco, Tunisia and Jordan has shown that decentralised photovoltaic-powered reverse osmosis (PV-RO) desalination systems have delivered operational water cost reductions of 20-40% compared with grid-dependent pumping. For water-stressed oases, this shift has not only lowered costs but also reduced groundwater abstraction by up to 50%, slowing aquifer depletion. While capital intensity remains a barrier (PV-RO installed costs of 1,500–3,000 US$ per cubic metre daily capacity), accelerated adoption scenarios supported by concessional finance indicate shortened payback periods of three to five years, compared with seven to ten years under baseline financing conditions.

Operational resilience is critical for these oases. PV-RO units have insulated farms from grid outages and tariff volatility, while enabling irrigation with low-salinity water that supports crop diversification. Yield improvements of 10-30% have been recorded when salinity levels have fallen from 6 grams per litre (g/l) to less than 2 g/l, directly enhancing revenue per hectare.

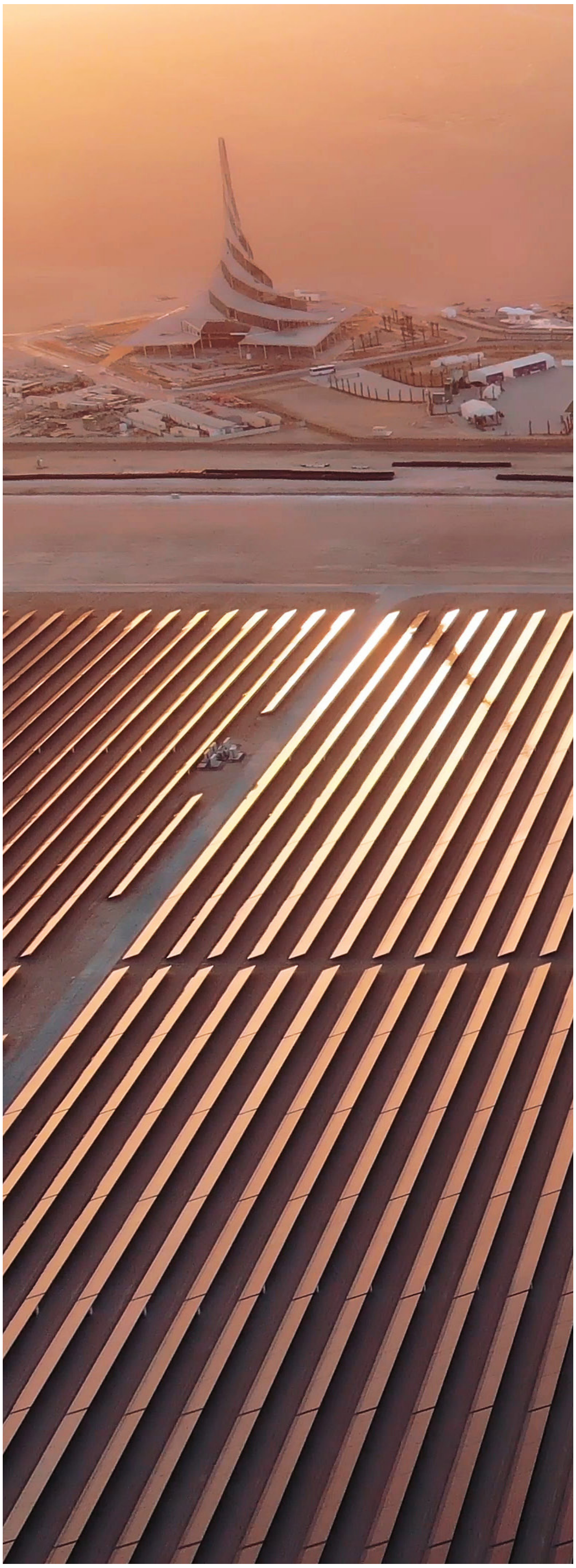
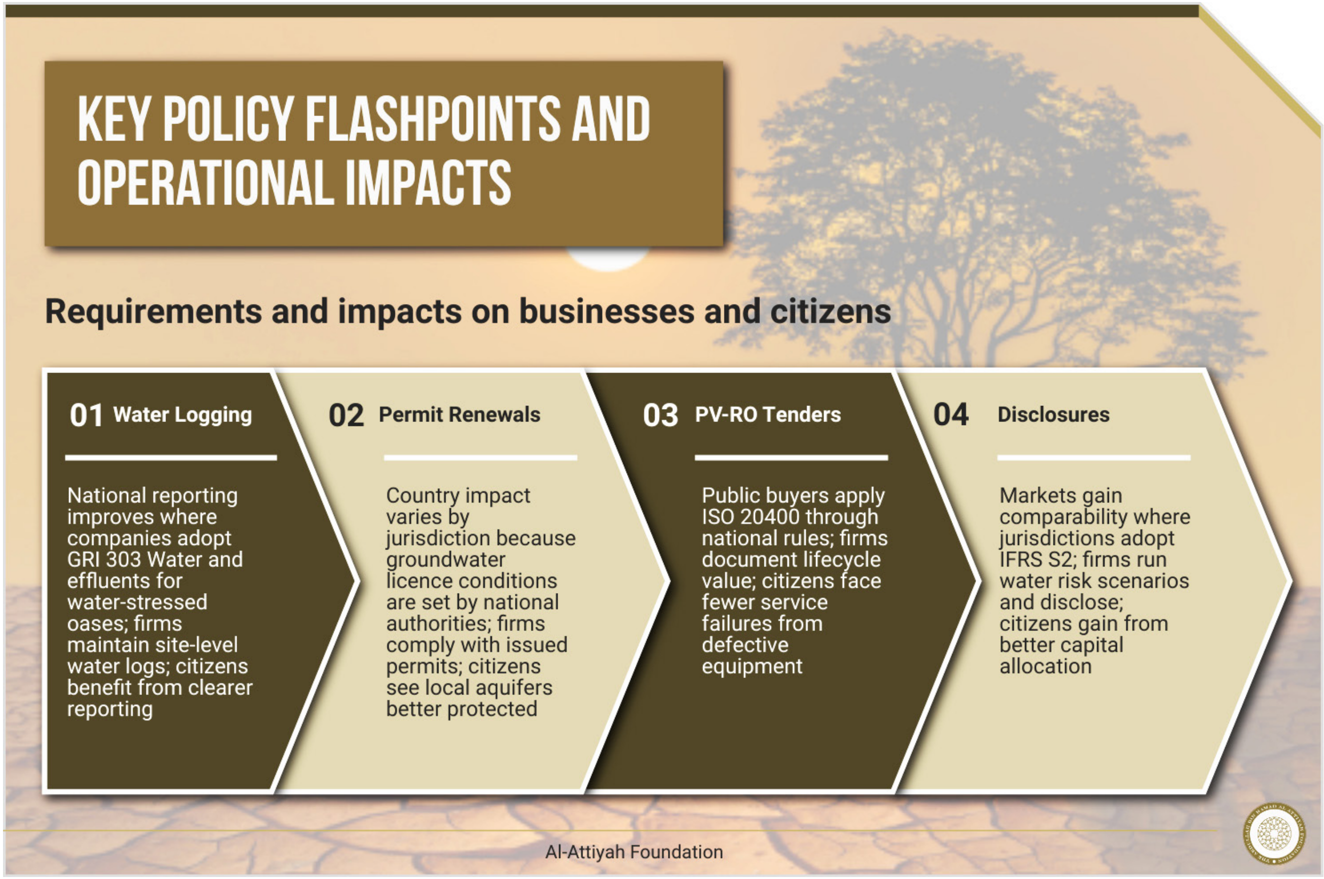


Figure 4: Policies, Impacts and Responses Under a Water-stressed Oasis Scenario



However, these benefits have depended on robust maintenance regimes and governance models that allow oasis communities to share costs and responsibilities.

Compliance and disclosure obligations have further shaped the outlook for water-stressed oases. Regulatory authorities have increasingly tied permit renewals to measurable reductions in abstraction intensity. At the same time, frameworks such as IFRS S2 and TCFD have required scenario-based disclosures of water availability assumptions and infrastructure trade-offs. Farms that have implemented metered abstraction monitoring and maintained audit-ready records of pump logs, PV generation and soil salinity have strengthened their resilience to both regulatory and financing risks.

Scenario modelling for the water-stressed oasis highlights materiality thresholds that can guide strategic decisions: a sustained 10% yield uplift, 20% operational cost reduction or 25% abstraction decline over three seasons has been considered sufficient to support the viability of the transition to PV-RO systems and justify capital allocation. Transferability of successful models, such as Morocco's Osmosun-Sand to Green project and Jordan's PV-BWRO retrofits, has underscored the scalability of decentralised solutions provided that partnerships integrate technology providers, water authorities and concessional finance. For policymakers, water authorities and agricultural cooperatives, these findings reinforce the urgency of acting now to secure the future of water-stressed oases and protect agrarian livelihoods in the region.

Sustainable finance and market signals across MENA continue to strengthen the case for climate-aligned agriculture. Green and sustainability bonds are supplying patient capital for irrigation, desalination and controlled-environment facilities with longer payback profiles. Meanwhile, blended-finance structures and equipment leasing remain critical for crowding in private buyers and reaching medium-scale farms. Precision agriculture platforms are scaling through falling sensor costs and service-based models, while sovereign and strategic investors back domestic production capacity in greenhouses and vertical farms.

Emerging technology suited to arid and saline contexts provides short-term possibilities for policymakers and investors:

- **Sandponics:** Using washed local sand as the growing medium, with nutrients delivered through irrigation, cuts water use and copes better with salty conditions. It can run on brackish water and modular nutrient-dosing units, reducing imported substrate costs and logistics risks. Ideal for coastal or desert edges characterised by saline intrusion and strong solar resources.
- **Date-palm biochar:** Turning pruned fronds and processing waste into biochar (carbon-rich material made by heating biomass with little oxygen) improves soil water retention, nutrient holding and long-term carbon storage. National programmes can connect municipal green waste and packhouse residues to small pyrolysis hubs, supplying horticulture clusters and restoring date oases. Benefits include less waste and potential carbon-credit income.
- **Hydrogel dosing:** Superabsorbent polymers placed in the root zone store water and cut irrigation frequency. Field "dose-response" trials should identify the best rates by crop and soil and check for salt build-up. Can be combined with drip irrigation and farm advisory services, with input finance offered to manage upfront costs.
- **Solar-powered desalination for irrigation:** Pairing high-efficiency reverse osmosis with utility-scale or distributed solar reduces energy risk and enables partial irrigation where aquifers are depleted or saline. Strong candidates include near-city horticulture zones, high-value export crops and strategic seed production. Can be co-located with brine-management pilots and nutrient recovery to limit environmental harm.
- **Controlled-environment agriculture in extreme climates:** Region-adapted greenhouses using heat-filtering films, closed-loop water capture and salt-tolerant varieties can produce year-round with far less water. Public–private partnerships and purchase agreements (offtake contracts) reduce exposure to power prices. Rooftop solar plus storage strengthens economics where tariffs are volatile.
- **Atmospheric water augmentation:** Cloud seeding, which releases particles into clouds to encourage rainfall, is established in the UAE and used as a supplement to aquifer recharge and irrigation during droughts. Results vary by location and conditions, so it should be treated as a complementary measure, not a primary water source.[30]

Table 4: Cost-Benefit Analysis of Key Dryland Technologies

Achieving scale in drylands

Cost and benefit ratings for six arid-zone technologies

Technology	Description	Cost	Benefit	Comment
Solar RO irrigation	Use solar power to run reverse-osmosis units for low-salt irrigation water	High	High	Water is cheaper and cleaner, but pipework, membranes and brine handling demand strong governance
Controlled-environment agriculture	Use sealed greenhouses or vertical farms with recirculating water and efficient lights	High	Medium	Precision irrigation in fields can beat vertical farms on profit and emissions in many cases
Sandponics	Grow crops in treated sand with precise water and nutrients	Medium	Medium	Old-fashioned drip systems may match water savings at lower risk if sand supply and skills are thin
Hydrogel dosing	Add water-absorbing polymers to the root zone to stretch irrigation intervals	Medium	Medium	Gains fade if dosing is off and salts build up; basic scheduling may pay better
Cloud seeding	Release particles into clouds to encourage rain over priority basins	Medium	Low	Useful at the margin only; invest first in demand management and leakage control
Date-palm biochar	Turn palm waste into charcoal to improve soil water holding and fertility	Low	Medium	Low-tech soil fixes can beat flashy hardware on value for money in drylands

Source: Al-Attiyah Foundation

Transforming agriculture in arid regions requires an approach that integrates proven technologies with emerging innovations, supported by stable financing and governance. To accelerate implementation, five policy priorities are identifiable:

1. Mobilisation of concessional and first-loss capital alongside results-based grants to de-risk high-impact pilots such as sandponics systems, date-palm biochar hubs and hydrogel dosing trials while signalling bankability to private investors.
2. Standardisation of technical specifications and measurement protocols for water productivity, energy intensity and salinity management, ensuring solutions qualify for green-bond allocations and climate-tagged lending.
3. Scaling access through leasing and pay-per-use models for controlled-environment agriculture and precision irrigation kits, reducing upfront cost barriers for medium and small farms.
4. Embedding smallholder inclusion by linking input finance, agronomic advisory and guaranteed offtake, creating integrated service ecosystems that strengthen rural livelihoods and food security.
5. Establishing cross-border demonstration corridors to accelerate replication in comparable climates, leveraging regional knowledge-sharing platforms and South-South cooperation mechanisms.

CONCLUSION

Arid-region agriculture requires integrated approaches combining water-efficient technologies, climate-resilient practices and policy frameworks that align environmental imperatives with food security objectives. Developments across MENA during 2025 demonstrate that technological solutions—including precision irrigation, vertical farming and satellite-based monitoring—have matured to commercial viability, while green finance mechanisms and multi-billion-dollar development initiatives have mobilised enduring capital for infrastructure based on extended payback periods. However, technology deployment alone proves insufficient without coordinated policy action. Subsidy reforms redirecting support from water-intensive cereals toward efficient irrigation systems, volumetric water pricing internalising scarcity costs and cross-ministerial governance structures are needed to enable a systematic rather than fragmented response to interconnected water, climate and food security challenges.

Priority actions centre on scaling proven interventions while addressing structural constraints that limit adoption beyond commercial growers. Governance reforms establishing basin-level water agencies with enforcement authority, bilateral cooperation mechanisms favouring South-South knowledge transfer and national food security strategies coordinating sovereign wealth fund investments are evidence of institutional support. Corporate water stewardship, achieved through internationally recognised certification and public-private partnerships that deploy blended finance structures, validates the private sector's alignment with resource constraints.

However, smallholder farmer engagement—where the majority of regional production originates—requires targeted support to address capital access barriers, technical capacity gaps and regulatory approval timelines that constrain technology diffusion. Success depends on coordinated action: development finance providing first-loss capital, governments implementing scarcity-based pricing and the private sector deploying equipment leasing.

Investment opportunities in precision agriculture and renewable energy integration reveal commercial potential, where supportive policy frameworks can facilitate viable financing projects. Institutional mechanisms include regional cooperation through technical training platforms and vertical farming partnerships. At the same time, in the corporate sector, ring-fenced allocations for agriculture from sustainable bond proceeds can provide financing for firms.

Achieving water security while advancing climate adaptation and food sovereignty in arid environments demands sustained commitment to integrated policy design, coordinated investment, and institutional capacity building. These efforts must treat water efficiency, climate resilience, and food security as interdependent rather than competing priorities. The need for such an approach is becoming increasingly urgent as climate impacts intensify and demographic pressures grow across water-scarce regions, particularly in the Middle East and North Africa.

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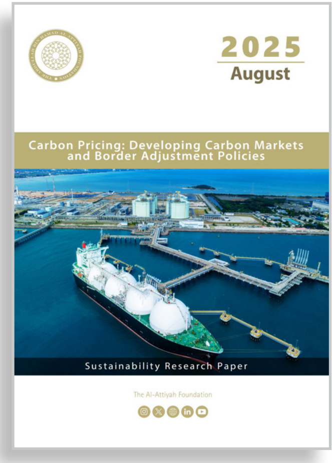

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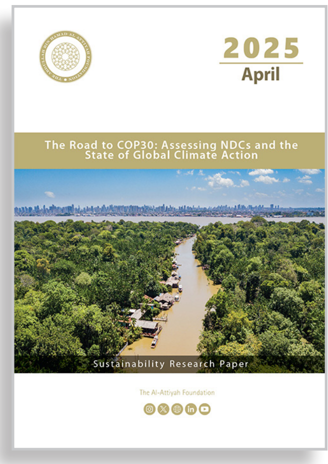

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