Agriculture and natural resources

Current status

Characteristics of agriculture in the Arab region

Agriculture contributes significantly to regional GDP and exports and to per capita incomes. Region-wide, agriculture accounts for $95 billion of value added annually, with agriculture adding more than $10 billion annually to GDP in Egypt and Morocco. Food exports ($20 billion annually, 4 per cent of total regional merchandise exports – and more than 10 per cent in Jordan and Egypt) make a considerable contribution to the economy of many Arab countries. Agricultural GDP per head of the agricultural population averages about $720, ranging from $133 in Yemen to $1,100 in Tunisia.[1] With modernization and urbanization, agriculture's share of the region's fast expanding economies has been declining, but the sector is still growing in absolute terms. Nonetheless, the sector remains key to primary production and is the mainstay of the rural economy. Overall, agriculture contributes 13 per cent to regional GDP, and considerably more in some countries, ranging from 2 per cent in Jordan to more than 20 per cent of the total in the Sudan and the Syrian Arab Republic (table 4.1).

Table 4.1. Key facts on agricultural contribution to GDP in $ and per cent share

Agricultural value added in $	*Agricultural value added as a per cent of GDP*
Agriculture contribution to GDP in $: ▪ >$10 billion annually: Egypt, Morocco, KSA ▪ >$2 billion annually: Sudan, Algeria, Syria, Tunisia, Yemen	Agriculture share in GDP: ▪ >20 per cent: Sudan, Syria ▪ >10 per cent: Egypt, Mauretania, Morocco ▪ >5 per cent: Algeria, Iraq. Tunisia, Yemen

Source: Aquastat.
Note: Figures are for 2014 and 2015, depending on availability.

Food production including trends over time was described in Chapter 1 Part I. There it was seen that production in the Arab region, measured in metric tonnes, has been stagnant in most food commodities. Even in the commodities for which there has been significant increase in production, those increases did not keep pace with the increases in domestic demand (consumption).

Rural areas and agriculture remain very important in most Arab countries, and 38 per cent of the region's households are still engaged in farming. Despite the pace of urbanization, there are still about 170 million rural people in the region. Of the total economically active population of 126 million, 48 million (38 per cent) are engaged in agriculture, ranging from under 5 per cent in Lebanon and the Gulf states to over 50 per cent in Sudan. Rural population growth rates – 1.6 per cent a year 1990-2004 - are high, and the rural population is expected to continue growing at over 1 per cent through to 2030.[2]

Regional farming systems are diverse, varying by geography, climate and natural resource endowments (table 4.2). Rainfed farming systems still predominate in many countries, covering 55 million hectares, more than two thirds of the region's cultivated land. Rainfed farming, largely growing cereals, provides livelihoods for nearly two thirds of the agricultural population region-wide, and produces more than half of the value in the region's agriculture. Rainfed farmers face particular challenges of low productivity and unpredictable rainfall, challenges which are growing as climates change.

Table 4.2. Principal farming systems of the Arab countries

Farming system	*per cent of the region's*		*Main livelihoods*	*Prevalence of poverty*
	Land area	*Agricultural population*		

Irrigated	2	17	Fruit, vegetables, cash crops	Moderate
Highland mixed	7	30	Cereals, legumes, sheep, off-farm income	Extensive
Rainfed mixed	2	18	Tree crops, cereals, legumes, off-farm income	Moderate
Dryland mixed	4	14	Cereals, sheep, off-farm income	Extensive
Pastoral	23	9	Camels, sheep, off-farm income	Extensive
Arid zones	62	5	Camels, sheep, off-farm income	Limited

Sources: FAO 2001 and World Bank 2013 (data refer to years between 2010 and 2012)

Rainfed farmers typically practice a mixed farming system with a balance of production for own consumption and for market. As precipitation falls over most of the Maghreb and Mashriq in winter, rainfed crops are grown in the winter months, maturing for harvest generally in spring and early summer. The main rainfed crops are wheat, barley, legumes, olives, grapes and fruits and vegetables. Grain production accounts for two thirds of the cultivated area (against a world average of 46 per cent). Yields for rainfed crops vary widely, depending on the farming system, but are generally below world averages. Livestock are integrated in all rainfed farming systems, providing important synergies and complementarities between and within systems – from extensive pastoralism to feedlots in peri-urban agriculture. Diversification of production between cereals, other field crops, tree crops and livestock allows both for risk management and for complementarity between enterprises, for example between livestock and fodder production or crop residues, and between livestock and fertilization. For rainfed farmers, the principal prospects of growth are access to water and to profitable markets. Even small additions of supplementary irrigation water from water harvesting, springs or seasonal flows make large differences to yields.

Rainfed agriculture is a crucial source of income for the region's poorest. Poverty in rural areas is widespread and this translates into food insecurity and malnutrition. Overall, 34 per cent of the region's rural population are poor (compared to about 25 per cent for the population overall), ranging from 8 per cent in Tunisia to over 80 per cent in Sudan. Rural unemployment is high, averaging about 13 per cent, with higher rates for women than men, and much higher rates for youth – 26-53 per cent depending on the country Poverty affects certain parts especially in the poorest nations of the region and hurts high risk categories like women-headed households and the landless. Rural poverty is particularly acute in certain parts of the region and under certain specific conditions and is chronic largely for specific countries and vulnerable segments In the poorest nations of the region - Yemen, Sudan, Mauretania - rural poverty is chronic and widespread. Elsewhere, rural poverty mainly affects three high risk categories: households headed by women, the landless, and farm labourers.[3]

Irrigated systems occupy less than one third of the cultivated area (24 million hectares) but contribute almost half of agricultural value. Because of the generally arid climate, there is a high level of development of water resources for irrigation and relatively high levels of performance in agricultural water management. Irrigated areas are cultivated all year round, with peak demand for irrigation water during the dry summer months. Under irrigation, yields can be very good, with yields of irrigated wheat in Egypt for example averaging 6.5 t/ha. A wide range of higher value crops is grown. Fresh fruit and vegetable production accounts for about 10 per cent of the cropped area region-wide, but for a much higher share in countries practicing intensive irrigated agriculture (Egypt 20 per cent, Jordan 28 per cent, Lebanon 37 per cent) – and very much less in the largely subsistence agricultural economies of Sudan (1 per cent) and Somalia (1 per cent). Irrigated agriculture is market-oriented and commercialized, responding to fast-growing demand from urban and export markets for higher value products. However, shortfalls persist in irrigation efficiency and in crop water productivity.[4]

Livestock and fisheries

Livestock are integrated in all farming systems and extensive pastoral systems are practiced across the region's more arid zones where cropping is not possible. Livestock keeping contributes to the livelihoods of millions of rural communities. Pastoral production is the most important farming activity throughout the semi-arid and arid rangelands of the region, making use of the scarce feed in the predominantly arid lands to convert them into nutritionally and economically valuable products. Although these systems are traditionally resilient, climate change is leading to growing aridity and will progressively reduce the potential of this system and lead to exit from the worst affected areas. Almost all countries of the Arab world have supported these systems but often with negative effects as policies promoted expansion of livestock numbers without attention to the carrying capacity of the land or to the institutional mechanisms to ensure sustainability. As a result, rangelands have been largely degraded leading to loss of biodiversity, soil erosion and a decrease in their carrying capacity.

Mixed systems constitute the largest portion of the sector where livestock are integrated into mixed farming systems and contribute significantly to household nutrition and finances. There is also a substantial modern livestock sector with intensive and semi-intensive production of meat, poultry and milk. As production of fodder and feed are heavily constrained by limited water resources, this segment places heavy reliance on feed imports estimated at US$10.4 billion (for only four major feed ingredients in 2012).[5]

As demand for livestock products is increasing in the Arab region driven by the growing population and incomes, there is enormous potential for import substitution, in addition to the effects on nutrition and incomes at the household level. There is also an important potential for further intra-regional trade, with very high levels of imports in the GCC countries.[6]

Fisheries and aquaculture make a significant contribution to food security and livelihoods of millions of people along the seashores and waterways of Arab countries. Collectively Arab countries have more than 23,000 km of shoreline and access to two oceans, three major seas and adjacent gulfs. The region also has 16,600 km of rivers, fresh and brackish water lakes and reservoirs. In 2013 its total fish production was estimated at 4.1 million tonnes from capture (2.9 m.t.) and from aquaculture (1.2 m.t.). However, the average per capita fish supply from all sources - local production plus imports less exports - is only about 11.3 kg/ annum while the current international average of fish consumption is around 20 kg/ per annum. Particularly important for both incomes of the poor and for production are the small/rural or artisanal fishermen and fish farmers who contribute consistently to the seafood supply chain, but do not have the capacity to optimize their farming or fish catch.[7]

Policies and incentives for agriculture

Policies in Arab countries have been consistently pro-agriculture and pro-rural areas, but with significant evolution over time. Until twenty years ago, state-led development policies were generally pursued, characterized by heavy investment in public goods like research, extension and rural infrastructure and in promotion of irrigated farming. These policies were often accompanied by guaranteed prices and public procurement and by public sector involvement in food storage, distribution and pricing.

Although these policies were generally successful in developing agriculture, some components introduced structural distortions in the sector which reduced its resilience and sustainability, and some of these distortions persist. These policies and distortions affected natural resource allocation and management, notably over-allocation of water to agriculture, lack of demand management through pricing or rationing which led to reduced water use efficiency, and lack of regulation of groundwater extraction which led to depletion of the resource. In addition, food self-sufficiency policies promoted production of lower value food crops with negative impacts on land and water resources and with an opportunity cost to both households and the national economy, as they reduced incentives to diversification and production of higher value crops.

Recent years have witnessed a move away from these policies towards a more balanced two-part approach. Most countries have developed a high value, often export-oriented, agriculture sector in which investment, production and marketing are private activities, underwritten by a legal and regulatory framework supporting private sector investment and controlling public good aspects such as water use. These developments have been supported by trade deals, particularly those that have given access to the rich markets of the EU and the Gulf. At the same time, most countries have also protected the critical role of smallholder agriculture in livelihoods by maintaining rural development programmes and some measure of support to agriculture, primarily through research, extension, investment support (e.g. in irrigation development) and input supply. In many countries, considerable progress has been made towards integrating these 'two agricultures': for example, Morocco's *Plan Vert* is designed to progressively bring smallholders into market-oriented production. Moves towards increasing smallholder participation in the financing and management of public irrigation schemes have also helped to increase efficiency and reduce state involvement and expense.

Recently, countries in the region have also come to a more integrated appreciation of agriculture's role in the economies, ecologies and societies of the region. These new perspectives include recognition of the value of conserving ecosystems and of the environmental services provided by rural areas, such as water infiltration and soil conservation, as well as recognition of socio-cultural services such as cultural heritage or traditional agriculture.[8]

Productivity and production responses

These policies have been generally successful in developing high value commercial agriculture and in sustaining smallholder livelihoods. Agriculture in the NENA countries has become predominantly market-oriented and commercialized, responding to fast-growing demand from urban and export markets for higher value products. In the Mediterranean countries, market linkages with demand from Europe and formal trade arrangements with the EU have provided profitable market outlets for fresh fruit and vegetables. In many countries the agricultural sector is still growing in absolute terms. The last 25 years have witnessed a strong average growth rate of 2 per cent per annum in agricultural value added, attributable to more intensive irrigation systems, particularly the spread of pressurized drip and sprinkler irrigation and to an increase in production of higher value crops. Growth has been in both high value products and in food production. In five countries of the region (Jordan, Kuwait, Morocco, Tunisia, Syria), agricultural growth averaged more than 4 per cent per annum growth over two decades 1990-2011. High growth rates have occurred predominantly in countries using modern irrigation and moving to high value exports (regionally and to the EU). In recent years, cereals production has also accelerated, with improvement in the terms of trade for cereals, and livestock production has also expanded fast. In addition, many households have diversified into related off-farm business lines such as catering, tourism etc. [IFPRI 2010]

However, not all countries have shared in this growth. In some countries, productivity improvements have virtually ceased, as access to improved technologies and support services has dwindled (for example, in Yemen, Somalia, and Sudan). Within countries, productivity enhancements for smallholder systems, particularly where irrigation is not possible, have proved few and far between. Research has made a substantial contribution, but has not focussed adequately on vulnerable production systems or on more efficient use of water. [IFPRI 2010]

Natural resource constraints are growing, exacerbated by climate change. Water use in agriculture is becoming a binding constraint in many locations. Water resources are already over-allocated and pressure on water resources is expected to grow as populations continue to expand. Environmental pressures are growing: groundwater is being overused, in-stream environmental flows have diminished, and rangelands have come under considerable stress.

Rebalancing towards private enterprise was accompanied by a decline in public investment – the net average public investment in agriculture across the region dropped from $6.1 billion annually 1986-90 to $1.9 billion 1996-2000. In addition, terms of trade in some countries remain unfavourable to agriculture, for example in Egypt and Tunisia, and there is scope to remove remaining constraints and improve incentives. This would foster further growth.

Agriculture and food security

Agriculture's contribution to food security is vital in four ways: it provides foodstuffs for domestic consumption; it provides food for consumption for poor smallholders and pastoralists as well as produce for sale that generate cash income for the household; it provides revenues for commercial scale farmers and hence incomes that assure food security for farmers and farm employees; and it generates or saves foreign exchange that can be used to finance food imports.

As discussed earlier in this paper, in most Arab countries this contribution of agriculture combined with all other relevant policies has worked fairly well. The region has amongst the world's lowest proportion of undernourished people, the lowest prevalence of underweight children, and the lowest under-five mortality rate of any non-OECD set of countries, and has registered significant improvements in recent decades. However, the picture is not uniform across the region, particularly in rural and remote areas and in the poorest countries. Nutrition status is worse in rural areas and far worse in the very poor countries. In some poorer countries and remote or very poor parts of middle income countries, markets are often imperfect and households lack the income or information needed to maintain adequate diets. The poorest countries are particularly at risk. The high rate of chronic malnutrition and stunting in Yemen is a witness to this problem. Most at risk are rural non-farm households which spend a higher share of their income on food, making them more vulnerable to price surges. The periodic catastrophic famines in Sudan bear testament to the more general systemic food security risk of poor countries dependent on a fragile natural resource base, poorly developed markets, and institutional environments which hinder both development and relief operations. In addition to these structural problems, the shocks of 2008 have provoked a reflection on whether there are better ways to organize food markets. [IFPRI 2010]

Agriculture, food security and food self-sufficiency

It is important to note that no Arab country approaches self-sufficiency in cereals, and most Arab countries in fact import a large share of their food needs. Only four countries - Egypt, Iran, Morocco, and Sudan – cover two thirds of their cereals needs from domestic production (Table 4.3). Six NENA states cover less than 20 per cent of their cereals consumption. The two poorest of these countries (Mauretania, Yemen) are vulnerable to national-level food insecurity (see below). Food imports average 13 per cent of total merchandise imports, and for two of the poorest countries (Sudan, Yemen) the share of food in merchandise imports exceeds 20 per cent. These two poor countries are spending large sums of foreign exchange on importing food. [World Bank 2013: 3]

Table 4.3: Key facts on cereals self-sufficiency and food import dependence

Cereals self-sufficiency	**Food imports as a share of merchandise imports**
NENA countries with rates of cereals self-sufficiency of: ▪ >70%: NONE ▪ 60-70%: Egypt, Iran, Morocco, Sudan ▪ 40-60%: Algeria, Syria, Tunisia	NENA food imports as % of total merchandise imports: ▪ Average 13%

▪ <20%: Lebanon, Libya, Mauretania, WBG, KSA, Yemen	▪ More than 20%: Algeria, Libya, Sudan, Yemen

Source: Aquastat (data refer to 2015)

Studies have found scant relation between national food security and the level of self-sufficiency in food production. Empirical studies have tried to establish the relationships between national food security and the level of self-sufficiency in food production. In fact, these studies show the counter-intuitive result that policies which tilt the incentive structure in favour of domestic food production may bring economic losses to the nation and may even increase food insecurity of producing households by reducing their potential incomes. A recent study showed that Morocco could achieve 85 per cent self-sufficiency in cereals at current yields, and that full self-sufficiency could be achieved if yields rose by 40 per cent. However, this self-sufficiency would come at a high cost – about $10 billion 2008-2022 – through revenue forfeited by not producing higher value crops. If Morocco produced instead the high value crops, the $10 billion could be used to purchase a much greater quantity of imported cereals. In addition, production of higher value crops would create far more agricultural employment for landless labourers than cereals production.[9]

Nonetheless, recent policy analysis has found links between agricultural production and food security. Best practice links food security and insecurity to four factors: availability of food, economic and physical access to food, the ways in which food is used, and the stability of these factors over time. The relation of these factors to agricultural production and to the food security status of populations varies considerably. In Morocco, for example, one study identified three factors contributing to relative food insecurity: the volatility of levels of agricultural production; low purchasing power; and low levels of investment in agricultural research. It should be noted that it is not food production but agricultural production as a whole which is a factor contributing to Morocco's food insecurity.[10]

The water/energy/agriculture nexus

Agriculture is an energy-intensive business, to the extent that world oil prices and world food prices tend to move in tandem. In the Arab countries, the main impacts are on the price of oil-based fertilizers and on the direct energy costs of production, particularly in farm mechanization and in irrigated production, particularly on pressurized or lift schemes, and this makes for high O&M costs.

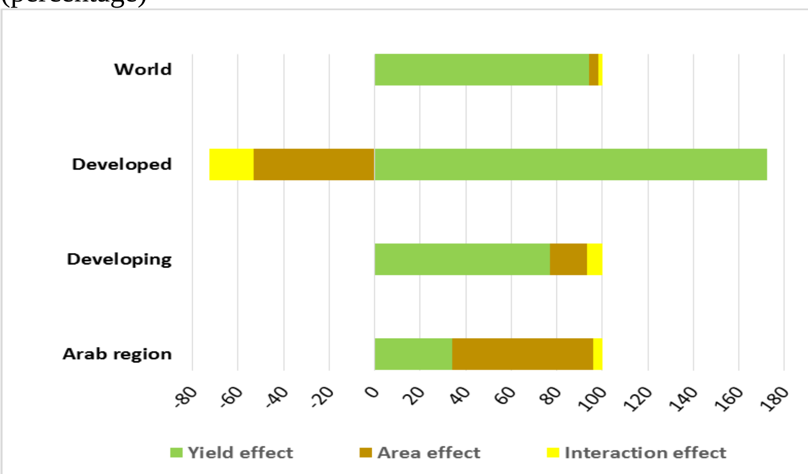
In many Arab countries, farmers have been protected by what are in effect energy subsidies, but this has introduced its own distorted incentives. Energy subsidies have made it cheaper to pump water, and this has improved the financial profitability of both surface water lift pumping for irrigation and of groundwater abstraction. This has contributed to the decline of non-renewable groundwater reserves in some locations. The most extreme examples have been in the Arabian Peninsula where cheap energy has led to massive depletion of fossil aquifers.

On the cost side, rising energy prices create a new reality for pump-based irrigation, which needs to be factored into planning and infrastructure. On the recovery side, there are significant trade-offs involved in decisions about whether to pass on the real cost of energy to farmers. Low energy prices keep agricultural employment and incomes up but create incentives to overuse and misapplication. Economic pricing is politically more difficult, it can lead to impoverishment of farmers, and it will have knock-on effects throughout the economy. In addition, investments to raise irrigation efficiency may not always be cost-effective as energy prices rise.

Extent of land farmed and yields

National production of basic foodstuffs is a function of extent of land farmed and of the yield obtained. Historically everywhere in the world, expansion of food production has come first from increasing the area under cultivation (extensivity) followed by increasing productivity (intensivity), as areas suitable for cultivation became scarce. Figure 4.1 decomposes the contribution of changes in area and yield to cereal production in various regions of the world. Whereas in the recent past increases in yields are the dominant force behind increases in production in other parts of the world, this has not been the case in the Arab region. During the 20-year period of 1990/1996 to 2010/2016, increases in area under cultivation contributed only negligibly to the growth of global cereal production, while the bulk of additional output (95 percent) has come from increases in yield. In dramatic contrast, two thirds of increased cereal production in the Arab region is attributed to area under cultivation, with only a third coming from improvements in yield.[11]

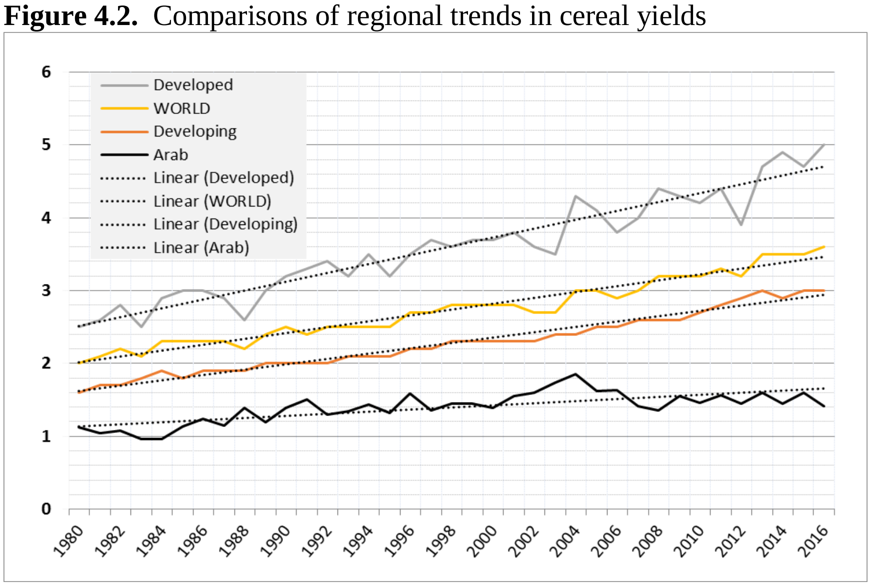
Figure 4.1. Area and yield contribution to cereal production increases from 1990/1996 to 2010/2016 (percentage)[12]



Source: Based on data from FAO, Country Cereal Balance Sheet data. Available from http://www.fao.org/giews/data-tools/en/ (accessed April 2017).

Figure 4.2 shows improvements in yield over time, going back to 1980. This figure is consistent with the relatively low yield increases in the Arab region and shows that regional differences in producitity trends have continued over a long period of time.

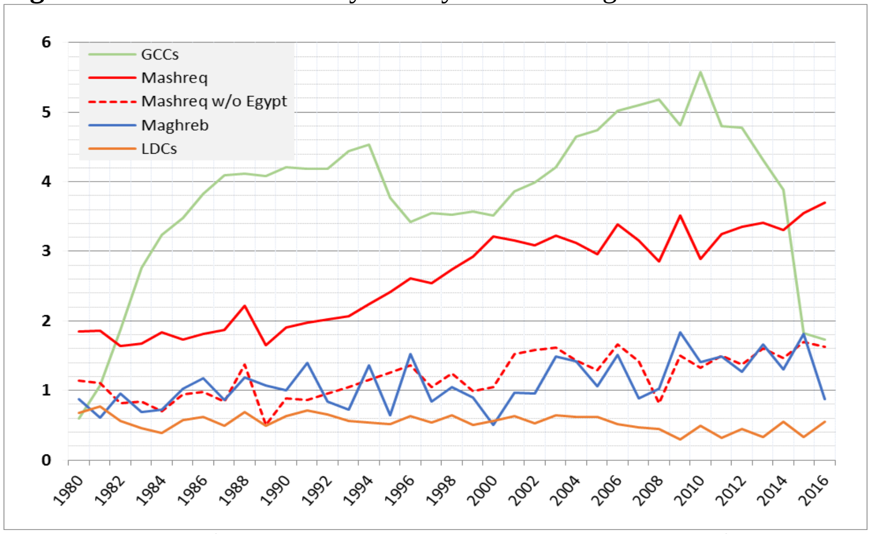
Figure 4.2. Comparisons of regional trends in cereal yields



Source: Based on data from FAO, Country Cereal Balance Sheet data. Available from http://www.fao.org/giews/data-tools/en/ (accessed April 2017).

There are important differences in yield trends among the Arab sub-regions (figure 4.3). The Mashreq, which accounts for the bulk of the area devoted to cereal production in the region and harvests the lion's share of cereal output, has achieved yields consistently much higher than those of the other sub-regions. However, this performance is due to Egypt, as Mashreq without Egypt has much lower yields, similar to the other subregions. The most worrying case in the Arab region is that of the LDCs where, as underlined previously, yields have stagnated and even declined during the past decade. The experience of the GCC countries is also noteworthy. The pattern for the GCC countries is largely due to the adoption and subsequent rejection by Saudi Arabia of expensive and environmentally unsustainable reliance on underground fossil water supplies.

Figure 4.3. Trends in cereal yields by Arab sub-region



Source: Based on data from FAO, Country Cereal Balance Sheet data. Available from http://www.fao.org/giews/data-tools/en/ (accessed April 2017).

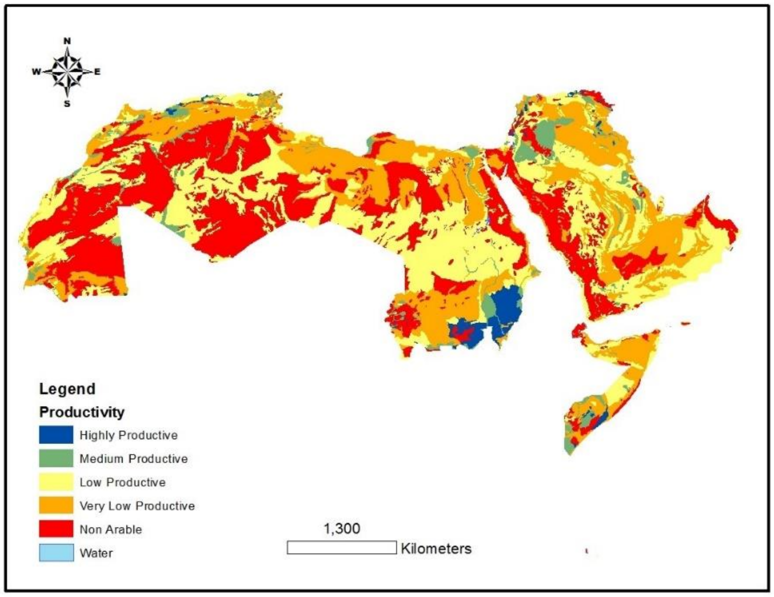
Productivity and the natural resource base

As the world's most water scarce and arid region, the Arab region has always – and will always – suffer from geoclimatic limitations in terms of quality of land and access to water. This section examines in detail the role that these constraints play in limiting productivity and how these contraints can be relaxed.

Quality of land.

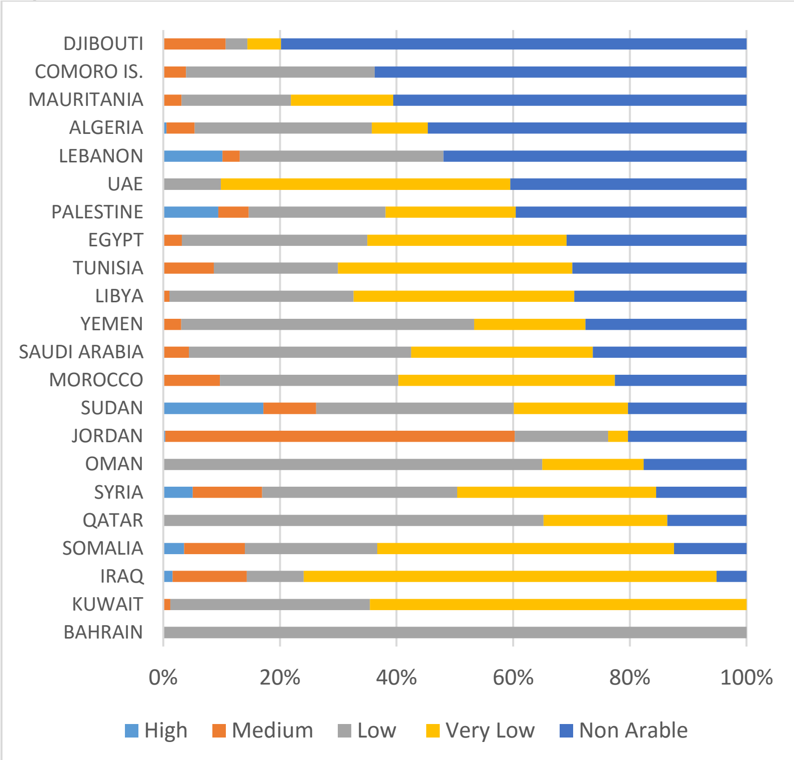
Of the total land area of the Arab countries (of some 1.3 billion hectares) about 500 million hectares is arable. However, only 100 million hectares have medium or highly productive soils (figure 4.4). The individual countries within the region vary widely in their endowment (figure 4.5). In the Sudan 17 per cent of the land area is considered to have high productivity. Jordan has no highly productive land but has 60 per cent of its land area categorized as medium productivity. At the other end of the spectrum, almost 80 per cent of Djibouti is non-arable. With the rapid rate of urbanization in the region, significant quantities of arable land are being lost to construction.

Figure 4.4. Land capability map of the Arab countries



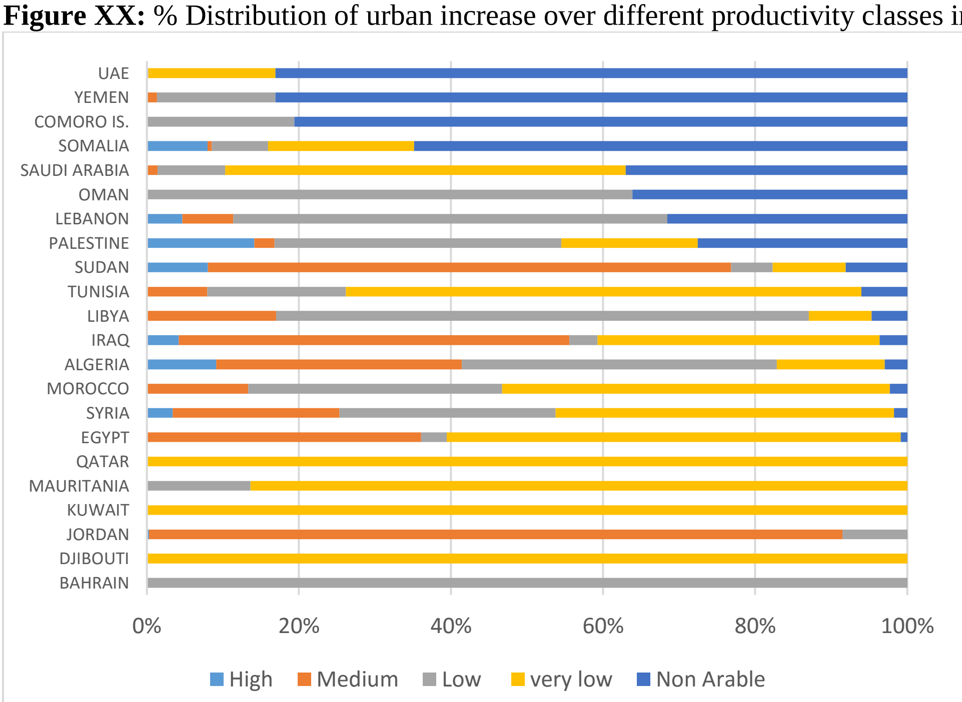
Source: Produced using the USDA model and soil information of the DSMW (data source: Land and Water Development Division, FAO, Rome, 2007 (http://www.fao.org/geonetwork/srv/en/metadata.show?id=14116).

Figure 4.5. Proportion of land capability classes in the Arab countries



Source: Calculated from the adapted USDA model applied to soil information using the Digital Soil Map of the World (data source: Land and Water Development Division, FAO, Rome, 2007 http://www.fao.org/geonetwork/srv/en/metadata.show?id=14116

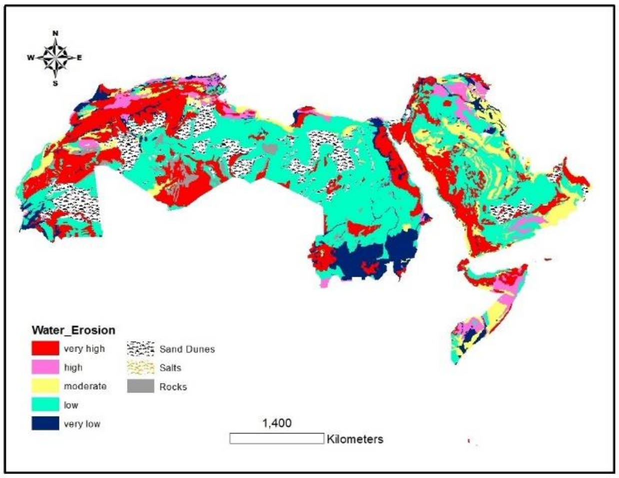
Figure XX: % Distribution of urban increase over different productivity classes in each country



Source: Calculated from the adapted USDA model applied to soil information using the Digital Soil Map of the World (data source: Land and Water Development Division, FAO, Rome, 2007 http://www.fao.org/geonetwork/srv/en/metadata.show?id=14116

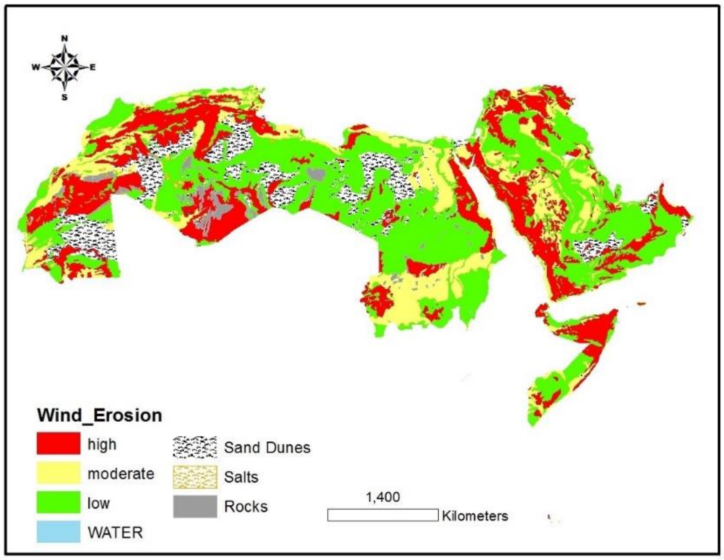
Much of the region's soil suffers from severe, ongoing degradation: in some Arab countries, the reduction in soil productivity has been estimated to be in the range of 30 to 35 per cent of the potential productivity. Types and causes of degradation differ by farming systems. For rainfed systems, the primary causes are water and wind erosion (figure 4.6 and figure 4.7). Of the region's 30 million hectares of rain-fed cropland, three quarters (22 million hectares, 73 per cent) are estimated to be degraded. Recent studies have estimated the economic cost of land degradation in the region at a massive $9 billion each year (between 2 and 7 per cent of individual countries' GDP). For irrigated land, the farming practices themselves are the primary cause of degradation in the form of salinity and sodicity.[13] Losses from salinity alone across the region are estimated at $1 billion annually, equivalent on a per hectare basis to $1,600 to $2,750 per hectare of affected lands.

Figure 4.6. Water erosion risk in the Arab Countries



Source: based on the USLE soil erosion model using soil data from the DSMW (Data source: Land and Water Development Division, FAO, Rome 2007 (http://www.fao.org/geonetwork/srv/en/metadata.show?id=14116).).

Figure 4.7. Estimated wind erosion risk map of the Arab countries



Source: Based on soil information adapted from the DSMW (data source: Land and Water Development Division, FAO, Rome, 2007 (http://www.fao.org/geonetwork/srv/en/metadata.show?id=14116).

Farmers across the region have found ways to adapt to the low quality of land and overcome the soil limiting factors restricting crop yield and food production. In several cases, land conservation policies, programmes and incentive frameworks have succeeded in establishing sustainable management of currently cultivated lands to prevent erosion, urban expansion and soil salinity hazards. The technical methods depend on the specific land quality problem. Sandy soils are usually classified into the lowest productivity group, though they can often be cultivated if adequately cropped and properly irrigated. Low water holding capacity can be improved by organic matter, compost or polymer addition and localized irrigation. High pH values can be treated by diluted acid addition to the irrigation water in modern pressurized irrigation systems. Salinity problems can be overcome by positive water balance with improved drainage to leach and evacuate the salts. Sodicity can be managed through chemical treatment and drainage. Use of cover crops can protect soil from the splashing effect of rainfall as well as improving soil fertility by fixing nitrogen from the air and attracting small ruminants. Box 4.1 presents several examples of ongoing activities in the Arab region which are successfully addressing land quality constraints.

Box 4.1. Ongoing activities in the Arab region to address land quality constraints

Zero tillage. Tilling has several effects on the soil, which can be problematic in the context of poor land quality. Tilling can cause loss of organic matters, increased evaporation, and increased vulnerability to water and wind erosion. Eliminating or minimizing tilling solves these problems. In particular, leaving the roots from previous crops protects against erosion by stabilizing the soil while the stubble increases soil fertility and improves water-holding capacity by adding organic matter. The principle approach to zero tillage involves use of seed drills to plant and fertilize directly into unploughed soil. At about $30,000 each, imported seed drills are prohibitively expensive for smallholder farmers. A recent project by ICARDA and the Australian government, has resolved this problem. Working with local farmers and craftsmen, the project has produced and distributed almost 200 affordable seed drills which are now being used across the Syrian Arab Republic, Iraq, Lebanon, Jordan, Algeria, Tunisia and Morocco.

Soil maps. Soil data is vital to both policy-makers and farmers alike, but is often outdates, of low resolution and not readily interpreted outside academic audiences. The Amman-based Institute of Digital Soil Mapping is serving as a regional hub for a global consortium of scientists and researchers. The consortium is developing GlobalSoilMap.net, which can combine data from several sources and present it in a user-friendly format for a broad range of audiences. The data can include soil pH, water storage electrical conductivity and carbon content data derived from remote sensing, near- and mid-infrared spectroscopy and field sampling and can make use of the Global Soil Partnership system of the International Network for Soil Information Institutes.

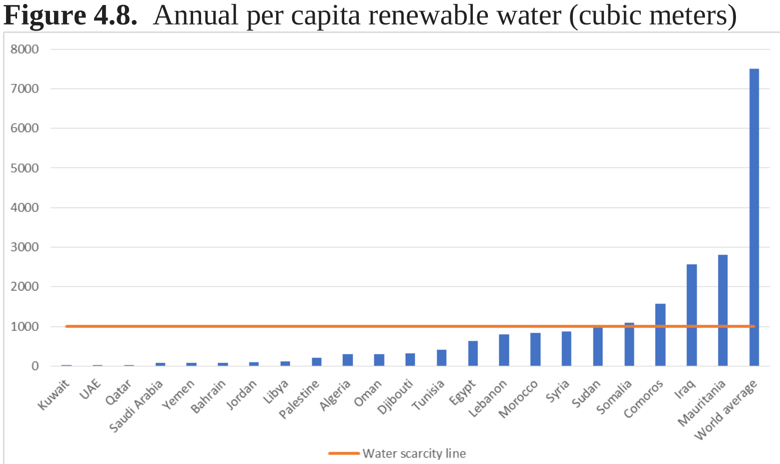
Sources: www.icarda.org/conservation-agriculture/zero-tillage-seeders

Issues of land quality are closely intertwined with issues of water. It is clear, for example, from the previous discussion that poor irrigation practices can lead to salinity and sodicity, but that these quality problems can be reversed with improved practices. Furthermore, as described above, low water holding problems can be addressed by addition of organic matter and proper irrigation can help make even sandy soils productive.

Access to water

The Arab region is the most water scarce in the world with most of the countries falling below the generally accepted water scarcity line of 1,000 m^3 per capita per annum of renewable water resources (figure 4.8).[14] All Arab countries use most of their water for agriculture (table 4.4). This reflects the historic and contemporary importance of the agricultural sector and of food production, but in most countries, the fast-rising demand from other sectors is creating calls for water transfer out of agriculture. Some argue that there is an economic case for transferring water out of agriculture to higher value municipal and industrial uses, others argue agriculture's importance for incomes of the poorest and to protect against risks related to the global food markets. But all agree on the priority of improving management for optimal allocation and efficient use, environmental protection to prevent degradation, and adaptation to climate change.

Figure 4.8. Annual per capita renewable water (cubic meters)



Sources: Population data is from UNDESA: United Nations, Department of Economic and Social Affairs, Population Division (2017). World Population Prospects: The 2017 Revision, DVD Edition. Water data is from Aquastat, last accessed 27/07/2017.

Table 4.4. Shares of water by sector in selected Arab countries

		Percentage withdrawn by sector		
Country		*Agriculture*	*Domestic*	*Industry*
More than 90 per cent of withdrawals used in agriculture				
Yemen		95	4	1
Syrian Arab Republic		95	3	2
Iraq		92	3	5
Oman		90	8	2
More than 80 per cent of withdrawals used in agriculture				
Morocco		87	10	3

Egypt		86	8	6
Saudi Arabia		86	10	3
Libya		83	14	3
Tunisia		82	14	4
Less than 80 per cent of withdrawals used in agriculture				
Jordan		75	21	4
Lebanon		67	33	1
Algeria		65	22	13

Source: Based on data from Aquastat, available from http://www.fao.org/nr/water/aquastat/main/index.stm (accessed April 2017).

Soil and water for rainfed farming

To a large extent, existing differences in productivity among Arab countries are driven by differences in reliance on rain-fed versus irrigated farming systems. Rain-fed farming systems still predominate in the Maghreb, the Mashreq (other than Egypt) and the LDCs, covering 55 million hectares (more than two thirds of the region's cultivated land), and provide livelihoods for nearly two thirds of the agricultural population region-wide.[15] In Algeria, Iraq, Jordan, Lebanon, Libya, Mauritania, Morocco, the Sudan, the Syrian Arab Republic, Tunisia and Yemen, rain-fed agriculture is practiced on more than half of all arable land.[16]

The biggest constraint and risk in rainfed farming is ensuring adequate soil moisture available to the plant roots during the growing season. Rain-fed farmers face the challenge of unpredictable rainfall and consequent stress on plants due to inadequate soil moisture. This risk is growing with the rising variability and aridity brought by climate change. An important approach to addressing unpredictable rainfall is water harvesting, which allows farmers to collect water from outside the field and to convey the water to their fields when it is needed. It is essentially a form of supplementary irrigation which can boost yields by two to three times over conventional rainfed agriculture. Technologies range from simple in-field structures diverting water to a planting pit, through structures in the catchment which divert run off to storage or run-on fields, to permanent terraces and dams. The terrace systems of the Yemeni and Omani highlands, which date back at least 3,000 years are legendary examples of rainwater harvesting. More recently, low cost approaches to water harvesting have been developed by ICARDA in the Jordanian and Syrian badia with support from the Arab Fund for Economic and Social Development, the International Fund for Agricultural Development, and the OPEC Fund for International Development. Other solutions to conserving and enhancing soil moisture include mulching, soil contouring, bunding and windbreaks. The cost and the accuracy of land contouring has been dramatically improved using a modified, low-cost portable laser-guided system with a tractor-mounted receiver and guidance controller.[17] Agronomic measures include selecting drought-tolerant crops or varieties, choosing shorter-cycle varieties, adapting planting dates etc,

Where water is unpredictable, soil fertility is absolutely essential: for soils that are naturally poor in nutrients or are degraded, maintaining and enhancing soil texture and fertility will improve crop water productivity. The most widespread response in the region has been to step up fertilizer use, and average fertilizer use in the region is above world average, although with wide variations.[18] Despite the importance of rain-fed agricultural systems, there has never been a rainfed 'Green Revolution' and in many Arab countries agricultural incentive structures have disfavored research and investment in rain-fed systems, focusing instead on commercial and irrigated production.

Land, water and irrigated farming

Whereas the countries in the region that rely on rain-fed systems have generally low productivity, those that focus on irrigated farming systems have yields that are higher than the global average. Irrigated systems occupy less than one third of the region's cultivated area (24 million hectares) but contribute almost half of agricultural value, thanks to the focus on high-value added commercial crops and generally efficient irrigation systems that result in relatively high yields.[19] Some countries are exceptionally high performers. For example, Egypt's productivity per hectare is three times the regional average.[20]

The region's irrigated agriculture has traditionally relied on diversion of water from rivers, streams and springs, and some of the world's greatest irrigation systems have been developed on the Nile, Euphrates, Tigris and the many river systems of the Maghreb and Mashreq. However, since the introduction of the tubewell fifty years ago, the groundwater boom has revolutionized agriculture across the Arab world, driving the rapid growth of commercial and export-oriented high value agriculture, and seven of the world's top twenty groundwater irrigating countries are in the region (table 4.5). There are many reasons why groundwater development and abstraction have proved very popular with farmers throughout the region, as they have worldwide. The most important is its just-in-time availability close to the field. Groundwater also plays a key buffer role in maintaining optimal soil moisture during dry spells, and this role will grow with increasing climatic variability.

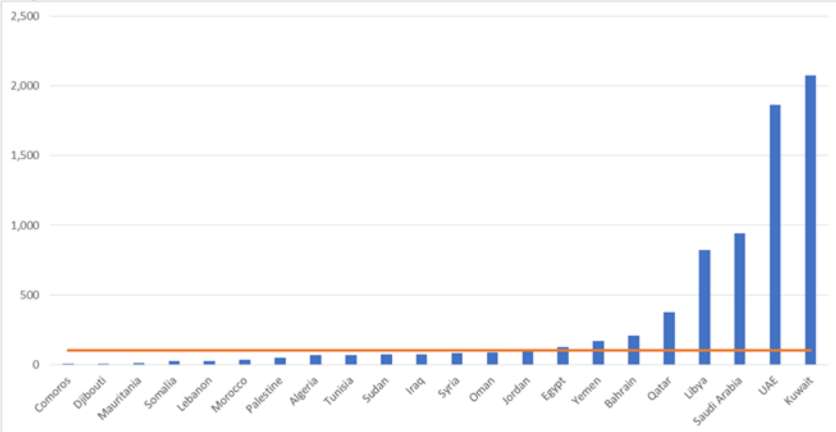
Table 4.5. Seven of the world's top twenty groundwater irrigating countries are in the Arab region

Country	*Area under groundwater irrigation ('000s hectares)*	*Share of global groundwater irrigated area*	*Share of irrigated area*	*Share of total cultivated area*
Saudi Arabia	1,538	2.2 per cent	96 per cent	40 per cent
Syria	610	0.9 per cent	60 per cent	11 per cent
Libya	464	0.7 per cent	99 per cent	22 per cent
Morocco	430	0.6 per cent	29 per cent	5 per cent
Yemen	383	0.6 per cent	80 per cent	23 per cent
Egypt	361	0.5 per cent	11 per cent	11 per cent
Algeria	352	0.5 per cent	62 per cent	4 per cent

Source: Adapted from IWMI 2007: 401 Table 10.2

The key challenge of groundwater irrigated farming systems is sustainability. Groundwater over-use has resulted in depletion, deterioration and destruction of aquifers. Several countries in the region withdraw more than 100 per cent of their renewable water source (figure 4.11). As described earlier, the apparently impressive yield performance of the GCC subregion is mainly due to the resource-intensive and expensive production systems in those countries, based on depleting underground fossil water supplies. However, as underground water supplies were progressively exhausted, Saudi Arabia adopted in 2008 a major shift in policy to phase out all wheat production in eight years.[21] Wheat production has plummeted since then and the country has been relying exclusively on imports since 2016.

Figure 4.11. Water withdrawal as a share of renewable water resources



Source: Aquastat. Available at http://www.fao.org/nr/water/aquastat/data/glossary/search.html.
Note: The reference line is drawn at 100 per cent.

Increasing water use efficiency

In many contexts, the sustainability challenges associated with irrigation can be mitigated by increasing efficiency. Management of irrigation occurs at two levels: water service to the field and in-field water management. Water service to the field, which applies mainly to surface irrigation schemes which are delivering water to many farmers, has been shown by FAO studies to be more efficient in the Arab region than the global average.[22] Nevertheless, further efficiency gains in water service to the field as well as in-field management will be required if agriculture is to continue to grow in the water-scarce Arab region.

There are several ways to assess relevant aspects of efficiency and a wide range of technical approaches available. A commonly used measure of efficiency is the proportion of water that contributes to plant growth, referred to as Water Use Efficiency. Even in countries with generally efficient systems, there remains large scope for improvements, as indicated by the large variations across neighboring farmers. In a large scale study in Doukkala, Morocco, all farmers in the 110,000 hectare area were given the same quantity of water.[23] Although average yields across the area were excellent, yield gaps within the area were large. For wheat, the area's average yield was twice the national average. However, the average yield of all farmers was 33 per cent below the best yields obtained on the scheme. All farmers essentially farmed in the same way, the difference was water management: the farmers with the highest yields had invested in reservoirs to store water so that it could be applied when needed; others had invested in pressurized irrigation, and some had simply followed extension advice for irrigation scheduling. For maize, the area's average yield was four times the national average, while the gap between the best and the average farmers within the area was even larger than for wheat, 44 percent.

Another way of looking at water use efficiency is in terms of reductions in loss of water. A separate study in Morocco found that improvements in network delivery (e.g. closed canals and timely delivery) and in-field management (e.g. conveying water to the root zone and minimizing evaporation) reduced water losses by an average of 25 percent.[24]

Water Use Efficiency can approach 100 per cent in greenhouse environments. The more stable, controlled environment of greenhouses allows more targeted use of fertilizers, dramatically reduces evaporation of irrigation water and makes pest and disease control far easier. In an ICARDA project in Oman, low-cost greenhouses were fabricated, erected and operated on marginal lands. The farmers were able to achieve yield improvements of 60 per cent.[25] Taken a step further, controlled environments can be designed for hydroponic farming. Hydroponic farming typically involves suspending the roots system of plants directly into water. Nutrients are added to the water and an aeration is used to ensure oxygen availability. In many cases, hydroponic farming is prohibitively expensive for farmers. Egyptian Hydrofarms, however, has adopted low-cost technology, as well as eliminating environmentally harmful run-off and using 80 percent less water than in traditional agriculture. Operating on marginal land outside of Cairo, the firm provides pesticide-free herbs and salads to high-end supermarkets and hotels.

Increasing returns per unit of water

While Water Use Efficiency focuses on the physical efficiency of water, Economic Crop Water Productivity (ECWP) measures the value of crops produced per unit of water, which is a critically important objective in such a water-scarce region. Globally, ECWP can vary by a factor of 8 and can be enhanced through soil moisture retention (e.g. zero tillage farming), efficient timing of irrigation, and harvest and post-harvest management to reduce food loss.[26] Choice of crop is also essential. Egyptian Hydrofarms, described in the previous paragraph is an excellent example of combining technological solutions with focus on high value-added crops. Table 4.6 provides global benchmarks for the range of possibilities found across the whole range of farming systems and levels of intensification, in both irrigated and rainfed conditions. The upper bound in each case represents the level of water productivity that can realistically be obtained under best practice conditions. The lesson is that increasing economic crop water productivity – '*more dollar per drop*' – is the essential objective for agriculture in the water-scarce Arab countries – and there is considerable scope to do this.

Table 4.6. Physical and economic crop water productivity (CWP) ranges for selected crops

Crop	*Assumed price per kg (US cents/kg)*	*Physical CWP (kg/m3)*	*Economic CWP (US cents/m3)*
Wheat	20	0.20-1.20	4-30
Rice	31	0.15-1.60	5-18
Maize	11	0.30-2.00	3-22
Lentils	30	0.30-1.00	9-30
Fava beans	30	0.30-0.80	9-24
Potatoes	10	3.00-7.00	30-70
Tomatoes	15	5.00-20.00	75-300
Onions	10	3.00-10.00	30-100
Olives	100	1.00-3.00	100-300
Dates	200	0.40-0.80	80-160

Source: based on IWMI 2007: 292 Table 7.3

Virtual water

The trade-offs involved in making more rational use of scarce water resources by focusing on water-efficient crops has also given rise to the concept of "virtual water" which measures the quantity of water needed in the production process in relation to the weight and value of the output (Table 4.7). From a national perspective, rational allocation of water resources would call for a concentration of production on those crops that require the least water in relation to the value of the output (in other words have the highest economic crop water productivity) and import those whose production requires the most water so that considerable increases in national income can be gained through trade. To the extent that this happens in reality depends on water policy and whether the price farmers pay for inputs in the production process (including water) fully reflects their opportunity cost. If water is artificially cheap (e.g. through irrigation subsidies), its use in the production process will not be based on its true economic value to society but on individual profit maximization considerations (water use will increase to the level that maximizes farmers' profit). Thus farmers may find it profitable to produce crops which give lower returns per unit of water consumed even though this may not be in the interests of the nation. One lesson is, that where water is scarce there should be some mechanism, either pricing or rationing that reflects that scarcity and so gives farmers incentives to grow the most water efficient crops. Another important lesson is that, wherever possible, nations – particularly water-scarce ones - should look at food security from the perspective of maximizing economic returns to water and not at maximizing output volumes.

Table 4.7 "Virtual water" (litres of water per kg of product)

Wheat	1,150
Rice	2,656
Maize	450
Potatoes	160
Soybeans	2,300
Beef	15,977
Pork	5,906
Poultry	2,828
Eggs	4,657
Milk	865
Cheese	5,288

Source: UNDP (2009)

UNDP, 2009. *Arab Human Development Report 2009: Challenges to Human Security in Arab Countries*. New York: United Nations Development Programme.

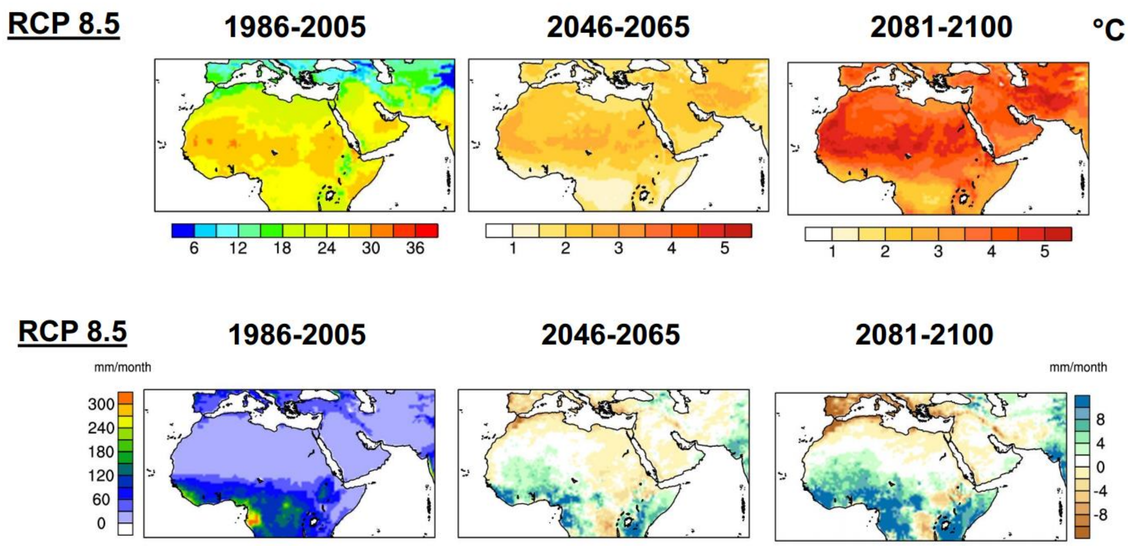
Increasing water availability

As water is the scarce factor and the binding constraint to increasing production and farm incomes in the region, increases in Water Use Efficiency and Economic Crop Water Productivity are essential but they can be usefully combined with technological approaches to increase the quantity of water available. Water harvesting, as in the above example from the Jordanian and Syrian badia, can be expanded. Reuse of treated wastewater also has potential in the region and examples of its use are available in Jordan and Egypt. The As-Samra Waste Water Treatment Plant in Jordan provides about 10 percent of the water used in agriculture. The plant also generates 230,000 kWh of hydropower and biogas each day – meeting 80 percent of the plant's needs, thereby reducing reliance on the national grid.[27] Drainage water reuse is a resource that has been largely neglected in the region with the exception of Egypt, which is considered a world leader in drainage technology and practice.[28] Drainage water is being reused on 90 per cent of the irrigated land in Egypt, and is successfully reusing over 10 per cent of the annual freshwater withdrawal without deterioration of the salt balance.

Climate change

Any forward looking approach to agricultural production and productivity will need to address climate change. Climate change is an especially pressing issue for the predominantly dry countries of the region, which are already prone to frequent droughts and a looming water supply shortage. Over the last century, the Arab region has experienced an increase in mean temperatures of up to 0.5°C. In some countries like the Sudan and parts of North Africa, precipitation has decreased by up to 10 per cent in recent decades. Most of the region is expected to become hotter and drier in the future due to climate change. Simulation models indicate that average yearly rainfall could decrease by 10 per cent in the next 50 years.[29] With higher temperatures (causing increased evaporation) and reduced precipitation, loss of surface water would be accelerated and droughts would become more frequent. Figure 4.12 shows projected increases in temperature and reduction in precipitation across the region. The already low average yields of rain-fed crops would decline and be more variable. Agricultural output could decrease by 21 per cent by 2080.[30] All farming systems will be exposed to increased aridity and to declines in water availability, with rain-fed systems most at risk.[31]

Figure 4.12. Projected changes in temperature (centigrade) and precipitation (mm/month)



Source: RICCAR

These anticipated changes are expected to affect different farming systems in different ways (table 4.8). Because aridity will increase and water is the binding constraint to agriculture in the region, governments will need to evaluate trade-offs between supporting climate change responses in agriculture and preparing parts of the rural economy for transition away from agriculture including off-farm income.

Table 4.8. Climate change impact on farming systems of the Arab region

Farming system	*Exposure* *What climate change-related events will occur*	*Sensitivity* *Likely impact on farming systems*
Irrigated	Increased temperatures Reduced supply of surface irrigation water Dwindling of groundwater recharge	More water stress Increased demand for irrigation and water transfer Reduced yields when temperatures are too high Salinization due to reduced leaching Reduction in cropping intensity
Highland mixed	Increase in aridity Greater risk of drought Possible lengthening of the growing period Reduced supply of irrigation water	Reduction in yields Reduction in cropping intensity Increased demand for irrigation
Rain-fed mixed	Increase in aridity Greater risk of drought Reduced supply of irrigation water	Reduction in yields Reduction in cropping intensity Increased demand for irrigation
Dryland mixed	Increase in aridity Greater risk of drought Reduced supply of irrigation water	A system very vulnerable to declining rainfall Some lands may revert to rangeland Increased demand for irrigation
Pastoral	Increase in aridity Greater risk of drought Reduced water for livestock and fodder	A very vulnerable system, where desertification may reduce carrying capacity significantly Non-farm activities, exit from farming, migration

Source: World Bank, 2013.

Looking forward

Despite the region's natural resource constraints, there are considerable opportunities to increase agricultural productivity, production and incomes. The key will be to focus on what is the comparative advantage of a water-scarce, relatively developed region. This means that emphasis will be on production that has the highest value added per unit of water consumed and on production systems and patterns that return the highest incomes to farmers and generate or save the most foreign exchange for the country. A subsidiary but vital objective will be to protect the livelihoods and food security of the poor in rural areas.

Policies should therefore focus on the following:

Exploiting comparative advantage in agriculture. This is likely to lie in the increasing commercialization of all agriculture, with a move towards more intensive production systems and crops that return the most $ per drop of water. Importing cereals, oilseeds, and animal feed will be cheaper than local production. Instead, farming can focus on high value perishable produce for the rapidly growing cities and export to Europe during the winter.

A supportive incentive framework. The development of markets and likely changes in world prices are likely to improve incentives, and these need to be supported by pro-business and pro-private enterprise policies. Increases in output and incomes are likely to come about through a combination of improved incentives due to rising commodity prices together with increased investor confidence.

Increasing integration and efficiency along the production and food chain. Productivity can be enhanced and risks managed by improving general efficiency in supply chains 'from farm to fork'. There are different challenges in different Arab countries. In Oman, for example, post-harvest losses of 25 per cent or more could be reduced by improved in-field management and just-in-time field chilling. The impact of heat extremes on post-harvest losses in food storage and distribution can be managed by adequate cold storage and refrigeration of food during heat extremes. Managing risks at bottlenecks in exposed storage and transport infrastructure could increase value all along the chain. Some countries have bottlenecks in ports, while others have inefficient inland transportation systems.[32]

Developing a more sustainable and resilient agriculture. This will require policies and practices that focus on efficient use of water resources and address soil quality and climate change. A holistic approach, including both land and water management issues, is likely to be most effective.

Investing in adaptive research to boost productivity. Studies show that even with the impact of climate change, yields, including cereals yields, can grow significantly in the region through technological adaptation. Even the negative impacts of climate change can be offset by improved water use efficiency and water productivity. An IFPRI study found that, although output would still be below trend due to climate change, the application of productivity-enhancing measures is likely to keep yields rising through to mid-century, after which they will begin to drop off under natural resource and climate change pressures.[33]

Adoption of new technology. Improved agricultural techniques, selecting crop varieties for drought and heat tolerance, and improving the management of agricultural water use are likely to benefit yields. Technologies promoting water efficiency, such as drip irrigation, will be important but must be tailored to specific hydrological and institutional contexts.

More efficient water use. All farming systems need to refocus on 'more income per drop'. In irrigated agriculture, for example, investments include physical infrastructure, such as conversion to pressurized irrigation as well as measurement, control and monitoring systems, appropriate accountability mechanisms and capacity-building.[34] To encourage adoption of these technical approaches to water efficiency, pricing and rationing policies are important to create the right incentives: water pricing should reflect scarcity and opportunity costs.

Improving the productivity and commercial potential of rainfed farming systems. For rain-fed farming systems, approaches are needed to address the region's constraints in terms of low and variable water availability on the one hand, and soil salinity and lack of nutrients on the other hand. To date, relatively little attention has been paid by governments and institutions to rain-fed systems and further research and development will be needed in order to increase yields for rain-fed farmers. Table 4.9 identifies a range of strategies and techniques that could usefully be developed.

Table 4.9. Strategies and techniques for improving rain-fed productivity

Aim	*Agricultural water management strategy*	*Purpose*	*Techniques*
Improve water use efficiency by increasing water available to the plant roots	Soil and water conservation	Concentrate rainfall around crop roots	Planting pits
		Maximize rainwater infiltration	Terracing, contour cultivation, conservation agriculture, dead furrows, staggered trenches
	Water harvesting	Mitigate dry spells, protect springs, extend growing season, enable off-season irrigation	Surface dams, subsurface tanks, farm ponds, diversion and recharging structures
	Evaporation management	Reduce non-productive evaporation	Dry planting, mulching, conservation agriculture, inter-cropping, windbreaks, agroforestry, early plant vigour, vegetative bunds
Improve water productivity by increasing productivity per unit of water consumed	Integrated soil, crop and water management	Increase proportion of evapotranspiration (ET) flowing as productive transpiration and so obtain 'more crop per drop'	Increase plant water uptake capacity through conservation agriculture, dry planting (early), improved crop varieties, optimum crop spacing, soil fertility management, optimum crop rotation, intercropping, pest control, organic matter management

Source: Adapted from International Water Management Institute (IWMI), 2007.

Applying policies and programmes to protect poor and marginal producers and production systems. Small, poor producers in remote, marginal environments will be particularly vulnerable to climate change and extremes. Pastoralism – a system traditionally adapted to drought – will remain an important source of animal products, but will increasingly rely on purchased animal feed and proactive drought management to manage climate risks. Support to the development of modern rangeland management systems and investment in infrastructure will be needed to increase productivity and sustainability. In the most marginal environments, households will need to be supported to exit from farming.

Improving the productivity and sustainability of the livestock sector. The sector is challenged by the scarcity of natural resources in terms of feed and water, lack of supporting infrastructure and services and a history of poor policies. The sector is today particularly vulnerable to the effects of climate change and water scarcity. Nonetheless, there remains potential for growth. In addition to support to pastoral systems (see above), mixed systems can be improved through better animal health and financial and infrastructure services, along with access to alternative cheap feed resources such as food industry by-products. For intensive systems, a regulatory framework is needed to control their negative impact on natural resources and public health, as well as adoption of technology to improve productivity.

[1] FAO 2001: 87, FAO/IFAD 2007:72; World Bank 2013: 2
[2] FAO 2001: 83, IFAD/FAO 2007: 70, FAO 2010; CC1A
[3] World Bank 2013; FAO 2001: 84, IFAD 2010, FAO/IFAD 2007: 67, 73.
[4] FAO/IFAD 2007: 47, 49
[5] Source: Livestock and food security in the Arab region: policy framework. Available from: https://www.researchgate.net/publication/307952238_Livestock_and_food_security_in_the_Arab_region_policy_framework [accessed Aug 23, 2017].
[6] Livestock products imports in 2011 estimated at US$8.6 billion in the Gulf countries vs. US$7.8 billion in all other Arab countries, in 2011.
[7] FAO has major initiatives to support artisanal fisheries and aquaculture through its Blue Growth Initiative, which is on-going in Algeria, Morocco and Mauritania with others are in the pipeline. Source: FAO Blue Growth Initiative to help boost Fisheries and Aquaculture in Arab countries, article by Izzat Feidi, FAO Fisheries Development Consultant, accessed online August 23rd, 2017 *[*http://www.fao.org/in-action/globefish/fishery-information/resource-detail/fr/c/379558/]
[8] [CC2-4]
[9] Magnan, N et al. 2011, Lampietti et al 2011
[10] Source: FAO Regional Initiative on Water Scarcity – Morocco Country Study (2015): 14
[11] The increase in the total number of hectares farmed in the Arab region was paralleled by a faster increase in population size. As a result, the quantity of farmed land per person has fallen by 6 per cent in the last 50 years.
[12] The increase in quantity produced between two time periods can be decomposed into effects attributed to yield increase, effects attributed to area increase and the combination of these two factors. The related formula is as follows:

$$Q2-Q1 = A2*Y2 - A1*Y1 = A1*(Y2-Y1) + Y1*(A2-A1) + (Y2-Y1)*(A2-A1)$$
$$= \text{Yield effect} + \text{Area effect} + \text{Interaction effect}$$

where :

Q, Y and A are quantity produced, yield realized and area harvested, respectively, and subscripts 1 and 2 correspond to averages of periods 1990-96 and 2010-16, respectively. When the area harvested remains unchanged, the area effect is zero and the yield effect is ±100per cent. When yields remains unchanged, the yield effect is zero and the area effect is ±100 per cent. The reality is always somewhere in between, whereby both area and yield vary between the two periods (not necessarily increasing) which results in a positive interaction term (if changes in are and yield are of the same sign) or a negative one (if of the opposite sign). In the case of the Developed region in the graph, had area harvested remained the same between the two periods, output would have increased by over 170 per cent on account of yield increases alone. The contribution of area to the total output increase in the Developed region was actually negative, with area harvested declining by some 55 per cent during these periods.
[13] Sodicity refers to high concentrations of sodium in soils. Sodic soils have a poor structure as sodium causes soils to swell and disperse. A dispersed soil structure loses its integrity, becomes prone to waterlogging, and is usually harder, making it difficult for roots to penetrate.
[14] The 'water scarcity line' is defined by the UN in the *Human Development Report 2006. UNDP, 2006, and also in Coping with water scarcity. Challenge of the twenty-first century. UN-Water, FAO, 2007*
[15] World Bank (2013).
[16] FAO and World Bank (2001), IFAD (2010), and FAO and IFAD (2007).
[17] In addition to increasing the amount of water in the soil profile, the water harvesting project was found to reduce wind and water erosion of topsoil by almost 70 per cent.
[18] Based on data from FAOSTAT, available from http://www.fao.org/faostat/en/#data (accessed April 2017).
[19] World Bank (2013).
[20] In 2014, Egypt held a share of about 13 per cent of the cereal area and produced about 35 per cent of total cereal output, demonstrating that its productivity per hectare was three times the regional average.
[21] See http://www.fao.org/giews/countrybrief/country.jsp?code=SAU.
[22] FAO (2015a).
[23] FAO (2015) and Ward and Ruckstuhl (2017).
[24] Regional Initiative on Water Scarcity – Morocco Case Study.
[25] www.icarda.org.
[26] International Water Management Institute (2007) and FAO (2015a).
[27] SUEZ (2015) and Gammoh & Oweis (2011)
[28] Egypt's experience helps to define four features that characterize successful programmes for drainage water reuse: (a) drainage water reuse has to be assessed at the level of overall basin efficiency and socioeconomic benefit; (b) a legal and regulatory framework is needed to control drainage water reuse; (c) successful programmes

for drainage water reuse should be developed in association with users and should be extended explicit water entitlements in the same way as fresh canal water; and (d) trade-offs should be well managed.

[29] Intergovernmental Panel on Climate Change (2007).

[30] Cline (2007). Some farming systems may benefit from warmer temperatures which will extend the growing season or increase productivity of winter crops. In Yemen, for example, where rain falls in the summer months, an increase in average temperatures of 2ºC could be expected to extend the growing season by about six weeks. See World Bank (2013). Some areas are expected to receive more rainfall, with higher frequency of floods. This trend has already been observed in Oman, Saudi Arabia and Yemen.

[31] World Bank 2013; FAO 2015; Ward & Ruckstuhl 2017

[32] Ianchovichina, 2014

[33] IFPRI's comprehensive series of global crop models support this assessment (see World Bank 2007b, IFPRI 2010).

[34] The Mapping System and Service for Canal Operation Techniques, developed by FAO, has been successfully used in the Arab region, including in a variety of irrigation methods and sizes.