Best practices, innovations and technologies to inform climate action for resilient and sustainable agriculture systems

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Economic and Social Commission for Western Asia

Best practices, innovations and technologies
to inform climate action for resilient
and sustainable agriculture systems

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Preface

Climate change has already impacted the agricultural sector in the Arab region. The region has been engaged in the United Nations Framework Convention on Climate Change (UNFCCC) and the Paris Agreement, with all Arab States, except for Iraq, Libya, and Yemen, having signed and approved the agreement to date. More importantly, in 2017, through the Koronivia Joint Work on Agriculture (KJWA), the agriculture sector has become an integral part of the Paris Agreement for reducing emissions. This is a unique moment for the Arab region to catch onto the global momentum and international call for sustainable recovery.

This document is intended to guide countries on adaptation and mitigation benefits from technologies and practices that can be applied to enhance water and land management and livestock production for a more resilient agriculture sector.

Acknowledgements

This report was prepared by Dr. Hadi Jaafar, Chair of the Department of Agriculture at the American University of Beirut, in cooperation with a team from the Climate Change and Natural Resources Sustainability Cluster at the Economic and Social Commission for Western Asia (ESCWA). ESCWA team was led by Ms. Carol Chouchani Cherfane, cluster leader and comprised Ms. Reem Nejdawi, Mr. Tarek Sadek, Ms. Julie Abouarab, Ms. Maya Atie and Ms. Layale Gedeon. Funding for this report was provided by the Swedish Government through the Swedish International Development Cooperation Agency (Sida).

Key messages

Policies should facilitate coordinated cooperation between Arab countries at the political, institutional and technical levels to leverage existing platforms and knowledge for assessing and addressing the impact of technologies on climate vulnerability and to examine their scalability and affordability in different socioeconomic and natural ecosystems in the region.

Technologies should be appropriate for the region and/or country in which they are suggested.

Consumers, producers, stakeholders and decision makers must be targeted for capacity building through intense knowledge, mentorship, management and extension services.

Climate change provides a clear opportunity to reconsider gender inequity and involve both men and women in developing innovative solutions to common environmental problems.

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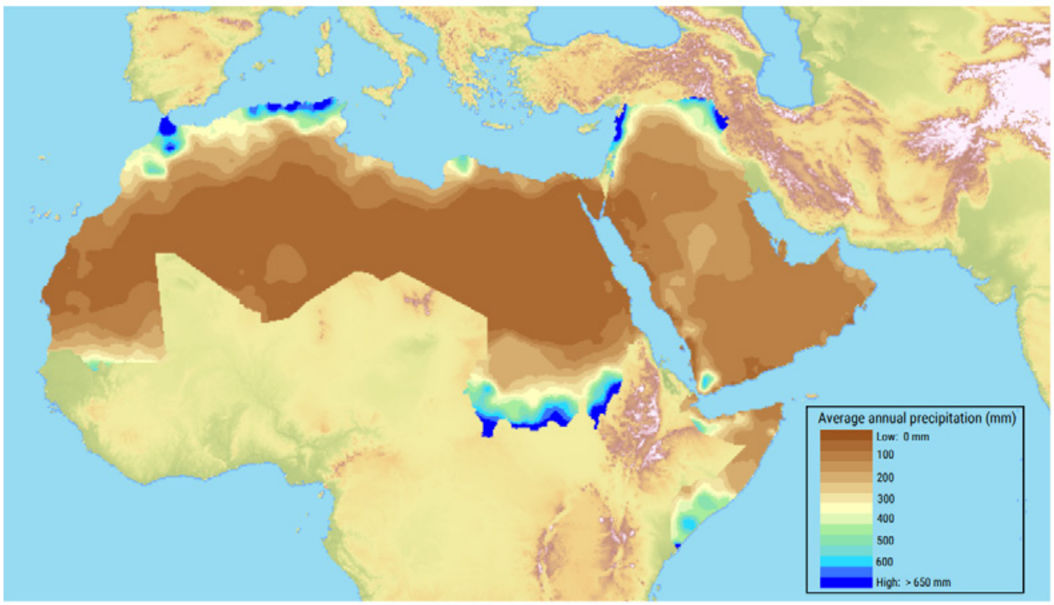
Introduction

The green revolution failed to achieve the United Nations Millennium Development Goals of halving hunger by 2015 in water-scarce regions, such as the Arab region. Most of this region is characterized by limited arable lands (less than 4.5 per cent of total area on average),[1] poor renewable water supplies (less than 275 m^3/capita/year on average)[2] and semi-arid or arid climatic conditions. Rain-fed agriculture accounts for around 85 per cent of the arable land, and climatic conditions are characterized by inconsistent and unpredictable rainfall.[3] The average annual precipitation in the southern Mediterranean states is less than 1,000 mm, which is significantly below the evaporation potential[4] (figure 1).

High population growth rates, averaging over 2.2 per cent per year, and increasing urbanization are putting a strain on natural resources at a time when food demand is on the rise. Population growth is one of the foremost causes of increased water demand in the region. The Arab region is home to 444.81 million inhabitants, comprising approximately 5.6 per cent of the world population. Eighty per cent of the region's population is concentrated in eight countries: Algeria, Egypt, Iraq, Morocco, Saudi Arabia, the Sudan, the Syrian Arab Republic and Yemen. The region's population is expected to reach 586 million by 2030 and 731 million by 2050.[5] At the same time, environmental deterioration and climate change are putting a huge strain on agriculture's natural resources. The region's small and fragile natural resource base, as well as diminishing productivity, severely limit the food supply, making it highly reliant on imports and subject to increases and volatility in international food costs, as well as other externalities.

Figure 1. Mean annual precipitation over the Arab region, 1985-2005



Source: E/ESCWA/SDPD/2017/RICCAR/Report.

Many of these challenges will need to be addressed through transformational changes in the existing agricultural practices. For example, the use of modern information and technologies for decision-making and operations in the management of water, agricultural and land resources is important to adapt crop production to climate change. The integration of new and advanced technologies into the value chain can be an important approach to improve resilience and food production. Watering with smart irrigation apps, improving fertilizer applications based on localized needs detected by sensors, targeted spraying activities with drones, and harvesting mature crops with artificial intelligence–guided harvesters are all examples of technological practices that have a lot of promise for conserving natural resources, reducing environmental damage and increasing crop yield.

A critical lens at the Arab region groups of countries facing severe challenges

The Arab region extends across about 1.2 billion hectares, forming around 10 per cent of the world's total land area.[6] The region has been classified into five major groups of countries. The Gulf Cooperation Council (GCC) countries are Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates. The least developed countries (LDCs) are the Comoros, Djibouti, Mauritania, Somalia and the Sudan. The middle-income countries (MICs) are Algeria, Egypt, Jordan, Lebanon, Morocco and Tunisia. Countries in conflict (CiCs) are Iraq, Libya, the State of Palestine, the Syrian Arab Republic and Yemen. Despite their heterogeneous geography, natural resources and political and income levels, many Arab States share a mutual context of critical environmental challenges threatening the region's long-term stability.

The Arab region faces serious challenges stemming from a backdrop of constraining factors that increase its vulnerability to climate change. These can be political (conflicts), technical (unavailability of sufficient infrastructure to treat wastewater, ageing infrastructure) and institutional (lack of enforcement of regulations controlling water pollution, water mismanagement) as well as natural (agricultural production that is mainly rain-fed and relies mostly on non-renewable groundwater resources) and behavioural (overextraction of resources and unsustainable use).

Limited water resources

Up to 60 per cent of the region's surface water resources originate from outside the region's borders.[7] As a result, the Arab region is one of the most water-stressed regions on earth, and is undergoing a high level of renewable freshwater stress at varying extents across states and within its subregions. Extremely high-stress levels prevail in Libya and the GCC countries, particularly Kuwait, Saudi Arabia and the United Arab Emirates, with less than 500 m^3/capita/year of available freshwater resources.[8] Water stress levels are lower in Lebanon, Mauritania and Morocco than in the GCC[9] (ranging between 500 to 1700 m^3/capita/year). As shown in figure 2, agriculture is the major consumer of water in all subregions.

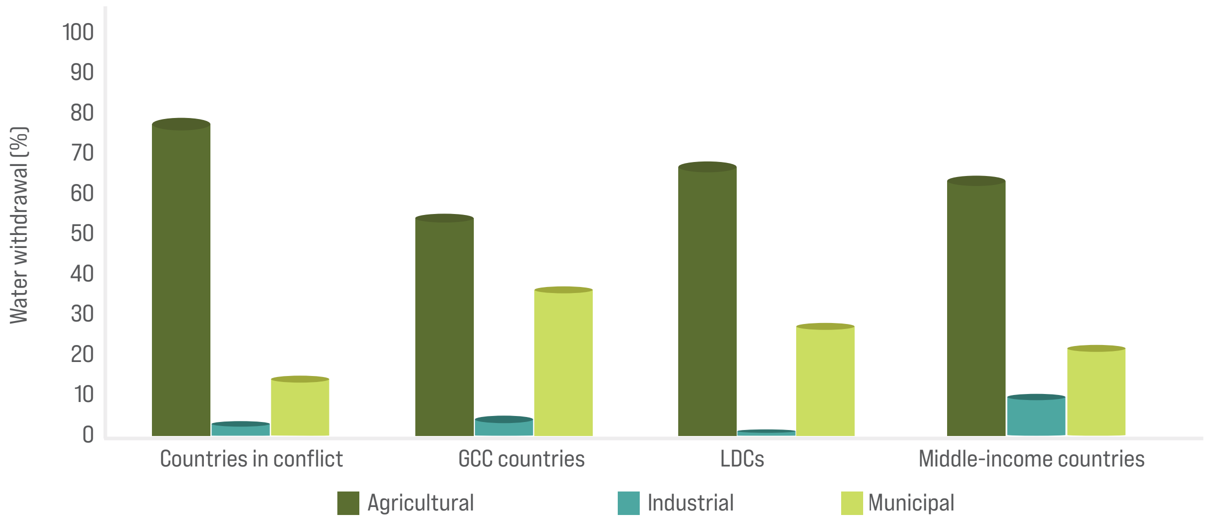
The LDCs and countries in conflict have the lowest access to safe drinking water, with the rural population being the most vulnerable group. Only 52 per cent of the total population in LDCs have access to safe drinking water (figure 3).

Limited natural resources

Less than 5 per cent of the region's land is arable, and the aridity climatic condition means that most of this land requires irrigation to produce food.[10] The fuel-based conventional technologies increase greenhouse gas (GHG) emissions through energy required for spraying, irrigation and other farming activities for harvest and post-harvest practices. As a result, the Arab region's per capita GHG emissions are on the rise. To date, the Arab GHG emissions are similar to the 2013 global average, with the highest cumulative emissions recorded in Egypt, Saudi Arabia and the United Arab Emirates. In addition, the agricultural sector represents the highest emitter in the Comoros, Djibouti, Mauritania, Somalia, the Sudan and Yemen, but at much lower scale when compared to global agriculture contribution to GHG emissions.[11]

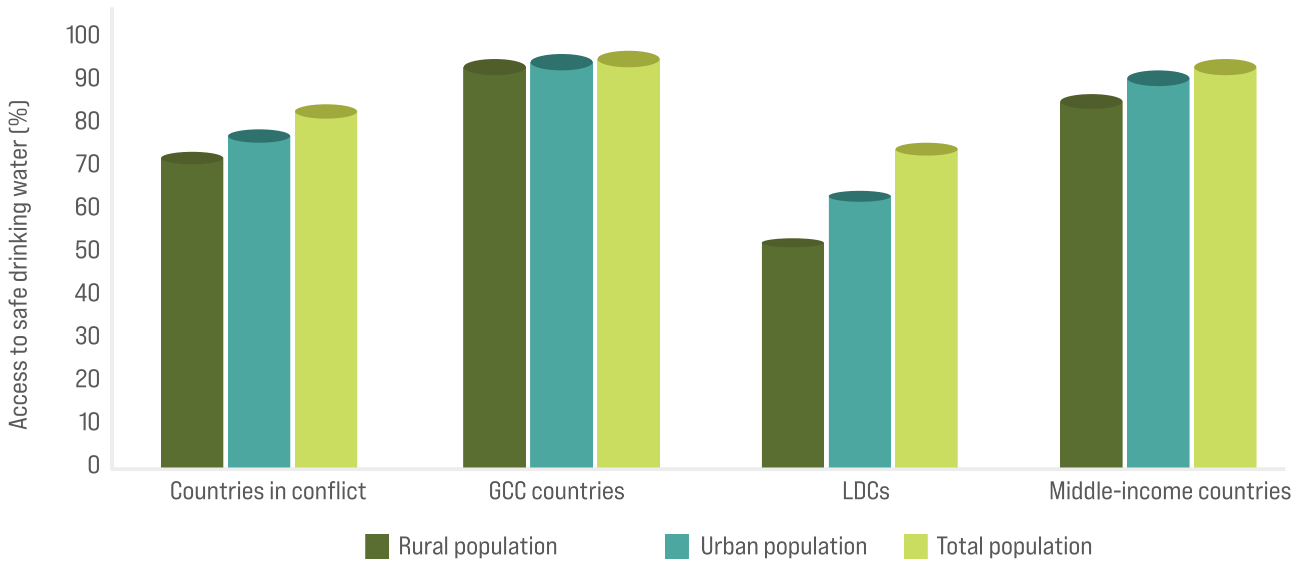
The agricultural sector of the Arab countries has always constituted a significant element of the Arab economy and livelihood but is now holding on to radical transformations driven by water shortages, threatening about 70 per cent of the region's rural people who depend on the agriculture sector for their livelihoods, which poses a significant risk for economic and social stability. Moreover, 70 per cent of the agricultural sector is rain-fed, making it highly vulnerable to changing climatic conditions.[12] Soils are eroding, groundwater is being depleted in many aquifers, and renewable surface waters are declining in both quality and quantity. Unsustainable agricultural practices threaten the region's already scarce forest ecosystems (which cover less than 3 per cent of the land). As a result, the agricultural value is expected to decrease by 20 per cent by 2080,[13] putting 5 per cent of the population in some countries of the Arab world at risk of starvation. Efforts to increase agricultural productivity in the Arab region have so far failed to yield results. Expected economic losses from climate change-induced water scarcity are significant and could cost the region between 6 and 14 per cent of gross domestic product by 2050.[14]

Figure 2. The average share of water withdrawal by sectors per cent of total water withdrawal in the Arab region, 2018-2020



Source: Food and Agriculture Organization of the United Nations (FAO), AQUASTAT Core Database, 2020 (accessed on 18 October 2021).

Figure 3. Percentage of population with access to drinking water in the Arab region

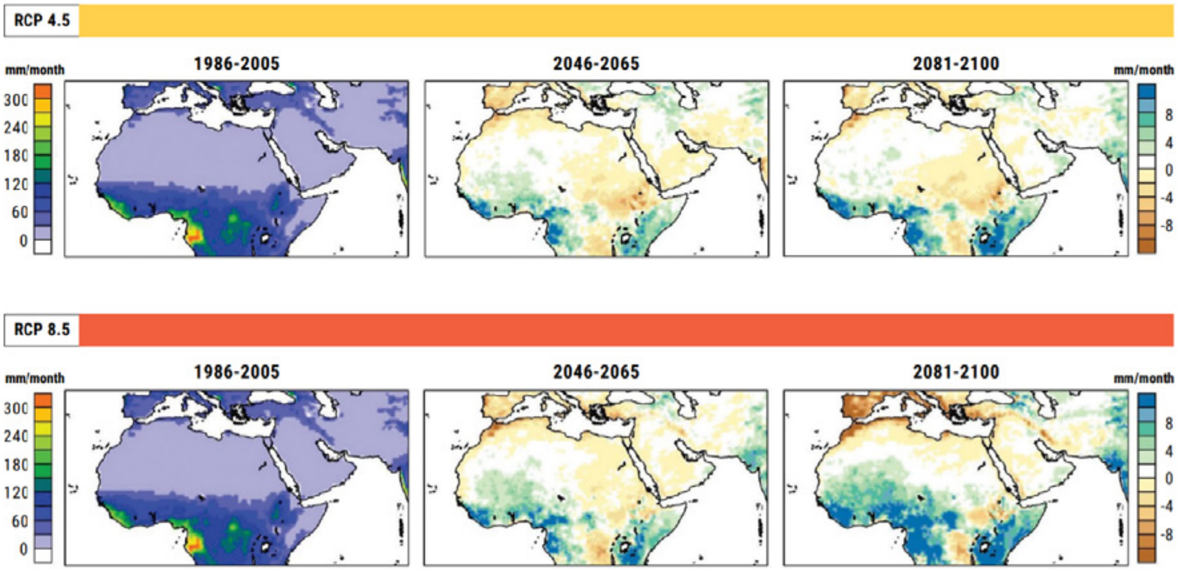


Source: FAO, AQUASTAT Core Database, 2020 (accessed on 18 October 2021).

The limited natural resources have compelled the Arab countries, especially the Gulf States, to import more than half of their basic food needs with a higher percentage of imports from animal products.[15]

The Arab region is susceptible to climate change-related outcomes due to pre-existing high temperatures. An outlook to the future is that many countries in the region will face an estimated increase in temperature under RCP 4.5 of 1.2 °C–1.9 °C at mid-century and 1.5 °C–2.3 °C by end-century. Temperatures may increase to 1.7 °C–2.6 °C for mid-century and 3.2 °C–4.8 °C towards end-century under an RCP 8.5 scenario.[16] Projections also estimate intensified extreme weather events of all types, ranging from wildfires and floods, to snowstorms and droughts. Annual precipitation is also expected to decrease (figure 4). In addition, years of political instability and conflicts have caused a refugee crisis of over 7.8 million,[17] more than one third of whom reside in Jordan and Lebanon,[18] causing more demand on finite natural resources and eco-services for a growing population. The way forward to tackle these challenges requires the adoption of technologies in water, land and livestock management that can help mitigate and adapt to climate change impacts.

Figure 4. Average changes in annual precipitation (mm/month) for mid- and end-century for ensemble of three RCP 4.5 and RCP 8.5 projections compared to the reference period



Source: ESCWA and others, ***Arab Climate Change Assessment Report – Main Report***, E/ESCWA/SDPD/2017/RICCAR/Report (Beirut, Economic and Social Commission for Western Asia, 2017).

Need for climate action that is to be implemented through appropriate technologies

Data-intensive approaches may facilitate the implementation of practical agricultural climate solutions by farmers as they provide actual and visible advantages. These approaches also provide access to more responsive policies, commercial opportunities and space for community projects. In other words, data-driven climate action provides opportunities for a diverse set of stakeholders, which could secure broad institutional support by appealing to a variety of institutional kinds. In terms of climate action, this broad appeal is a vital success factor.[19]

In order to achieve a balance between privacy and data property rights and the enhanced innovation prospects provided by data access, data governance is crucial in terms of legislation and organizations. Creating an open space for enterprises and community organizations to establish interdependent and decentralized data management systems required for agricultural climate action requires proactive legislation and public support and investment.

There are plenty of benefits of digital technologies for improved management in the water sector. Despite these benefits, however, challenges persist, particularly when it comes to implementing these technologies on a wider scale in the Arab region. Many of these solutions still need to be piloted or brought up to scale to have a broader impact.

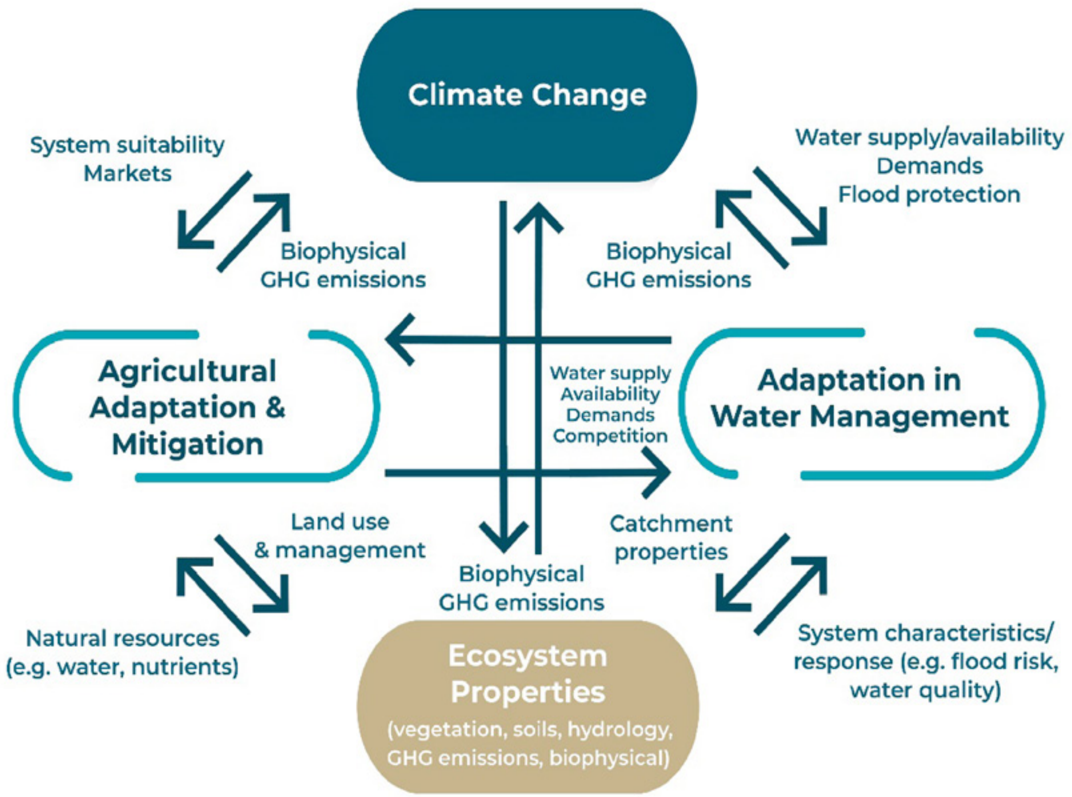
On the other hand, despite the fact that there are many sustainable soil, land and livestock management approaches that have multiple benefits in terms of climate change mitigation and adaptation, their adoption in agricultural policies is restricted. The implementation of these solutions is hampered by the following difficulties, in addition to insufficient regulations and processes to control soil and land management: (1) Insufficient technical capacities and information on sustainable land and soil management practices and their impact on different ecosystems; (2) Poor quality agricultural extensions in some conflict-affected countries; (3) Inadequate financial resources in Arab low-income countries; and (4) Lack of promotion of crop diversification for a variety of reasons (such as markets and management difficulties).

Climate action in water, land and livestock should involve building systems that respond to local problems caused by climate change with extensive feedback from future users; establishing institutional arrangements or developing business models to make their use sustainable and influencing the enabling environment so that these approaches gain long-term policy support and are enshrined in solid regulations, which is key in this process.

1. Enhancing water management

Climate change expresses itself mainly through water resources availability by exacerbating the current water level stress. The recurrent drought threatens agricultural production and results in growing water demands, leaving water availability in the Arab region of only 600 cubic metres per capita per year, which is less than one-tenth of the world's average of 6,500 cubic metres per capita per year.[20] Water scarcity is accentuated by utilizing about 80 per cent of total water withdrawals for the agriculture sector,[21] yet irrigation efficiency is low and is being offset by increasing energy requirements for pumping and diverting water. Moreover, almost all coastal Arab countries, particularly the Mediterranean ones, are exposed to rising sea levels due to global warming, increasing the risk of seawater intrusion into these coastal regions' groundwater aquifers. The interactions between climate change and adaptation and mitigation practices in water management is shown in figure 5. Understanding the interactions between climate change and adaptation/mitigation measures in agriculture, and adaptation in water management with ecosystem properties, is crucial for addressing the climate change-human nexus.

Figure 5. Understanding the interactions between climate change and adaptation/mitigation measures in agriculture, and adaptation in water management with ecosystem properties, is crucial for addressing the climate change-human nexus



Source: Adapted from Pete Falloon and Richard Betts, "Climate impacts on European agriculture and water management in the context of adaptation and mitigation—the importance of an integrated approach", Science of the Total Environment, vol. 408, No. 23, 2010.

A. Impact on climate

1. RICCAR water vulnerability hotspots

For the ***reference period***, 70 per cent of the study area signifies high vulnerability for water availability, with the remaining areas demonstrating a moderate level of exposure. Areas with the most increased vulnerability are clustered around the Marra Mountains in the Sudan, the upper Nile Valley, Wadi Hadramaut in the southern Arabian Peninsula and the Horn of Africa. Conversely, the Atlas Mountains and adjacent coastal areas, the Levantine coast and upper Mesopotamia represent the lowest vulnerability of the Arab region (figure 6).[22]

As for ***future periods***, at mid-century (2046-2065), 43 per cent (RCP 4.5) of the region predicts high vulnerability (figure 7) (table 1). At the end-century, areas of high exposure will increase slightly, representing 48 per cent (RCP 4.5) of the region's area. Such sites include the upper Nile Valley, the southwestern Arabian Peninsula and the northern Horn of Africa due to low adaptive capacity. The remaining areas show moderate vulnerability. Areas with relatively low vulnerability include the Tigris–Euphrates basin and the lower Nile Valley, including the Nile Delta.

The implications of hydrological changes for adaptation measures in agriculture would be a reduced water supply from precipitation and an increased water demand for irrigation in the affected regions. This would result in an increased vulnerability of production. The vulnerability of agricultural mitigation measures to hydrological changes would be:

1. Reduced net primary productivity, carbon inputs and above ground carbon storage.

2. Reduced soil carbon decomposition and GHG fluxes.

3. Increased soil carbon losses via wind erosion.

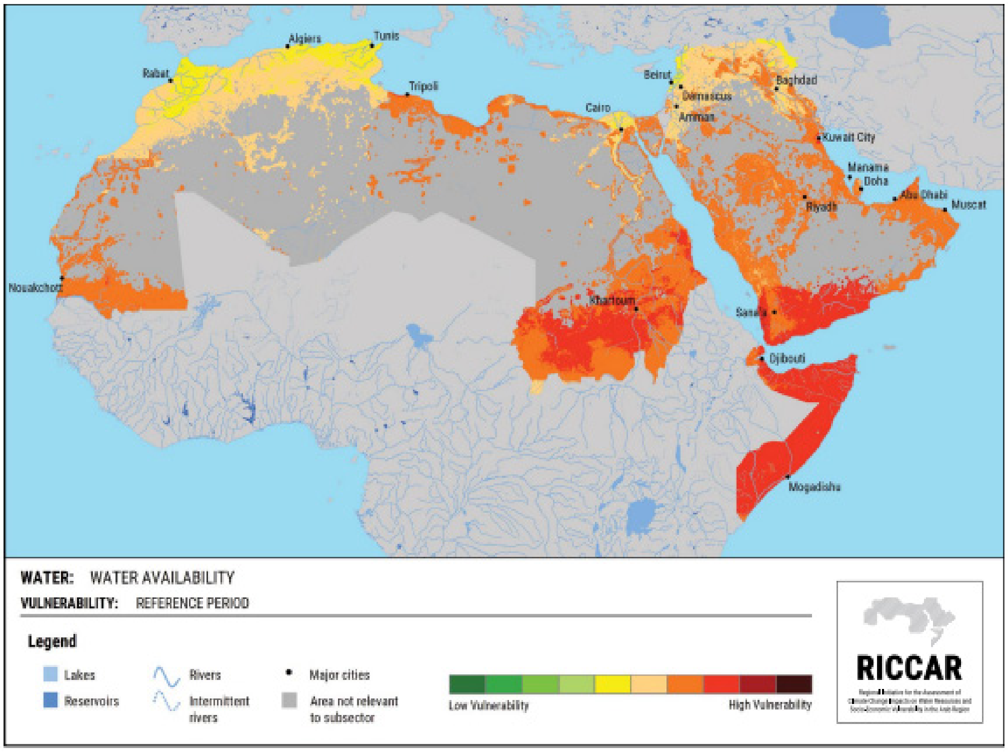
This projected vulnerability should guide climate action in the region. A better understanding and utilization of the wealth of information presented by the RICCAR reports and data in terms of their impact on guiding the adaptation and mitigation measures in each country of the Arab region should be sought. Each country should focus on addressing its vulnerabilities and prioritize its actions, while taking into consideration the inherent complexities and interlinkages between the water, land and livestock sectors in agriculture.

Table 1. Percentage of Arab region by vulnerability grouping for water availability

Scenario	Vulnerability (Percentage of the Arab region)		
	Low	Moderate	High
Mid-century RCP 4.5	0	57	43
Mid-century RCP 8.5	0	48	52
End-century RCP 4.5	0	52	48
End-century RCP 8.5	0	53	57

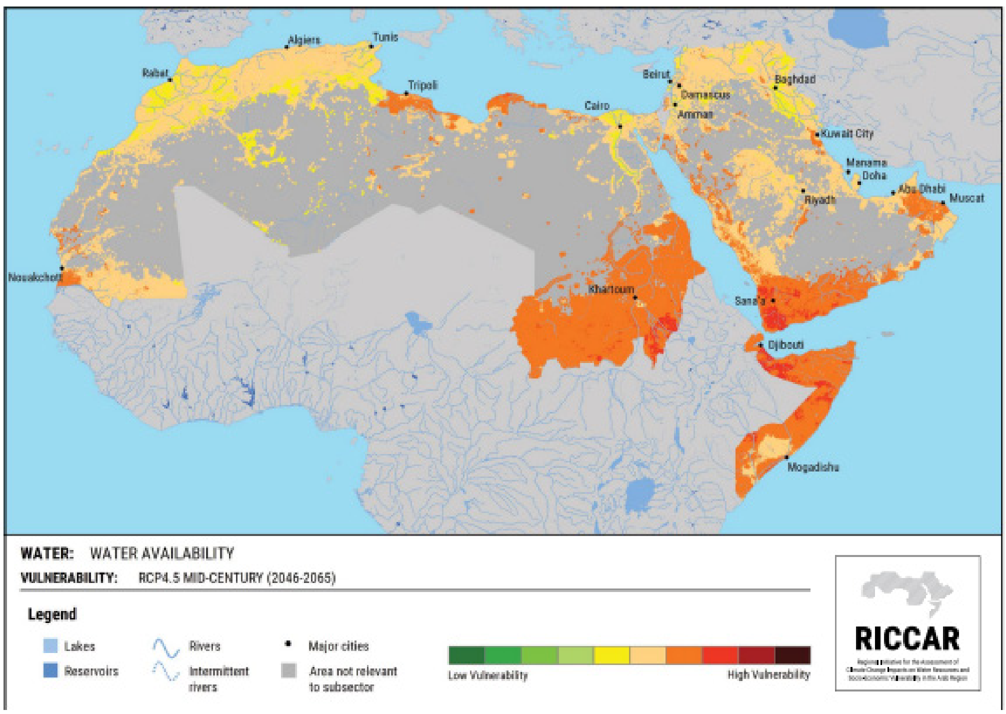
Source: ESCWA and others, ***Arab Climate Change Assessment Report – Main Report***, E/ESCWA/SDPD/2017/RICCAR/Report (Beirut, Economic and Social Commission for Western Asia, 2017).

Figure 6. Water availability – Reference period – Vulnerability



Source: ESCWA and others, *Arab Climate Change Assessment Report – Main Report*, E/ESCWA/SDPD/2017/RICCAR/Report (Beirut, Economic and Social Commission for Western Asia, 2017).

Figure 7. Water availability – Mid-century RCP 4.5 – Vulnerability



Source: ESCWA and others, *Arab Climate Change Assessment Report – Main Report*, E/ESCWA/SDPD/2017/RICCAR/Report (Beirut, Economic and Social Commission for Western Asia, 2017).

2. Impacts of digital water solutions

Integrating new technologies such as digital water solutions with the water value chain, from watershed to infrastructure to farm level, plays a significant role in tackling substantial regional risks, addressing water scarcity and simultaneously boosting the Arab region's resilience to climate impacts through sustainable practices.[23] These technologies would help in:

4. Reducing water and carbon footprints.
5. Controlling the increased frequency of extreme weather conditions.
6. Improving adaptation capacity by assessing and acting upon emerging risks.24
7. Minimizing environmental damage.
8. Optimizing crop production.
9. Reducing losses from climate shocks.25
10. Decreasing fertilizer requirements, matching inputs to yield while reducing costs.[26]
11. Reducing non-point source pollution.[27]

B. Digital water transformation

1. Description

Digital water, Internet of water and smart water are all terms used to define the transformation that is currently occurring to resolve pressing water challenges through innovative solutions: information and communication technologies (ICTs). These solutions leverage the latest enabling technologies, including mobile applications, cloud, smart sensors, drones, real-time detection systems (ground-vehicles), intelligent infrastructure, analytics and big data.

Digital technologies are knocking down knowledge and skills barriers to rational water management by increasing potential beneficiaries encompassing ***farmers, water authorities, advisory services and regional environmental agencies***. In addition, ICTs offer new opportunities to adapt to climate change and mitigate its impact by building and enhancing access to information for water suppliers and users' lucrative operations.

2. Functionality

Digital water solutions can be integrated at every key area across the legal framework (inform, plan, allocate, protect and adapt). Water challenges should no longer be managed with analogue solutions. If the Arab countries continue to do so, they will be further degrading their water resources. Digital technologies take hold of managing water resources through **geographic *information systems (GIS), remote sensing, visualization tools and sensors technologies***, at field-scale, watershed and regional and global levels.

The remotely sensed data are used in meaningful ways to prepare and advise water resource managers on coping strategies necessary to help in water management (box 1). Such and other digital systems can pro-actively detect and prevent detrimental events (e.g., pipe bursts, sewer collapses/ blockages, etc. using GIS-based SCADA systems) and also react to water quality issues, among other countermeasures, thereby allowing for improved water management.

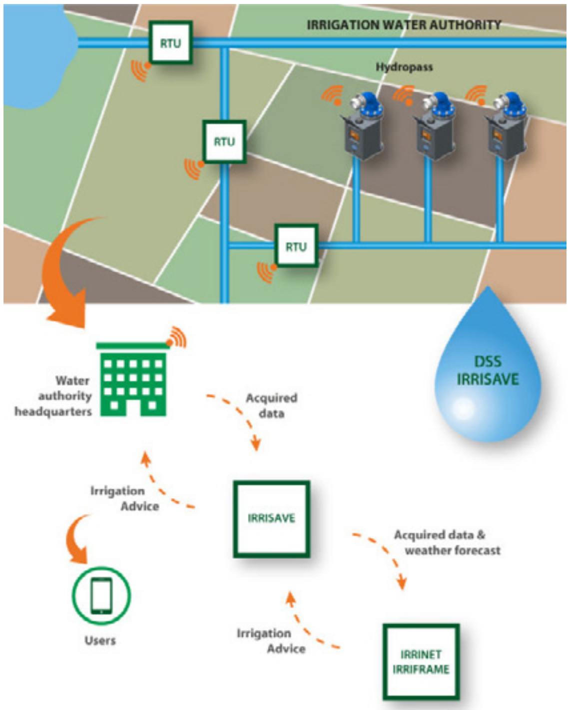
The progress of digital water technologies is sweeping different sectors, ranging from homes (e.g., smart taps, watering, etc.) and water and wastewater utility, to the agricultural sector. The integration of digital technologies in agricultural activities provides farmers with timely and low-cost information services, helps private and public agencies in coordinating agricultural agents and improves water efficiency and productivity.

Technologies tailored to ***"Precision Irrigation" (PI)***, water allocation, harvest and reuse and early warning systems are top priorities for the region.[28] PI is a new frontier for efficient water use in any irrigation method. Through data acquired from monitoring devices (sensors) and forecasting tools (weather predictions), this innovative practice helps end users in deciding on when and how much to irrigate by calculating and forecasting crop water requirements.[29]

Innovations such as smart irrigation apps,[30] sensor-based machine-to-machine irrigation systems,[31] solar-powered irrigation systems and monitoring devices (soil and plant sensors, meteorological information) are all aspects of ***PI***. They are among the emerging clean technologies gaining wide attention in the region.

Box 1. SENSING for water management

Enact appropriate conservation practices during drought periods (SMS messages, alerts, push notifications, drought monitors).	Optimize resource use via monitoring water use from space (for example using ET models on web applications).



Source: Compiled by authors.

3. Feasibility

Due to challenges caused by the lack of infrastructure or costly procurement processes of hardware, digital water is not reaching the last mile. In addition to the lack of Internet access in the least developed countries (e.g., Mauritania and Yemen), poor training and a low percentage of smartphone adoption (averaging 60 per cent in the Arab world, with 45 per cent in the Sudan and Yemen, 54 per cent in the North African Arab countries, 61 per cent in Iraq, Jordan, Lebanon and the Syrian Arab Republic and 79 per cent in the GCC countries[32]), are factors that hold the region back from adopting these innovations. While data are available is some countries (example: high-density weather station networks in Jordan, Lebanon, Morocco and Tunisia), there are gaps in data sharing, accessing and monitoring among authorities, stakeholders and end-users in some countries of the Arab region.

4. Suitability

To guarantee that water technologies bring value, the data they deliver have to be converted into actions. Thus, the elements characterizing the effectiveness of digital water solutions and defining the value of the provided information are:

Content of data: potential beneficiaries of smart water must be able include extracted information in their decision process and act upon it. Otherwise, the data are of little value. For example, simply providing weather data or even just reference evapotranspiration values may not be enough. It is important to guide the farmer in also providing irrigation run times.

Data accuracy and robustness: the data robustness to uncertainty and their accuracy would reduce the risk of failures, as inaccurate data will not induce any changes in potential beneficiaries' decisions and actions. For example, the PI approach impact is still unclear due to its limited dissemination and the varying accuracy of available monitoring devices. In addition, the accuracy of devices, such as canopy cover[33] and soil moisture sensors',[34] is influenced by the spatial variability,[35] affecting the reliability of the information used to manage irrigation. For example, many farmers in the Arab region use surface irrigation. Applying smart irrigation practices under these conditions is challenging due to the difficulty in measuring and controlling applied water in these systems and to the traditional methods in water diversion and application that govern surface irrigation systems.

Timing of information provision: the right-time data delivery is essential in the decision process, as late messages have no value. Contingency plans must be in place in case of system failures, such as providing information to farmers as to what to do in such circumstances (having pre-defined irrigation times/volumes in case of failures, reverting to existing knowledge, etc.).

C. Case study 1 – Mobile application for water management – AgSAT

1. Description

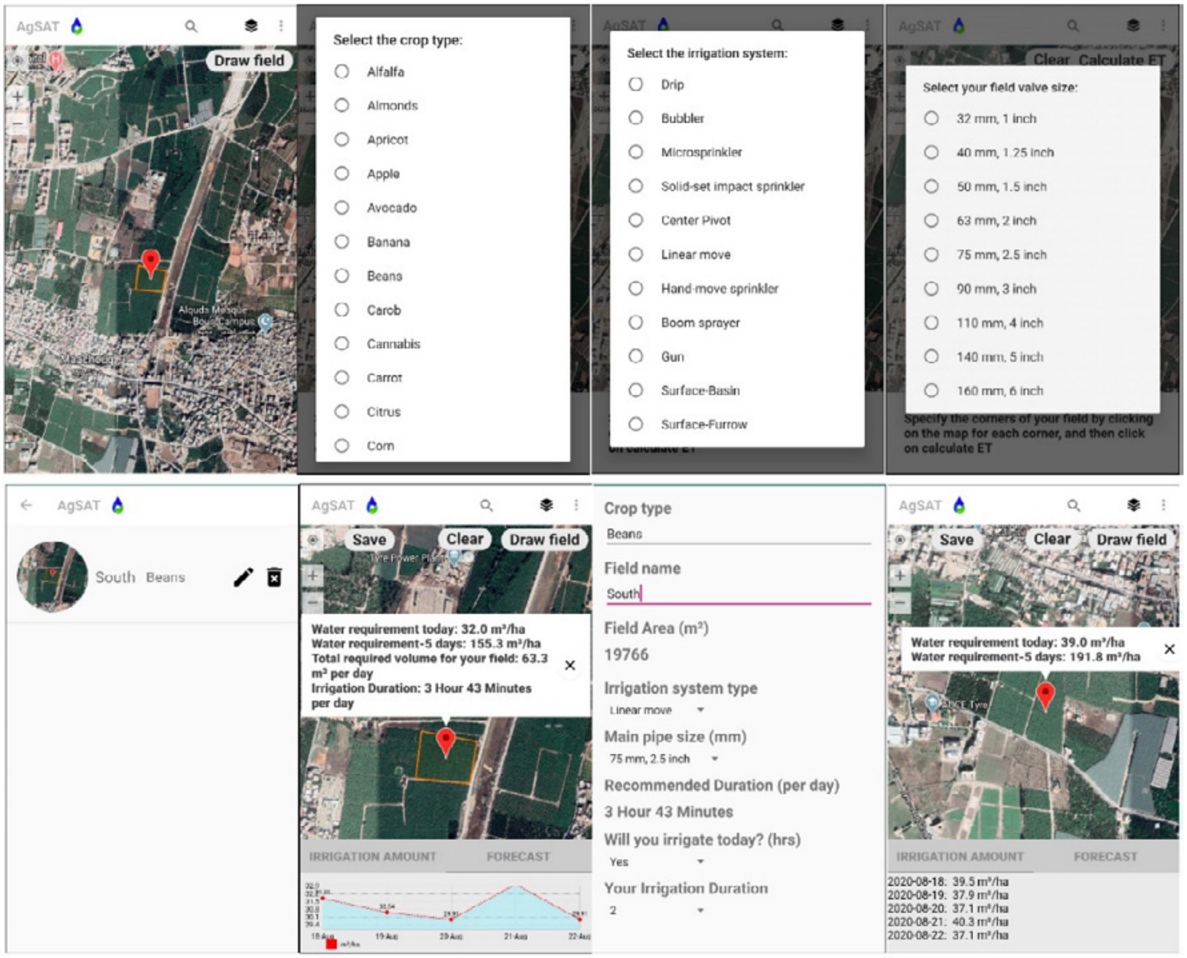
Smartphone application based on remote sensing and weather data

One example of these tools is the use of mobile applications and web platforms that calculate irrigation requirements. Recently, a new Android app for smartphones that calculates crop evapotranspiration in real-time was developed with backing from Google.org and IHE-Delft (Netherlands) to support field-scale irrigation management. The app (named AgSAT), which was developed at the American University of Beirut with Google Earth Engine as a backend, is featured on Sustainable Development Network StoryMaps website. AgSAT uses meteorological data to calculate daily water requirements using the ASCE-Penman–Monteith method[36] and vegetation indices[37] from satellite imagery to derive the basal crop growth coefficient, K_{cb}. AgSAT can provide water requirements data to all types of users, from small-holder famers to irrigation districts and regional water planners in the Arab countries. It is available on Android, IOS and also as a web application (www. AgSAT.app).

The design of AgSAT is based on two main principles. First, the app provides location and user-specific crop and weather data. Second, it is free for non-commercial uses and easy to use (the user simply pinpoints the field of interest). It also allows users to delineate their fields on the fly over a Google Maps background. The app provides water requirements based on crop vegetation status, weather conditions for the day, and irrigation system type (used to estimate irrigation efficiencies). Users who choose to delineate their fields can provide the valve size of their field and receive the irrigation run time. As the application starts, the user is prompted to grant the app permission to read the location of the device (figure 8). After that, the user can simply delineate the field and save it after being prompted to select crop types, irrigation system type and irrigation pipe size (for delineated fields only) from a drop-down list. The 'history' tab of AgSAT shows five days of irrigation requirements based on evapotranspiration (ET) and crop growth coefficient (Kc) from preceding satellite imagery. Once the user selects these details and assigns the corners of his field, the "Calculate ET" must be clicked to trigger an Application Programming Interface (API) request so that the necessary data for irrigation usage is fetched for the selected location, taking into consideration its latitude and longitude as per Google Maps. The returned API results are displayed for the user in a popup window with a description for each value. The user can toggle between two languages (Arabic and English) in the settings tab.

AgSAT can guide decision makers in water allocation for agriculture and landscape. It can help famers produce more crop with less water and energy, thereby reducing the environmental footprint of agriculture. Implementing smart irrigation solutions in other regions of the world has proven to reduce water use by up to 20 per cent. Reduction in water use is coupled with a reduction in energy consumption, reflecting positively in reducing GHG emissions. A case study in the United States, where a company (HydroPoint) implemented the usage of weather-based irrigation controllers in partnership with a telecom supplier (AT&T), has shown an energy saving equivalent to up to 750 metric tons of CO_2 per year. AgSAT is featured within a collection of stories relating to Sustainable Development Goal 6 as part of SDGs Today: The Global Hub for Real-Time SDG Data.[38]

Figure 8. Interface of AgSAT and screen shots of the application detailing the procedure to obtain results



Source: AgSAT application interface. https://play.google.com/store/apps/details?id=app.crop.smartirrigation&hl=en&gl=US.

2. Where it can be used

The application can be used anywhere in Arab countries where irrigation is practiced, where cellular network coverage is available and where farmers have smart phones. Also, it is best used in places where sprinkle and trickle irrigation is applied, and for surface irrigation at the district or water authority level. It can inform farmers and farm operators on the irrigation timing and volume required for their crops, thereby helping them save on energy use and water diversions. Currently, the app is being used in Egypt, Lebanon, Saudi Arabia, the Sudan and the United Arab Emirates. Extension to countries that are most affected by climate change is thus necessary to improve their agricultural water use management.

3. How to adopt

Adoption may be done by ministries and municipalities, farmers, irrigation engineers, water authorities, large and small farming enterprises, non-governmental organizations, agriculture companies, and leading organizations (such as ESCWA, the World Bank, the World Food Programme and others). Currently, the application is accessible freely for non-commercial usage, with a simple training demo available within the web application.[39]

In the Arab region, precision irrigation methods are not widely used. Lack of information, expensive capital expenditures and time spent on training and data collection are all factors affecting its use. Fertilizer pricing, production acreage and crop values are all important considerations when it comes to precision agriculture adoption.

4. Parameters to measure effectiveness and suitability of proposed technology/practice

Integrating digital agriculture into agricultural development strategies and programmes is still in its infancy in the region, with successful applications at the pilot scale. Policy interventions in the areas of socioeconomics and the environment are critical for boosting farmers' understanding of current digital practices. As a result, regulations might be devised to improve farmers' access to loans, markets and financial services. Furthermore, rules limiting non-beneficial water use to protect groundwater in water-scarce places may encourage farmers to utilize precision irrigation. Remote sensing of actual evapotranspiration can provide evidence of reduced non-beneficial water use. Other key indicators that can help evaluate the effectiveness of such techniques are:

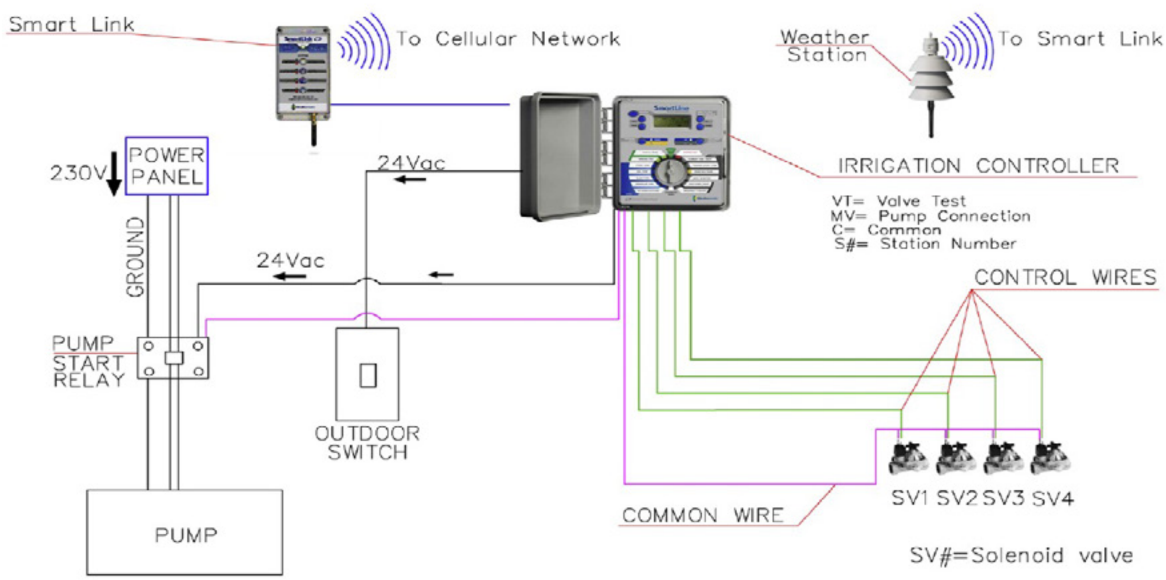
- Water measurements (surface flow, groundwater levels, etc...).
- Energy measurements (kilowatt-hour on power consumption of irrigation pumps, diesel consumption in various machinery operations such as tillage, planting, spraying and harvest).
- Yield measurements (pre and post technology, economic productivity, changes in yields).
- Reductions in water diversions to agriculture (which requires monitoring measurements at canals).

In addition, although floods are less prevalent in the region, they are the most destructive so far, causing more than $300 billion in damages.[40] In recent years, a substantial increase in the quantity and severity of floods has been seen in Saudi Arabia.[41] It is thus recommended that Arab countries, including the wealthier ones, invest in mapping and remote sensing technologies to improve disaster management and early monitoring systems.

D. Case study 2 – Machine-to-machine smart irrigation systems

Other technologies for the Internet of water could be the machine-to-machine smart irrigation systems. An experimental study was set up in the Bekaa Valley, Lebanon, where the system was successfully implemented for two seasons of cultivating an ***origanum*** crop.[42] The study aimed at testing the applicability and operability of smart and automated irrigation systems in agricultural settings. Rather than having the farmer deciding on irrigation times and amount, the designed system depends on field measurements that allow the automated start and shut off of the irrigation cycle so as to irrigate the crop when needed and as needed. Irrigation was made possible in an automated way remotely based on local measurements of evapotranspiration (figure 10).

Figure 9. Process and control diagram for a machine-to-machine smart irrigation system implemented at AREC, Lebanon, for the irrigation of origanum



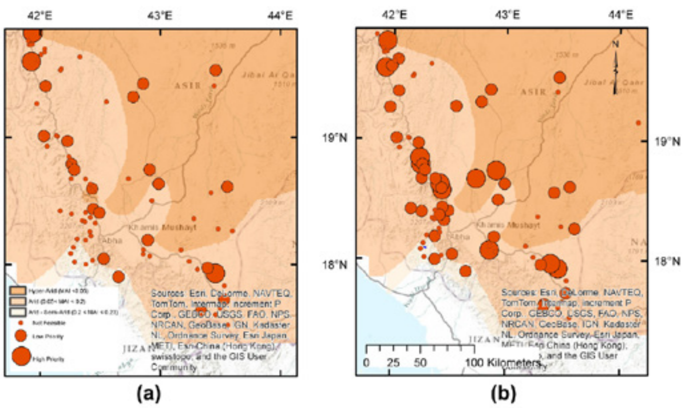
Source: Hadi Jaafar and others, "Determining water requirements of biblical hyssop using an ET-based drip irrigation system", ***Agricultural Water Management***, vol. 180, Part A, 2017.

The system is composed of an irrigation controller that communicates wirelessly with a small on-site weather station from which the irrigation run-times are derived based on reference evapotranspiration calculated based on the Hargreaves Equation (using on-site temperature measurements and the latitude of the site), as well as user-input data to determine the irrigation run times based on the application rate of the irrigation system, the type of soil, the slope of the field, and also the crop type/growth coefficient. Users can communicate with the controller when needed via a mobile application that connects to the smart-link air card that communicates with telecom towers. The system automatically turns on the irrigation pump and the solenoid valves and then shuts them off when the necessary irrigation amount has been applied, thereby reducing the uncertainty for the farmer/user.

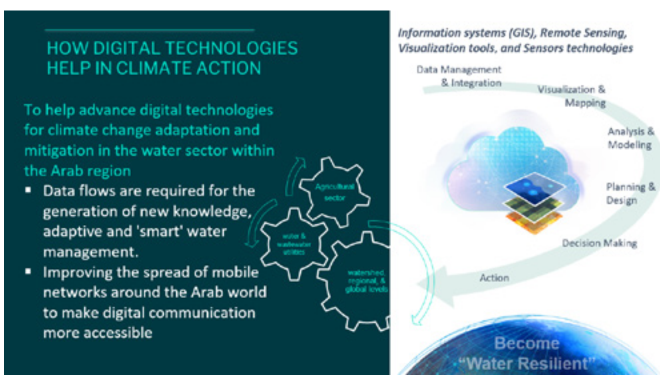
E. Case study 3 – Water harvesting at large scale

There are efforts in some countries, such as Saudi Arabia, to implement water harvesting measures and recharge depleted aquifers. One example is the Assir Dams Project Initiative conducted by the Ministry of Energy and Water in collaboration with the Amana of Assir,[43] where many dams have been constructed to collect floodwater and recharge shallow aquifers downstream for irrigation and domestic usage.[44] Most of the dams being constructed are small (with storage capacity of less than 1 million m^3). There are no rivers in Saudi Arabia, but Assir receives the highest amount of rainfall in the country. With its rugged terrain and steep slopes, the construction of dams to regulate the groundwater recharge will help lessen the impact of the increasing severity of weather patterns in the area. The dams will store flood waters that will later be released in a controlled manner to help recharge downstream agricultural wells and support water supply for local communities. The dams were constructed after a careful feasibility study that took into account the cost, location, available water supply, frequency of floods, hydrology of the watershed, number of beneficiaries, and other related factors (figure 9).[45] Out of the 81 proposed dams, as few as 10 were found to be feasible when taking into consideration the above criteria. While water harvesting is not a silver bullet, it can provide solutions in certain situations and environments.

Figure 10. Feasibility of groundwater recharge dams in Saudi Arabia



Source: H.H Jaafar, "Feasibility of groundwater recharge dam projects in arid environments", *Journal of Hydrology*, vol. 512, (May 2014).



Source: Compiled by authors.

2. Enhancing land management

The number of people in the Arab region who are food insecure is expected to rise from 51 million in 2019 to 75 million by 2030.[46] This is partially due to the rapid rise in the prices of wheat, rice and other staple foods, as well as conflict situations. Because of their direct and indirect effects, the anticipated impacts of climate change in the region are likely to worsen food insecurity risks, with low agricultural yields obtained by largely resource-poor and small-scale landholders (less than 2 ha). Low crop yields are caused by the serious problem of soil degradation, which is aggravated by the extensive use of extractive agricultural practices, with no soil restoration measures in place. Soils in many Arab countries are severely degraded by accelerated erosion and the depletion of organic matter and nutrients.

A. Impact on climate

1. RICCAR vulnerability hotspots: water available for crops

About 63 per cent of the region signifies high vulnerability for the reference period, with the remaining areas representing moderate vulnerability (figure 12). Areas with the most increased vulnerability are concentrated in the croplands south of the Assir Mountains, Sahel, the Jubba and Shabelle river valleys. Conversely, areas with moderately low exposure include lands in the northern Maghreb, the Zagros Mountains and the Levant. The cropland systems prone to climate change include wheat, maize, sorghum, potatoes, vegetables and olives, in addition to the irrigated and dry savanna agriculture, forests and grasslands.[47]

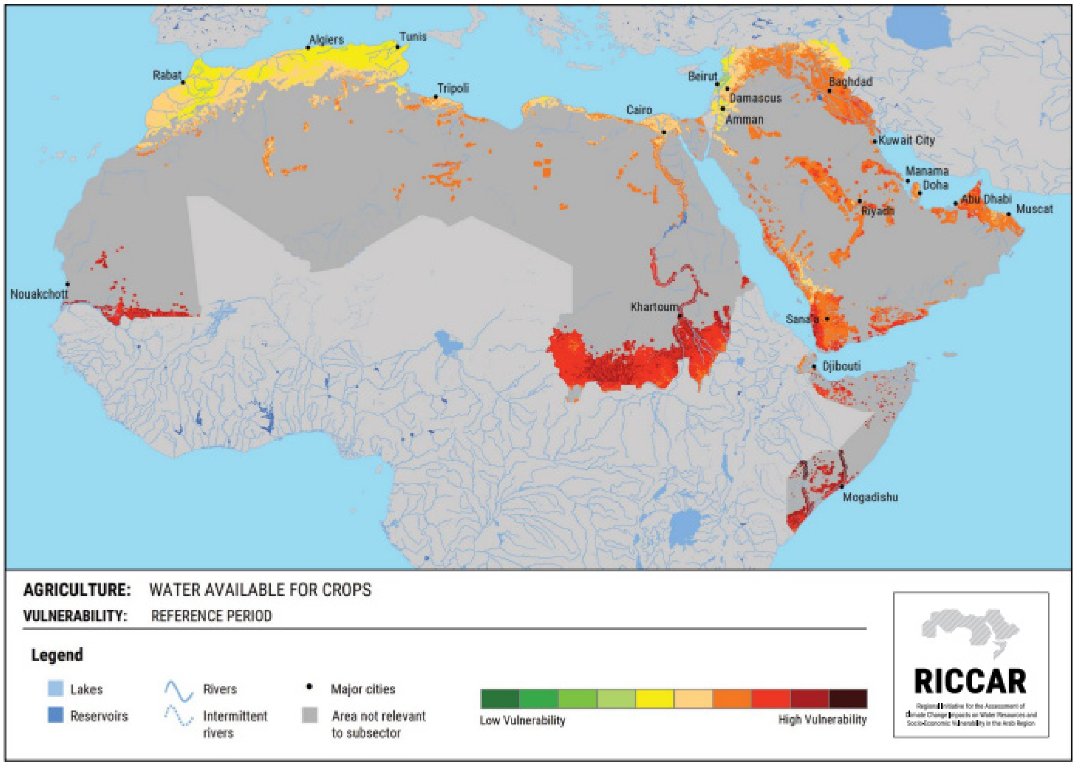
As for the ***future periods***, croplands throughout the region are expected to undergo moderate-to-high future vulnerability. At mid-century, 50 per cent (RCP 4.5) of the study area will be prone (figure 13), while 57 per cent of the area (RCP 4.5) will signify high vulnerability at the end century (table 2).

Table 2. Percentage of Arab region by vulnerability grouping for water availability for crops

Scenario	Vulnerability (Percentage of the Arab region)		
	Low	Moderate	High
Mid-century RCP 4.5	0	50	50
Mid-century RCP 8.5	0	33	57
End-century RCP 4.5	0	43	57
End-century RCP 8.5	0	16	84

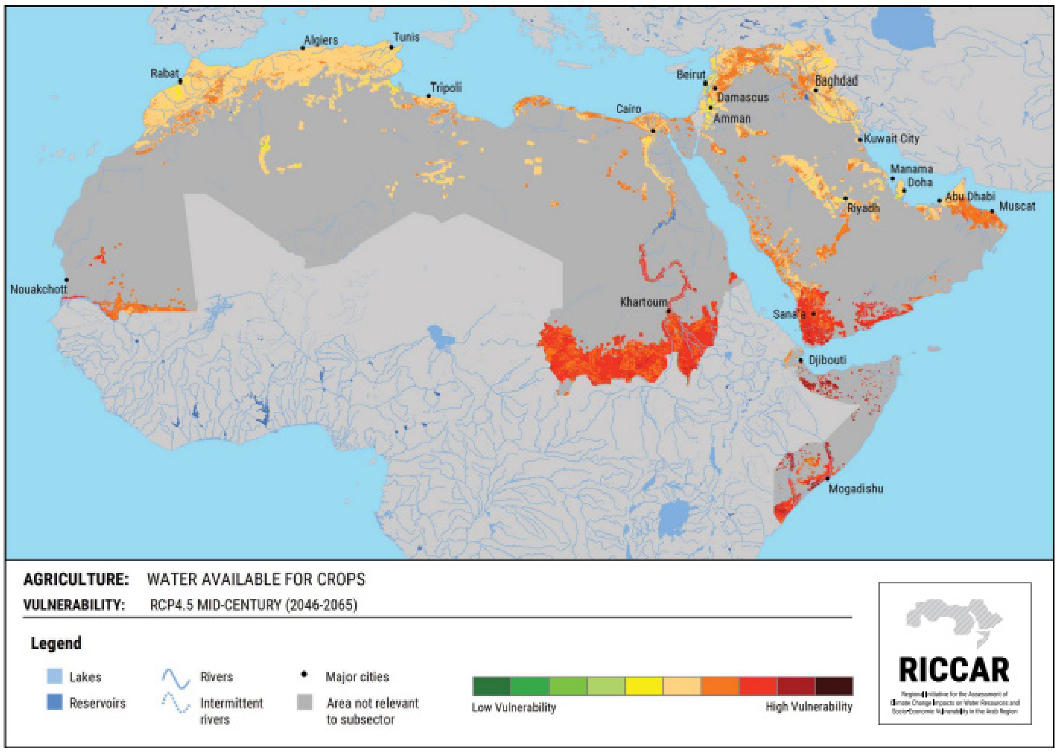
Source: ESCWA, *Climate Change Adaptation in Agriculture, Forestry and Fisheries Using Integrated Water Resources Management Tools*, E/ESCWA/SDPD/2017/Module.2 (Beirut, 2017).

Figure 11. Water availability for crops – Reference period – Vulnerability



Source: ESCWA and others, ***Arab Climate Change Assessment Report – Main Report***, E/ESCWA/SDPD/2017/RICCAR/Report (Beirut, Economic and Social Commission for Western Asia, 2017).

Figure 12. Water availability for crops – Mid-century RCP 4.5 – Vulnerability



Source: ESCWA and others, ***Arab Climate Change Assessment Report – Main Report***, E/ESCWA/SDPD/2017/RICCAR/Report (Beirut, Economic and Social Commission for Western Asia, 2017).

2. Impact of soil and land management solutions

Most sustainable land management approaches result in maintaining or growing Soil Organic Carbon (SOC) stocks, which provides synergies for tackling desertification, land degradation and drought, climate change adaptation and mitigation. SOC enhances soil health and fertility by increasing water and nutrient retention and availability to plants, which contributes to food production potential, drought resilience, climate change adaption and biodiversity. It is estimated that large-scale implementation of sustainable land management practices in all managed global soils (irrigated and rain-fed cropland, grazing lands, forests and woodlands) can theoretically amount to a net annual removal of about 1-2 Gt of CO_2 from the atmosphere over 30-50 years, offsetting a substantial part of the anthropogenic CO_2 emissions.[48]

Conservation tillage, erosion reduction, soil acidity management, double-cropping, crop rotations, greater crop residues, mulching and other practices can help recover soil organic carbon in cultivated soils. In addition, the no-till method leads to fewer losses in yield and ***reduces GHG emissions*** due to low energy consumption for mechanization, as compared to conventional farming practices.[49]

B. Climate-smart soil management for improved agriculture land

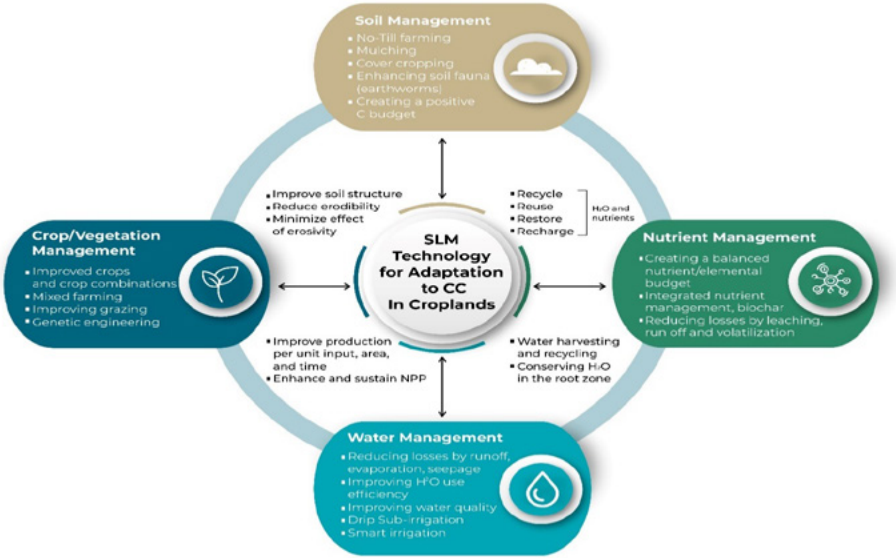
1. Definition and description

There is no single climate-smart soil and land management practice that can work on its own in adapting to climate change or even mitigating impacts of climate change. A systems approach should be followed that encompass soil, water and plants. The approach shall aim to control soil erosion (rain, wind and tillage), conserve soil biodiversity, restore soils, manage soil organic matter and improve water use in agriculture. A significant benefit of a systems approach would be to develop a resilient agro-ecological farming system that benefits productivity, food security, economics and water security.

2. Functionality

Climate-smart land and soil management is a practice specific to agro-climatic and societal contexts. Since prevailing agricultural paradigms pinpoint the conflict between high crop yields and low impact on the environmental functions, it is essential to identify an environmentally sound range of land management practices. Sustainable agriculture mainly focuses on increasing productivity while reducing the negative impacts of agricultural practices on climate, soil, water, environment and human health. Aspects such as control of soil erosion, water protection and biodiversity protection need to be taken into account to ensure productive soil, fewer chemical inputs and vital ecosystem function for climate change mitigation (figure 13).

Figure 13. Sustainable land management technologies for adaptation to climate change in agriculture. Many of these practices will help in climate change mitigation as well



Source: R. Lal, "Sequestering carbon in soils of arid ecosystems", ***Land Degradation and Development***, vol. 20, No. 4 (July/August 2009).

Approaches to help in mitigation and adaptation of land use management to climate change are:

1. **Control soil erosion:** Controlling soil erosion ensures soil health, a critical property building resilience in soil. Several practices can be conducted to prevent soil erosion, including optimizing vegetation cover, minimizing tillage or conservative agriculture, adopting rotational grazing to sustain the quality of rangelands and enhancing soil roughness by using tied ridges and clods and building windbreaks.

1. **Improve green water efficiency in agriculture:** Applying organic matter (green or animal) manure and crop residues increases water infiltration, enhances soil capacity to store water and reduces water evaporation. Other practices contributing to improved water use efficiency include rainwater harvest, no-tillage, precise irrigation, building conservative structures (dams or micro-dams) and inter-row water harvesting.

1. **Build soil carbon:** The addition of organic manure, crop rotation and intercropping with legume sequester carbon contribute to building carbon-rich soil and thus enhancing soil fertility. Decreased deforestation rates, reversal of deforestation through replanting, targeting for higher-yielding crops with better climate change adapted varieties, and improved land and water management can all help to sequester carbon.

2. Conserve land degradation: Regenerative practices such as planting trees, land shaping (e.g., contour cultivation using diversion ditches) and mulching contribute to the rehabilitation of the degraded lands. Others are reducing tillage, eliminating field burning and changing rice cultivation practices.

3. Crop variety and diversification: Selecting drought and salt-tolerant varieties and avoiding mono-cropping (crop rotation) are essential to increase crop productivity and combat low productivity.

4. Nutrient Management: Reducing fertilizer application rates, shifting nitrogen fertilizer applications from fall to spring, using variable rate technology and applying manure in place of synthetic fertilizers.

3. Feasibility

Feasibility of different land mitigation measures depends on many factors. For example, a study in an agricultural watershed in southern Italy[50] found that combining contour farming and reforestation was the most effective for erosion control, followed by no-tillage, contour farming and reforestation alone. In locations with a slope of less than 20 per cent, an analysis of the farmer return-production cost ratio (FR/PC) revealed that both conventional tillage and contour farming were economically viable (FR/PC = 1.12 and 1.11, respectively). In regions with a slope of less than 20 per cent, no-tillage obtained the highest FR/PC rating of 1.67. In steep slope zones, conventional tillage provided no economic advantage (FR/PC = 0.93). In locations with a slope of more than 20 per cent, reforestation was shown to be the most effective (FR/PC = 1.49), followed by no-tillage (FR/PC = 1.41). Another study in Bavaria designed C sequestration scenarios based on a site-specific study of current soil management, which included five land management approaches: cover cropping, improved crop rotation, organic farming, agroforestry and conversion of arable land to grassland. The five activities' combined capacity to sequester C resulted in annual increments of 0.3 to 0.4 Tg organic carbon (OC), or around 1 per cent of current SOC stocks. The study found that cover crop expansion and agroforestry are the most effective methods for increasing SOC in agricultural soils. The study recommends developing new incentive systems for agroforestry and a network of farmers and field trials that demonstrate improved soil management practices so that they can be widely adopted.

4. Challenges and suitability measures

Although sustainable soil and land management practices identified earlier bring multiple benefits to climate change mitigation, their promotion in agricultural policies is limited.[51] In addition to the inadequate policies and mechanisms to regulate soil and land management, the following challenges hinder the adoption of these solutions:

1. Absence of multidisciplinary and integrated approach to land use planning and land resource management.
2. Insufficient technical capacities and information on sustainable land and soil management practices and their impact in different ecosystems.
3. Poor quality agricultural extensions in some countries affected by conflicts.
4. Inadequate financial resources in low-income countries of the Arab region.
5. Lack of promotion of crop diversification for many reasons (markets, difficulty in management).

C. Case study: conservation tillage and conservation agriculture

1. Description

Conservation tillage (CT) is a seed-planting practice that causes the least amount of soil disturbance. Farmers plant seeds with sophisticated machinery, keeping most of the previous crop wastes (stalks or stubble, stems, leaves and seedpods) intact to keep soil in place and give organic matter and nutrients to the soil. Because the soil is covered with plant debris, this strategy helps to avoid soil erosion and conserve moisture. Conservation tillage includes minimum-till (min-till) and zero-till (sometimes known as no-till). In minimum-till, stubble is used to anchor the soil and plant residue is left on the soil surface. Zero-till operates in the same way, but with less soil and crop residue disruption.

Several field trials on conservation agriculture (CA) were undertaken in the northeast region of the Syrian Arab Republic (AL-Hassakha and AL-Raqa'a) between 2009 and 2014 as part of a cooperative development initiative between the Arab Center for the Studies of Arid Zones and Dry Lands (ACSAD) and Action Against Hunger (ACF) to strengthen the agro-ecosystems' adaptive ability to drought stress. Farmers' fields were separated into two halves, one using CA and the other using the traditional/conventional farming approach (CT). The experiments on wheat, chickpea, barley and lentil began in Syria in 2009 with the goal of determining the impact of tillage (CA vs. CT) on the performance and profitability of produced crops. The plantations occurred in a four-course rotation that was repeated four times, ensuring that each crop was present in the field each year.

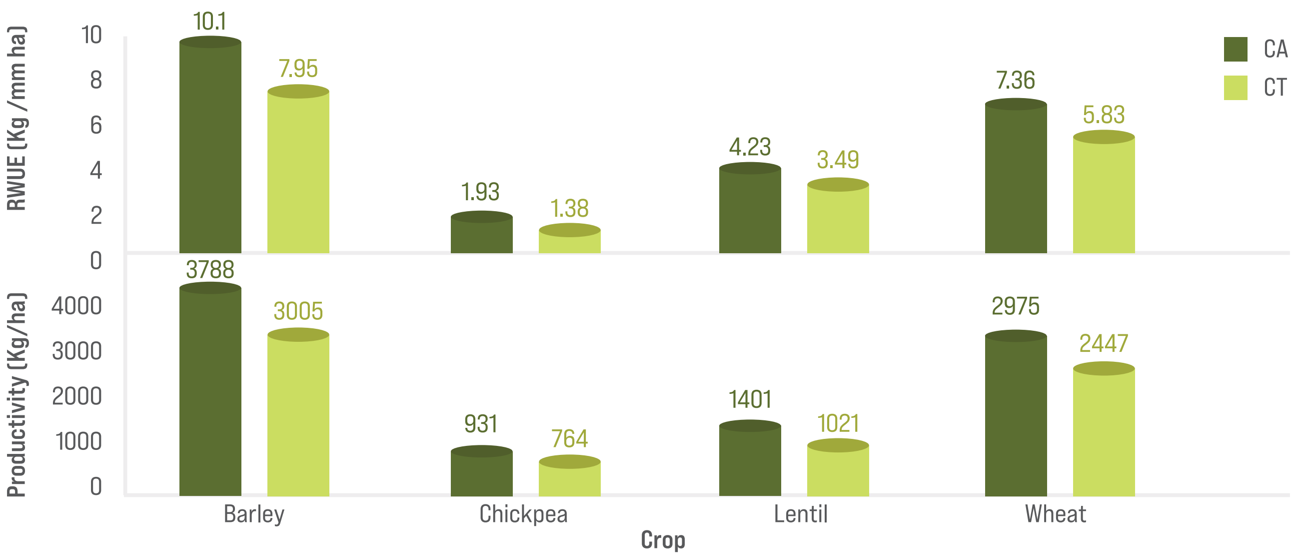
2. Benefits

- Because crop stubble is maintained in place, there is minimal soil erosion from wind and water occurs.
- The presence of organic matter and nutrients improves soil quality, resulting in healthier, more productive crops.

Drought and dry circumstances have less impact on crops because of the soil organic matter's ability to retain moisture, absorb water and distribute it throughout the soil. Crop residue from the previous year's harvest was left on the soil surface.

- Farmland emits fewer greenhouse gases.
- Farmers spend less money on labour and fuel because machinery travels over fields fewer times.
- Increase in rainwater use efficiency and productivity.
- Soil that has not been disturbed keeps soil nutrients and prevents them from escaping into ground water.

Figure 14. Productivity and rainwater use efficiency of four crop species under rain-fed conditions in the Syrian Arab Republic during the 2008-2009 growing season as affected by conservation agriculture (CA) and conventional tillage agriculture (CT)



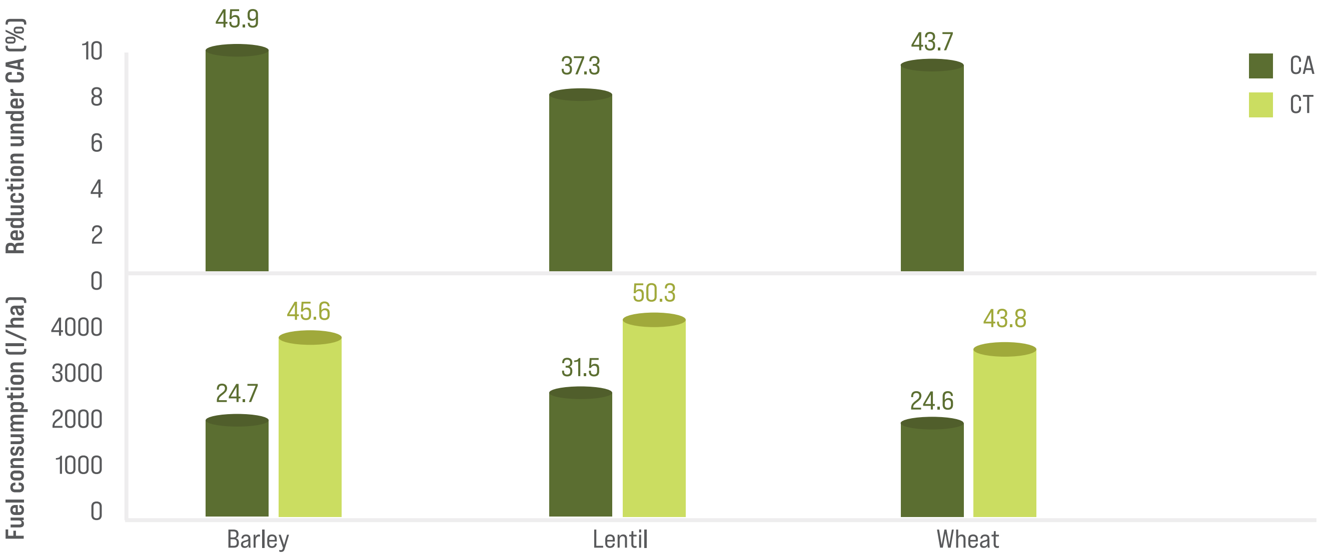
Source: I. Bashour and others, "An overview of Conservation Agriculture in the dry Mediterranean environments with a special focus on Syria and Lebanon", ***AIMS Agriculture and Food***, vol. 1, No. 1, 2016.

3. Parameters to measure effectiveness and suitability of proposed technology/practice

It has been reported that the reduction in labour can be more than 50 per cent with CA compared to conventional tillage. Also, in that study, average costs under conservation agriculture were lower than those under conventional farming by 25-30 per cent (table 3). Conservation agriculture would entail a lot of savings in energy costs that are otherwise required for tillage in conventional agriculture. Whereas the increase in yields reported in this study may not be replicated in other studies, the net benefit from conservation agriculture would still be higher than from the conventional one (on the crops studied herein), even if the yields were equal.

Improvements in organic matter and soil nitrogen have been noted (table 4), which would result in higher carbon sequestration and less nitrogen required for the next season. Organic matter increased by 10 per cent, soil nitrogen by more than 30 per cent, phosphorus by 35 per cent and potassium by 6 per cent. Measuring reductions in fuel consumption resulted in significant energy savings as well (figure 15).

Figure 15. Influence of conservation agriculture on fuel consumption for three different crops in the Syrian Arab Republic



Source: I. Bashour and others, "An overview of Conservation Agriculture in the dry Mediterranean environments with a special focus on Syria and Lebanon", AIMS Agriculture and Food, vol. 1, No. 1, 2016.

Measuring improvement in soil chemical properties:

Table 3. Economic feasibility of conservation agriculture as measured in two Syrian governorates, 2009-2014

Crop	Production costs ($ ha^{-1})		Production return ($ ha^{-1})		Outputs/inputs ratio	
	CA	CT	CA	CT	CA	CT
Barley	102.1	130.3	311.4	237.5	3.05	1.82
Wheat	108.4	141.4	337.7	263.8	3.11	1.86
Lentils	119.5	144.9	939.1	735.3	7.85	5.07

Table 4. Changes in soil chemical properties in the Syrian Arab Republic over three consecutive seasons (2011-2014) under conservation agriculture; SOM = soil organic matter, N = Nitrogen in the soil; P = Phosphorus in ppm and K = Potassium in ppm

Year	SOM (Per cent)	N (Per cent)	P	K
2011	0.91	0.05	3.46	419.5
2014	1.07	0.081	5.31	445.7

Source: I. Bashour and others, "An overview of Conservation Agriculture in the dry Mediterranean environments with a special focus on Syria and Lebanon", ***AIMS Agriculture and Food***, vol. 1, No. 1, 2016.

4. Where it can be used

A key constraint is the lack of appropriate machinery, primarily CA seeders, as well as the excessive cost of imported seeders. The problem was almost overcome in the Syrian Arab Republic by encouraging the local manufacture of CA seeders. By the end of 2011, there were more than ten local manufacturers in the country's northeast (Aleppo, Qamishli, Hassakha and Al-Raqa'a) who could build CA seeders that were as good as international ones but at half the price. Many other Arab countries, including Jordan, Iraq, Lebanon, Morocco and Tunisia, received the locally built equipment. ICARDA has been supporting the implementation of CA. To develop seed drills for use in conservation agriculture, an Australian–ICARDA project collaborated with local workshops in Jordan, Iraq and the Syrian Arab Republic. The seeders were only a tenth of the price of imported machines, costing between $2,000 and $6,000. In Jordan, where wheat production is sometimes hampered by extended drought, farmers in Irbid saw average wheat yields that were 16 per cent greater than those obtained using traditional methods, resulting in net returns of $296 per hectare. After trials showed a 19 per cent rise in wheat yields, Moroccan policymakers are considering conservation agriculture in a national drive to reverse plummeting agricultural output and stabilize yields. In Iraq, conservation agriculture's implementation developed rapidly as farmers became convinced of its benefits, from 0 ha in 2007 to over 15,000 ha now.[52]

5. How to adopt

CA-based agriculture should be promoted as a short- and long-term aim in the Middle East, and governments should integrate CA curricula in extension training and formal education. They should also help farmers learn and apply this new approach and technology for sustainable intensification by supporting the transfer of the technology to farmers, facilitating access to the necessary CA equipment and machinery, and allocating sufficient funds for research and extension programmes to help farmers learn and apply this new approach and technology for sustainable intensification.

Countries in the Arab region are encouraged to develop and implement policies that will ensure that climate change adaptation and mitigation measures are practiced in agricultural and natural land management to help control soil erosion, build soil carbon, improve soil moisture use efficiency, minimize land degradation, diversify crops and reduce fertilizer applications.

3. Enhancing livestock production

A. Climate change impact on livestock systems

The livestock sector in the Arab region contributes to food security, poverty alleviation and economic development, and provides 30-50 per cent of the agricultural output. The livestock practices are also susceptible to climate change-related impacts of dwindling water and feed resource base due to droughts, desertification and degradation of rangelands. The most vulnerable areas are located in the Nile Valley and the south-western Arabian Peninsula. The potential impacts of climate change on livestock are slight as compared to crops. However, the dairy cows are the most affected as they require the most water,[53] 89,000 to 160,000 m^3/ton over a lifespan,[54] followed by goats and sheep.

Livestock raised in grasslands production systems will be more vulnerable to climate change than those raised in a mixed system. More vector-borne diseases, parasites and new diseases will emerge among the livestock with the rising temperature and changing rainfall patterns,[55] coupled with reduced access and availability of drinking water. Feed intake, growth, reproduction, mortality and maintenance for livestock are all potentially altered by the rising temperatures. Heat stress induces behavioural and metabolic change, including reduced feed and crop residue intake, causing the livestock to lose weight and become less productive.[56] Persistent drought in the Syrian Arab Republic between 2005 and 2010 caused 85 per cent loss of animals, significantly affecting the communities relying on this as a core part of their livelihoods.[57] Interventions are needed to improve the adaptation of the water-land-livestock pillars of the agricultural ecosystem in these countries.

Furthermore, climate change will have an impact on the nutritional composition of livestock products, which are a major source of calories, proteins and critical micronutrients. To protect livestock production, climate change adaptation, mitigation measures and policy frameworks are essential.

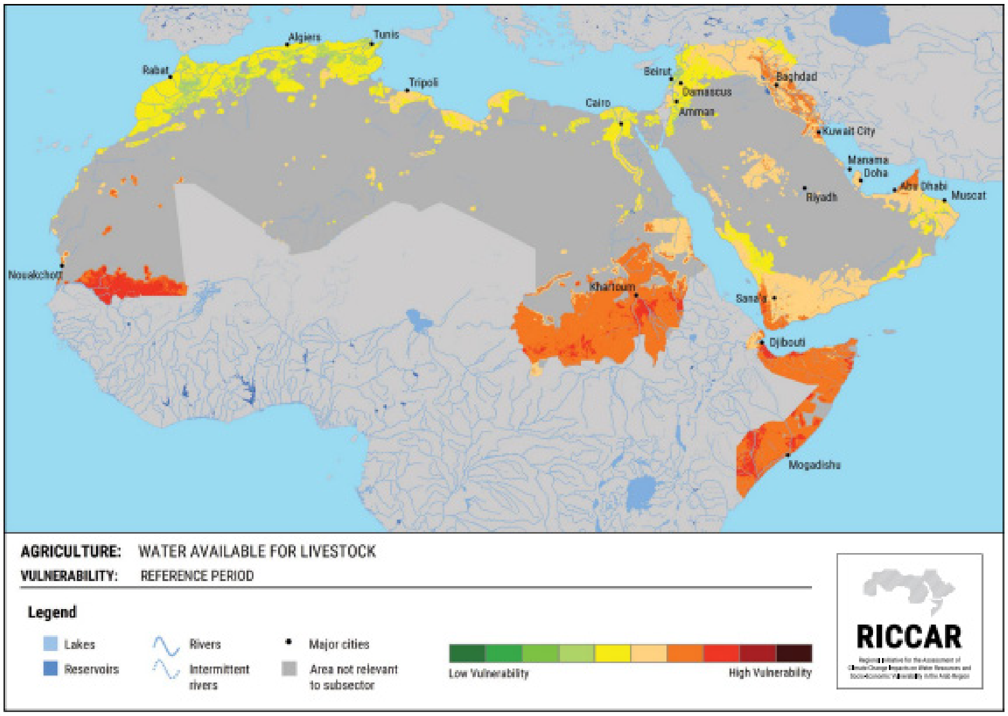
B. Impact on climate

1. RICCAR vulnerability hotspots: water available for livestock

The **reference period** signifies high vulnerability for 43 per cent of the region, while the rest represent moderate vulnerability (figure 16). The highest vulnerability dominates sections of the western Sahel, the Blue Nile River Valley just south of Khartoum, areas within the Jubba River basin, and areas along the southern Gulf of Aden coastline. Mainly, camels are impacted in the western Sahel and the Jubba River region. Cattle, goats and sheep are raised in the Blue Nile River Valley, and goats and sheep near the Gulf of Aden. In the eastern Sahel, including the Blue Nile River Valley, livestock has long been experiencing water scarcity.[58]

As for the **future periods**, the projected vulnerability related to water availability for livestock is either moderate or high. At mid-century, 33 per cent (RCP 4.5) of the region shows high vulnerability, increasing to 42 per cent (RCP 4.5) at end-century (figure 16). Areas with higher adaptive capacities have relatively lower vulnerability concentrated in the Atlas Mountains and Plains and the central Arabian Desert. Areas with high vulnerability are in sub-Saharan Africa, the upper Tigris–Euphrates basin, the Levant and the Al Hajar Mountains.

Figure 16. Water availability for livestock – Reference period – Vulnerability



Source: ESCWA and others, Arab Climate Change Assessment Report – Main Report, E/ESCWA/SDPD/2017/RICCAR/Report (Beirut, Economic and Social Commission for Western Asia, 2017).

The differences between mid- and end-century under RCP 4.5 tend to be relatively small, compared to pronounced changes under RCP 8.5, revealing increasing vulnerability. Cattles and goats will be strongly impacted by water availability, as up to 77 per cent of cattle and 72 per cent of goat populations are located in areas of high vulnerability. However, up to 67 per cent of the sheep population are primarily located in areas of moderate vulnerability (table 5).

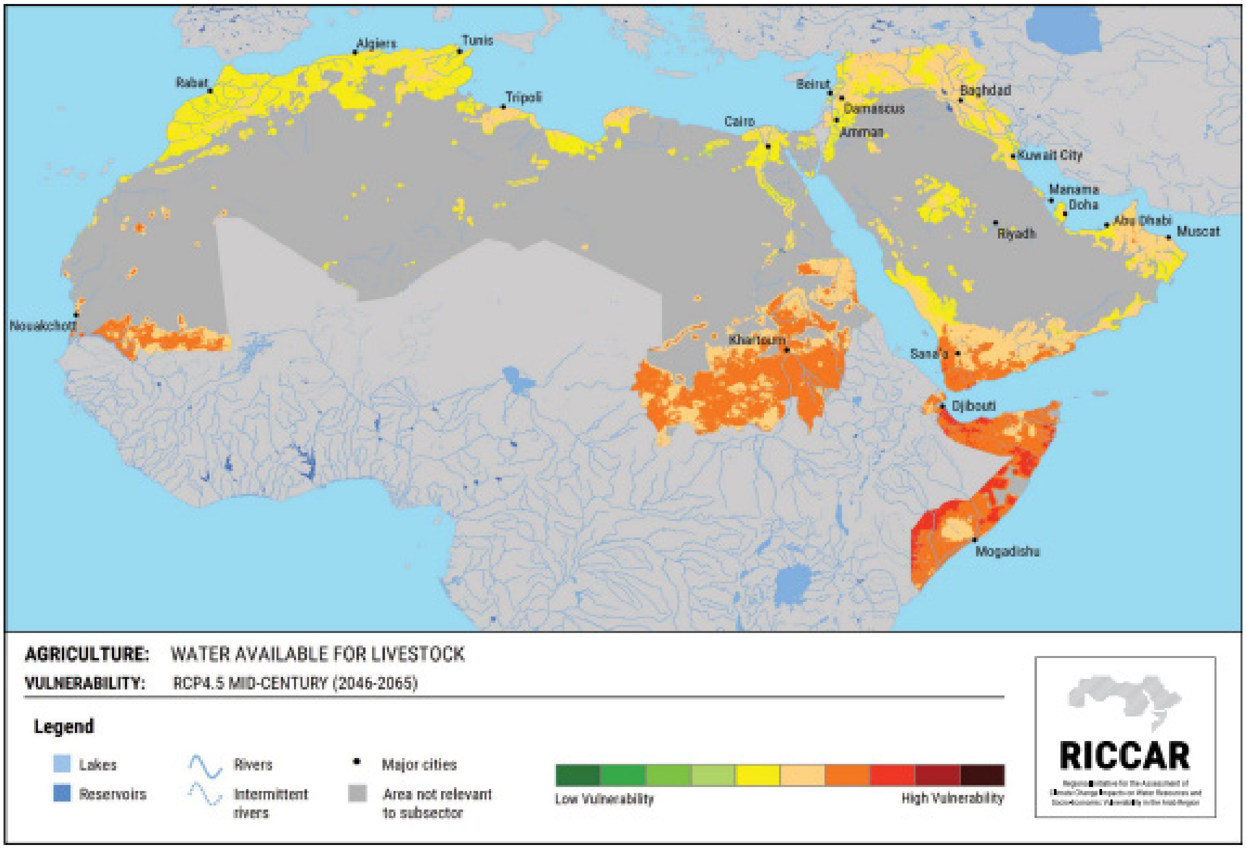
Table 5. Percentage of Arab region by vulnerability grouping for water availability for livestock

Scenario	Vulnerability (Percentage of the Arab region)		
	Low	Moderate	High
Mid-century RCP 4.5	0	67	33
Mid-century RCP 8.5	0	55	45
End-century RCP 4.5	0	58	42
End-century RCP 8.5	0	46	54

Source: ESCWA and others, *Arab Climate Change Assessment Report – Main Report*, E/ESCWA/SDPD/2017/RICCAR/Report (Beirut, Economic and Social Commission for Western Asia, 2017).

The reduction in water availability for livestock, mainly in southern regions, as well as the higher temperatures would necessitate the use of novel approaches in livestock management. Managements of pasture lands would require respecting the carrying capacity of the land, re-calculating the number of heads of cattle that can be grazed, and acting accordingly. Degraded lands should be excluded from grazing. Feed compositions should be adjusted to be more efficient in industrial systems. Energy efficient cooling mechanisms for indoor livestock should be sought whenever possible.

Figure 17. Water availability for livestock – Mid-century RCP 4.5 – Vulnerability



Source: ESCWA and others, ***Arab Climate Change Assessment Report – Main Report***, E/ESCWA/SDPD/2017/RICCAR/Report (Beirut, Economic and Social Commission for Western Asia, 2017).

C. Climate-smart solution to improve livestock productivity

1. Definition and description

Many technologies and approaches relating to climate change adaptation and mitigation exist in the livestock sector that covers aspects of animal nutrition, health and genetics.[59] Some of these adaptation measures can help in climate change mitigation as well. Also, some practices and technologies will enhance the management of both land and green water (rainfall or runoff water stored within the root zone of the plants), as the three systems (land, water and livestock) are interlinked and well connected.

2. Adaptation strategies

Diversification of livestock animals (within species), the use of different crop varieties for animal feed, and the transition to mixed crop-livestock systems appear to be the most promising adaptation measures among the studies examined.

1. **Systems for managing and producing livestock:** Diversifying livestock animals and crops, integrating livestock systems with forestry and crop production,[60] and modifying the timing and locations of agricultural operations are examples of adaptations, such as alteration of production and management systems. When livestock are exposed to temperature and precipitation challenges, diversification of livestock and crop kinds can boost drought and heat wave tolerance, as well as increase livestock productivity. Furthermore, the diversity of crops and livestock animals helps to combat illnesses and insect outbreaks linked to climate change.[61] Heat stress should be also accounted for (box 2).[62]

Box 2. Heat stress mitigation

Effects of high heat load can be minimized through: (1) adjusting the environment; (2) nutritional and watering strategies; (3) selection for thermal tolerance; and (4) change of livestock species, e.g. goats rather than cattle.

Environment The main strategies to improve heat exchange between an animal and its environment are: (1) design and construction of livestock facilities; (2) provision of shade; (3) increase of ventilation; (4) water misters, foggers, or pad cooling; and (5) using sprinklers to wet animals.

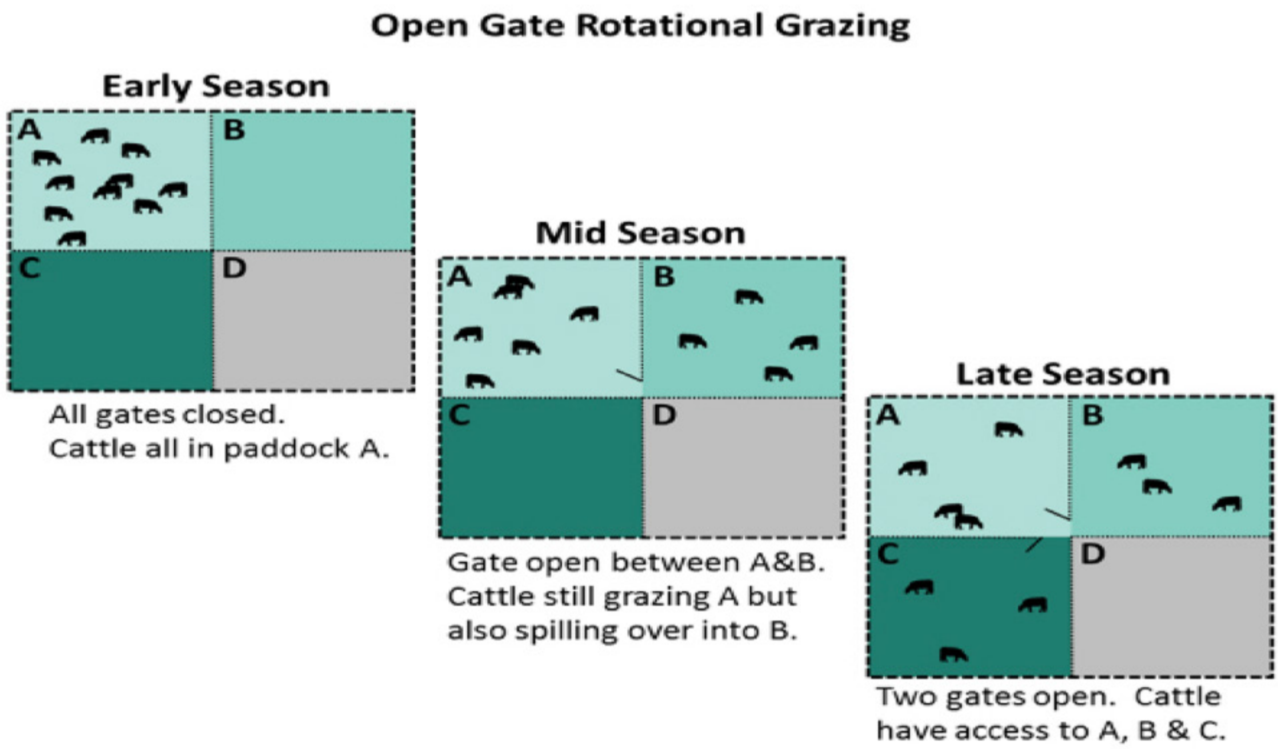
Source: Compiled by authors.

2. **Feed composition:** Improving feeding methods as an adaptation approach may indirectly improve cattle production efficiency. Modifying diet content and changing feeding time and/or frequency are some of the suggested feeding strategies. Others include agroforestry species in animal diets as well as training farmers in feed production and conservation for various agro-ecological zones.[63] By encouraging higher intake or compensating for inadequate feed consumption and minimizing excessive heat load, these approaches can help to mitigate the danger of climate change.[64]

3. **Nutrient management:** Nutrient management is key. Nitrous oxide emissions are increased when fertilizer is applied to crops. As a result, mitigation strategies, such as increasing nitrogen use efficiency, plant breeding and genetic modifications, using organic fertilizers, regular soil testing, and combining legumes and grasses in pasture areas may help to reduce GHG emissions in livestock agriculture.

4. **Grazing management:** Agroforestry (planting trees alongside crops and pastures in a mix) can help maintain the balance between agricultural productivity, environmental protection and carbon sequestration to offset the sector's emissions. Examples of other grazing management practices would be not to exceed pastureland carrying capacity by having an effective stocking rate, rotational grazing (figure 14) and excluding degraded pasturelands from livestock grazing.

Figure 18. Open-gate rotational grazing



Source: Chris Helzer, Open Gate Rotational Grazing (November, 2017). Available at https://prairieecologist.com/2017/11/21/open-gate-rotational-grazing/; Dan Undersander and others, ***Pastures for profit: A guide to rotational grazing*** (Cooperative Extension Publications, University of Wisconsin-Extension, 2002).

3. Mitigation strategies

1. **Manure management:** The storage and anaerobic treatment of manure account for most methane emissions. Even though manure placed on pasture might produce nitrous oxide emissions, mitigating methods are frequently difficult to implement due to manure dispersion on pasture.[65] As a result, most mitigation strategies include reducing storage time, improving manure timing and application, employing anaerobic digesters, covering storage, using a solids separator and altering animal diets.[66] Anaerobic digestion produces biogas while reducing methane emissions.[67] Anaerobic digesters are lagoons or tanks that keep manure in anaerobic conditions so that biogas can be captured and burned for electricity or for flare. By converting methane to CO_2, this method minimizes the potential for GHG emissions. Unfortunately, anaerobic digesters are expensive for producers. Covering ponds, tanks or lagoons, similar to digesters, minimizes emissions by trapping and eliminating methane.[68]

2. **Enteric fermentation:** Because enteric fermentation is a key GHG emitter in cattle production, improving animal diet and genetics is critical for mitigation. However, the effectiveness of these strategies in lowering emissions is unknown, and more study of effective enteric fermentation mitigation practices is needed. Enteric methane emissions can be reduced by 4-5 per cent with a 1 per cent increase in dietary fat.[69] To avoid a reduction in cattle performance, rumens must keep fat content below 8 per cent of dry matter.[70] Increased feed protein content can improve digestibility while lowering overall methane emissions per unit of product.[71]

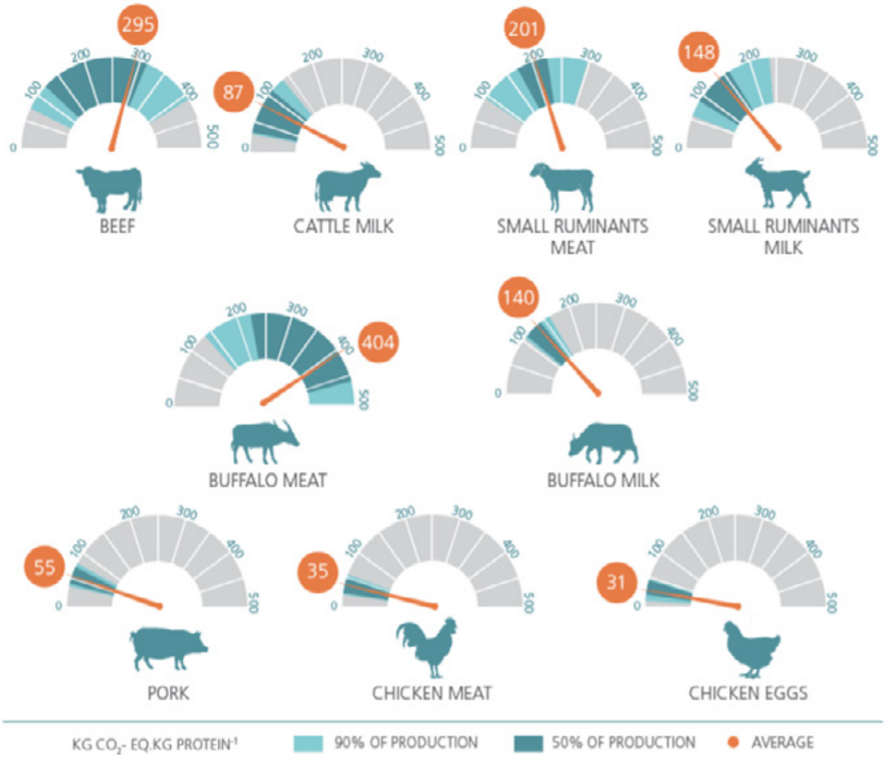
3. **Agroforestry:** Carbon sequestration can be achieved by adding trees, improving plant species, increasing legume inter-seeding, introducing earthworms and fertilizing pastures. Grass productivity and carbon sequestration in the soil could also be boosted. It is also beneficial to increase grazing pressure on grasslands when the number of grazing animals is less than the carrying capacity of cattle.

4. **Shifting livestock and crop production locations:** This approach could help to prevent soil erosion while also improving moisture and nutrient retention. Adjusting crop rotations and modifying the timing of management operations could be another adaptive approach (e.g. grazing, planting, spraying and irrigating). This indicator can be adjusted to account for changes in growing season length, heat waves and precipitation variability.[72] These measures can also work as land managementstrategies.

5. **Fertilizer management:** Because organic fertilizers do not emit as much nitrogen oxide as synthetic fertilizers, increasing the usage of organic fertilizers would reduce emissions.[73] Furthermore, fertilizer technology has advanced by controlling the release of nutrients from the fertilizer and suppressing nitrification to slow fertilizer breakdown and keep nutrients available to the plant. By integrating legumes and grasses in pasturelands, the use of synthetic nitrogen can be decreased.

6. **Shifting human dietary trends:** The majority of studies have focused on lowering GHG emissions in the livestock supply chain. However, there has been less research done on the demand side of animal product consumption. Research has shown that beef in the Arab region is the highest contributor to the total per capita-virtual water consumption (61 per cent), followed by broiler chicken (20 per cent), and sheep (17 per cent). Animal production has also increased by 50 per cent in the last decade compared to the previous one.[74] Therefore, reducing meat intake might dramatically cut GHG emissions. As beef is the least resource-efficient animal protein source and contributes a significant amount of GHG emissions from the livestock sector, a decrease in beef consumption in favour of poultry, for example, will have an effective impact on GHG emissions. Figure 19 illustrates that ruminant products, particularly meat, contribute significantly more to GHG emissions per kg of protein than mono-gastric livestock. The livestock products with the largest CO_2 emissions are beef and buffalo meat (295 and 404 per kg of protein, respectively), followed by meat from small ruminants (201/kg of protein). GHG emissions are lowest in chicken eggs (31/kg of protein).[75]

Figure 19. Contribution of animal products to CO_2 emissions (kg CO_2/kg of protein)



Source: FAO, *Climate-smart Livestock Production: A Practical Guide for Asia and the Pacific Region* (Bangkok, 2021).

4. Effectiveness and suitability

Local communities' ability to adapt to climate change and reduce its effects will be influenced by their socioeconomic and environmental circumstances, as well as the resources available to them. To be fruitful, mitigation measures, such as carbon sequestration, improving diets to reduce enteric fermentation, improving manure management, and more efficient use of fertilizers, all need public support. For example, carbon sequestration can be achieved by decreasing deforestation and replanting deforested areas, which require government legislation and law enforcement.

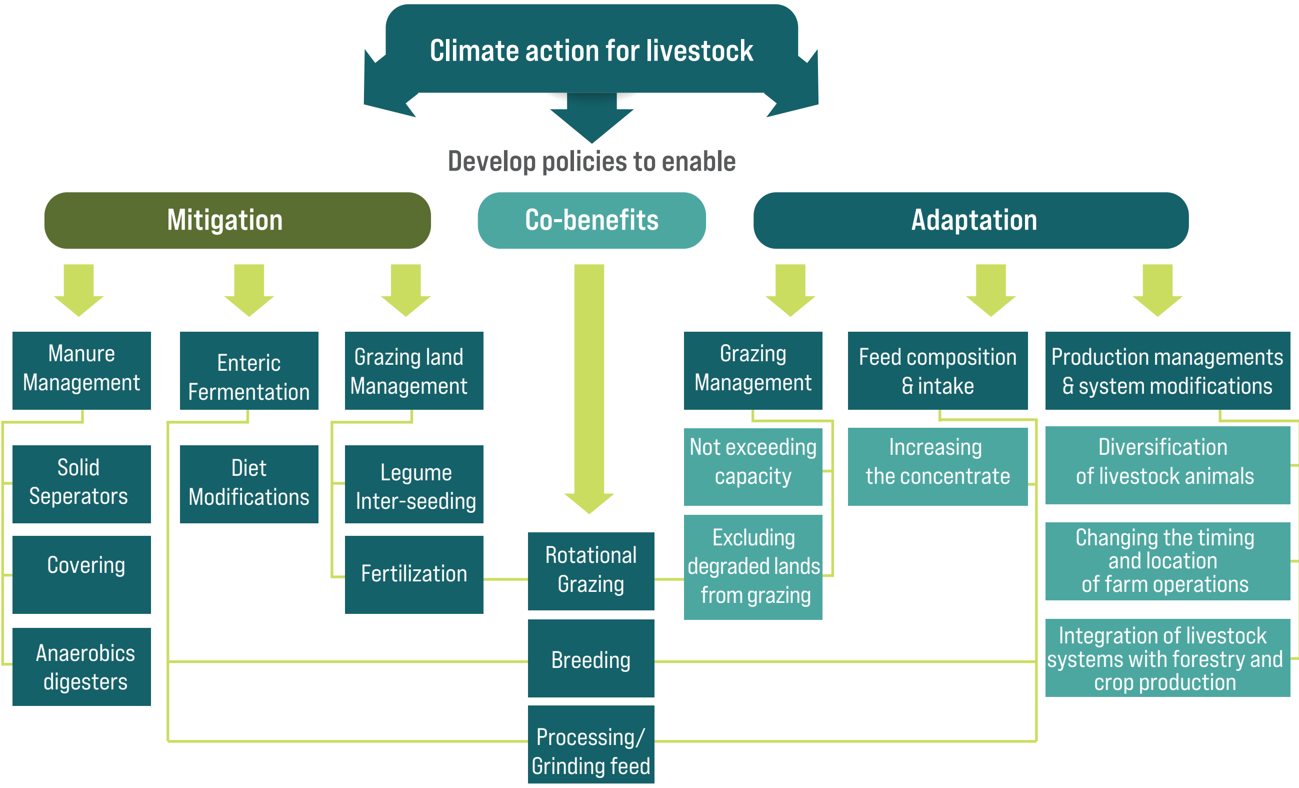
5. Impact of livestock solutions

Climate-smart livestock system management feeds into climate action by improving productivity and resource use efficiency,[76] which is key to improving rural livelihoods and food security. The suggested solution of enhancing productivity in livestock systems and ensuring the animals' longevity means that fewer animals will be required for the same amount of produce, thereby reducing GHG emissions.[77] Also, through increasing productivity, the number of under-performing animals will be decreased, resulting in more GHG efficiency at the herd level.

It is estimated that this approach can reduce GHG emissions by 20-30 per cent per unit of livestock product.[78] Animal disease surveillance, early warning systems and rapid response feed into climate change adaptation. Crossbreeding and genetic programmes produce breeds tolerant to heat and disease and have better reproductive traits than other common breeds. Many studies found that legume inter-seeding increased total plant-soil system carbon sequestration.[79] In contrast, studies show that legumes increase N_2O emissions, although the evidence is conflicting and additional research is needed.[80] Improvements in feed management integrated with breeding technologies can increase feed efficiency through developing breeds that grow faster, gain weight, or produce more quickly. As a result, feed efficiency can potentially increase farm profits and decrease GHG emissions.

Figure 20. Climate action for livestock

For climate mitigation/adaptation action in the Arab world for the livestock sector: Develop and enact policies that will foster the adoption of the following technologies:



D. Case study 1 – Using GLEAM

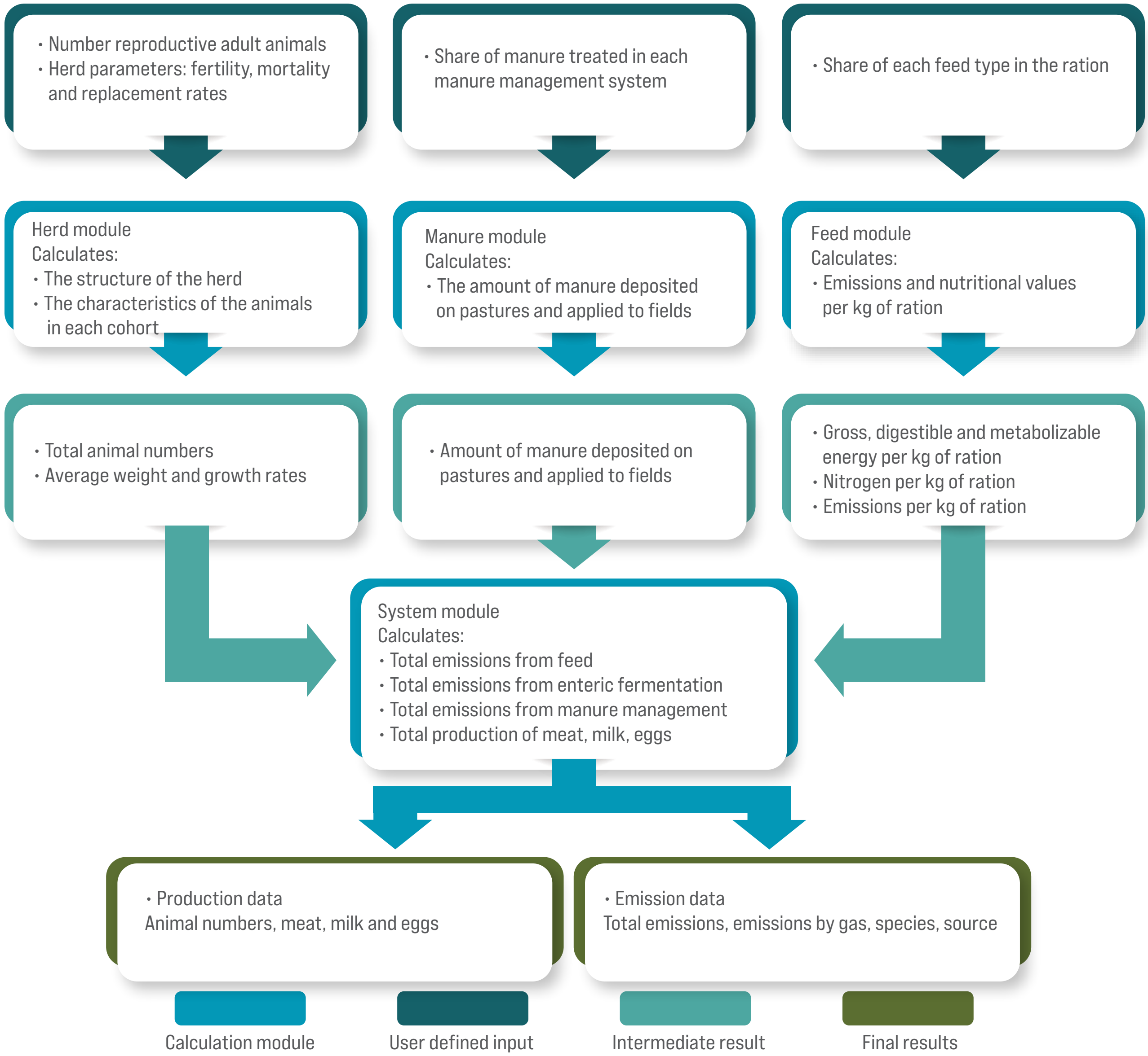
1. Description

The United Nations Food and Agriculture Organization (FAO) has created the Global Livestock Environmental Assessment Model (GLEAM) (FAO, 2020). GLEAM is a GIS-based simulation framework for analysing the impact of biophysical processes and activities along livestock supply chains. GLEAM's goal is to quantify livestock output and use of natural resources, as well as to detect environmental impacts of livestock to help evaluate adaptation and mitigation scenarios for a more resilient livestock sector.

GLEAM is a modelling system that mimics the interaction of livestock production activities and processes with the environment. The model can be used on a local, regional, national and global scale. GLEAM distinguishes critical steps in the livestock supply chain, including feed production, processing and transportation; herd dynamics, animal feeding, and manure management; and animal product processing and transportation. The model incorporates the unique effects of each step, providing a full and disaggregated picture of livestock production and resource consumption.

The GLEAM five sections include: (a) the Herd Module; (b) the Manure Module; (c) the Feed Module; (d) the System Module; and (e) the Allocation Module. GLEAM has various advantages in terms of modelling methodology. In impoverished nations, for example, geographical data on livestock distributions and crop yields allow rations to be calculated that reflect the local availability of feed supplies. A herd model is included in the Global Livestock Environmental Assessment Model, which allows livestock statistics to be disaggregated and variation in livestock performance and management to be represented.[81]

Figure 21. Required inputs, main modules and flow of calculations for GLEAM



Source: FAO, 2017. Global Livestock Environmental Assessment Model – interactive. User Guide.

2. Outputs

A complete GLEAM simulation generates a number of outputs, which can be final indicators or intermediate computations for later procedures. GLEAM 2.0 currently produces the following outputs:

- Numbers of livestock animals, production systems and spatial distribution; manure production and management.
- Feed intake, as well as the mix and quality of animal feed rations.
- Land usage and feed intake are linked.
- The production of livestock products.
- GHG emissions generated at each stage of the manufacturing process.
- Nitrogen used in each stage of the manufacturing process.
- A measure of spatial resolution.

Box 3. Where the case study happened – Mongolia

Mongolia- 57.6 per cent of Mongolian pastureland has been damaged to some extent. The Food and Agriculture Organization of the United Nations, FAO Mongolia has been working on the project "Piloting the Climate-Smart Approach in Livestock Production Systems" since December 2018. In three different cattle production systems, the project uses climate smart livestock techniques in three livestock production dimensions. Demonstration of low-carbon fodder irrigation techniques utilizing solar photovoltaic cells, reduced N_2O emissions through improved manure management, and lower CH_4 emissions from enteric fermentation are all expected outcomes of the research. These reductions will be aided by improved animal husbandry practices, improved feeding strategies, improved dry season feeding and improved pasture management with smaller, more productive herds.

After project completion in 2021, preliminary results from the GLEAM analysis show a considerable reduction in GHG emissions, on average -21 per cent for CH_4, -21 per cent for CO_2, and -15 per cent for overall GHG emissions.

Source: FAO, *Climate-smart Livestock Production: A Practical Guide for Asia and the Pacific Region* (Bangkok, 2021).

3. Where to be adopted

GLEAM is designed to be applied globally in any livestock system. FAO reports that six realistic case studies in selected locations and cattle production systems were used to construct a modelling effort using GLEAM. In South Asia, it was employed in mixed dairy production. In East and Southeast Asia, it was also utilized in commercial pig production. GLEAM was also used in the production of specialty beef in South America and small ruminant farming in West Africa. It was also used in East Africa for mixed dairy production. Therefore, GLEAM can be adopted in any Arab country.

4. Feasibility

GLEAM was used to assess mitigation strategies that were chosen based on their prior mitigation potential, how much they apply to specific geographies and systems, expected economic feasibility and positive productivity implications, as well as potential trade-offs with other environmental issues. The mitigation was mainly focused on improving feed quality, grazing management, preventative health measures, breeding methods, animal waste management, and energy efficiency at various levels of the livestock supply chain.

Each of the species, systems and areas studied had a mitigation potential ranging from 14 to 41 per cent. In Asia, Latin America and Africa, ruminant and pig production systems were estimated to have comparable strong mitigation potentials. The modelled actions, on the other hand, may result in a simultaneous reduction in emissions and a rise in output, which helps food security. GLEAM is useful to assess the mitigation potential of livestock practices relevant to climate change. GLEAM is free. However, as all other tools, it requires training.

E. Case study 2 – Solar cooling for milk – Tunisia

1. Description

The solar milk cooling system is a cutting-edge device that uses only renewable energy to cool milk on the farm. The system is composed of:

1. Traditional 40-litre milk cans.
2. Ice chamber.
3. Detachable insulation.

The ice is made using a solar-powered freezer that collects solar energy through an adaptive control mechanism. The system components are as follows: photovoltaic panels, small batteries, an adaptive control unit, a charge controller, and a small refrigerator with an integrated fan. There are 25 two-litre plastic cans for the ice blocks (figure 22)[82].

Using ice as a cooling medium, the device can cool 30 litres of milk. This allows for adjustable milk cooling on the farm or during transportation. Milk cooling is a vital stabilization procedure, but it consumes a lot of energy in the dairy industry.

Figure 22. Solar milk cooling in Sidi Bouzid – Tunisia

Source: F. Mrabet and others, "Solar Milk Cooling: Study case Sidi Bouzid, Tunisia" (Institute of Agricultural Engineering, Tropical and Subtropical Group University of Hohenheim, Germany, n.d.).

2. Feasibility

The dairy industry in Tunisia is a strategic and vital industry constituting 11 per cent of the agricultural sector production value. The system was tested in seven small farms in two regions: Zitouna and Hania, Sidi Bouzid Tunisia, where there are 10 milk chilling systems that were built and tested. Milk is collected twice a day on average. Typically, the collector brings the milk to the collecting centre at a temperature of 30°C, where it is immediately pumped to the refrigeration facilities and cooled to 4°C. The milk from some farms is frequently rejected by the collector because it has soured in the interval between milking and the collector's arrival. The use of a solar milk cooling system has resulted in significant improvements in thermal conditions and milk quality during transportation and overnight storage.

3. Climate change mitigation-adaptation impact

The milk arrives at the collecting centre two hours later, at a temperature of 15˚C instead of 30˚C, thanks to the solar milk chilling technology. The energy required to cool 1 litre of milk from 30˚C to 4˚C (assuming a heat pump with a mean coefficient of performance of one) is roughly 0.03 kilowatt-hour (Kwh) per litre. The amount of electricity required for this system would be lowered to 0.013 KWh/lit, a reduction of 0.017 KWh/lit. Because power in Tunisia is cheap (EUR 0.06 per KWh), it may not be economically feasible to utilize a solar system to save energy. However, when carbon emissions are taken into consideration, the solar milk cooling system will save 9.7 grams of CO_2 equivalent per litre, based on the country's electricity emission factor (0.572 kg of CO_2 equivalent per KWh).[83] The system will help in rural areas in other Arab regions where power is expensive/not available (such as Lebanon, the Syrian Arab Republic and Yemen).

4. Cost and pay-back period

The overall cost of the system is roughly EUR 2,700. The cost of one litre of milk in Tunisia is EUR 0.25. The innovation's payback period would be determined by the amount of milk refrigerated and sold per day. Assuming a 14.5 litres per day sales, the payback period would be about two years. The solar cooler could be shared by a group of farmers because it has a maximum capacity of 60 litres each day. Each farmer might be able to have his or her own milk cans. As a result, the system's expenditures will be shared among the small farmers, and the payback period will be shortened.

Conclusions

Given the benefits of digital agriculture for productivity, food security, economic growth, water security and climate change mitigation, stakeholders from the Arab countries should collaborate to mainstream innovative agricultural technologies and share best practices. It is critical to continue to investigate the extent and scale to which these technologies in the Arab world can contribute to food self-sufficiency, as well as how and for how long this can benefit human well-being.

Climate action is much needed to alleviate the impact, especially for the agriculture sector. The use of appropriate, affordable and directed technology is a mean to implement these actions among others. However, it requires financing and capacity building, as well scaling up good and positive experiences amongst the many smallholder farmers, who are a majority in the region.

Consumers, producers, stakeholders and decision makers must be targeted for capacity building through intense knowledge, mentorship, management and extension services. Specific proposals in this respect include, for example, the use of scientific information in agricultural practices, which provides incentives for farmers who use mobile applications that offer data on irrigation requirements in near real time, such as AgSAT.

Raising awareness of the added value of adaptation technologies and mitigation measures for climate change in agriculture across various groups through media campaigns and consultative sessions would be critical to encouraging adoption. This can be accomplished in particular by:

1. Increasing small-scale growers' access to investment and extension services.

2. Improving herbicide and pesticide application efficiency.

3. Providing discounts and free training on the necessary grey/blue water footprint technologies of agricultural and food systems along the entire value chain to encourage irrigation system automation.

4. Sharing effective lessons and experiences, including farmer-to-farmer knowledge exchanges.

5. Opening vocational training for technologies and practices.

6. Highlighting success stories and pilot projects.

7. Supporting climate change mitigation research programmes and targeted innovation and entrepreneurship.

Emissions from other value-chains in agriculture also need to be addressed. Examples could be reducing emissions in post-harvest[84] during transport. Finally, scaling up technologies in agriculture remains a challenge in the Arab region. Building awareness among diverse groups, such as women and youth, will add value and promote adaptation technologies as a necessary, if not essential, practice for the future of agriculture in this region. In this regard, it is critical to include youth – the farmers of the future – in all of these activities. Women's and men's responsibilities, as well as how they will be affected by climate change, should be considered in adaptation and mitigation plans. Climate change provides a clear opportunity to reconsider gender inequity and involve both men and women in developing innovative solutions to common environmental problems.

If Arab governments wish to address climate change and livestock production with effective adaptation and mitigation methods, there is a need to scale up these technologies through policy making and legislation. Understanding farmers' perspectives and incorporating them into policy development, for example, can help mitigate and adapt to climate change by encouraging wider adoption of best practices. In order to maintain sustainable production systems, the policy framework should also incorporate a full understanding of the costs, time and effort required from the producer. In addition, technologies should be appropriate for the region and/or country in which they are suggested.

Policies should also facilitate coordinated cooperation between Arab countries at the political, institutional and technical levels to leverage existing platforms and knowledge for assessing and addressing the impact of the suggested technologies on climate vulnerability and to examine their scalability and affordability in different socioeconomic and natural ecosystems in the region. Countries should work together and individually to develop technical and administrative solutions to provide for the best and most efficient implementation of climate change adaptation and mitigation measures to protect the freshwater resources and ensure the sustainability of climate-action related practices within the water, land and livestock sectors.

Dedicating adequate financial resources for investments in climate proof solutions for sustainable livelihoods would make policies more effective and easier to implement. Arab countries should work to develop national adaptation plans for climate change. National policy dialogues should be strengthened to create relevant legislation and regulations. Developing countries that suffer from poverty, conflicts and refugee crisis should have access to more financial resources from the international community.

Policymakers in countries of the Arab region should thus establish an atmosphere that encourages adaptability and resilience. This can be accomplished by improving farmers' access to information, credit and markets, and by enacting appropriate policies and regulations, with a special focus on small-scale holders who are the most vulnerable to climate change impacts.

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The green revolution failed to achieve the United Nations Millennium Development Goals of halving hunger by 2015 in water-scarce regions, such as the Arab region. Most of this region is characterized by limited arable lands, poor renewable water supplies and semi-arid or arid climatic conditions. High population growth rates and increasing urbanization are putting a strain on natural resources at a time when food demand is on the rise. The region's small and fragile natural resource base, as well as diminishing productivity, severely limit the food supply, making it highly reliant on imports and subject to increases and volatility in international food costs, as well as other externalities.

This document is intended to guide countries on adaptation and mitigation benefits from technologies and practices that can be applied to enhance water and land management and livestock production for a more resilient agriculture sector.

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