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Unlocking the potential of rainfed agriculture in the Arab Region

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Acknowledgments

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Abstract

In the Arab region, rainfed agriculture is vital in sustaining rural populations and ensuring their livelihood including food security. However, the state of rainfed systems is poor despite that it has great potential, which remain largely untapped. There are approximately 40 million hectares of drylands currently cultivated representing nearly 80% of the total agricultural area though they produce only less than 40% of the food needed in the region. The rainfed areas of the region are concentrated in 6 Arab countries. They are expected to shrink over the coming decades by over 8% largely due to reduced precipitation as a result of climate change. Cereals, legumes, and trees are the major crops cultivated in rainfed systems, with yields varying from country to country but generally remaining very low. The key constraint to improved rainfed agriculture are unfavorable climatic conditions, degraded soils, and low adoption of improved practices, which are also the primary reasons for low yields. The focus to enhancing productivity in rainfed systems is primarily placed on technical aspects while less attention is given to institutional, financial, and governance factors. However, even these technical aspects are not fully exploited despite the availability of a wide range of technologies and practices that could help unlock rainfed potential. Their adoption is slow and uneven due to the high risks involved, and insufficient investments compared for example to irrigated agriculture systems and despite that rainfed systems require less resources to attain great improvements. To unlock the potential of rainfed agriculture in the Arab region, a paradigm change in development strategies is needed. Water is the most limiting factor and increasing water availability is a prerequisite to realizing the potential of other factors such as agronomic and genetic ones. To achieve substantial improvement in the system productivity, it is only logical to focus on strategies on water and to this effect four strategies are suggested. Among the most important suggested strategies are enhancing crop water availability notably through supplementary irrigation, enhancing crop water use through genetic improvement for example, improving rainwater productivity through various agronomic practices, and adopting climate-smart practices that might include rainwater harvesting. To support farmers in adopting these strategies an enabling environment has to be established through targeted investments, supporting policies, revamped institutional setup and promoting related research and development.

Contents

1. Introduction

Global food production outstrips current and near future food demand. However, several regions of the world experience a food deficit – difference between production and consumption – including the Arab region. Arab internal food production cover less than 50 percent of its food need meaning that the region has to cover the widening food gap through food import. The annual food gap has been growing at an alarming rate and is expected to reach US$ 71 billion by the 2030s from a low of US$ 11.8 billion in the 1990s. As a result, food security is a priority issue in the region with most countries trying, to some extent, to enhance food self-sufficiency as local production reduces the food gap while providing livelihood to rural population (Al-Fawwaz et al., 2016; ESCWA, 2019b).

Nearly 70 percent of the poor and hungry people in the world live in rural areas and depend predominantly on agriculture and food production for their livelihoods. In the Arab region, about 44 percent of the population lives in rural areas. In Egypt and Sudan, some two-thirds of the population is rural while in Yemen 70 percent of the population lives in rural areas. About 34 percent of the rural population of the region are poor, ranging from 8 percent in Tunisia to over 80 percent in Sudan. Agriculture remains the primary source of employment and livelihood in rural areas as a quarter of the working population is involved in it even though the sector amounts to about 5.9 percent of the region Gross Domestic Product (GDP) (World Bank, 2021; IFAD, 2016).

Cereals are essential food commodities in the region. The cereal import dependency ratio for all Arab countries stands at nearly 74 percent, which is the highest globally. The heavy dependence on the global food markets has been a political concern over decades and more so since the 2008 food price crisis and more recently the dramatic increase in world food prices and food export restrictions following the COVID-19 pandemic and the war in the Black Sea region. As a result, many Arab countries have been exploring ways to enhance their food self-sufficiency notably for key commodities. However, most efforts towards agriculture development continue to give high proiority to irrigated agriculture, which occupies less than 20 percent of the cultivated land but contributes about 40 percent of the food production. However, the productivity of irrigated systems is reaching a plateau with further expansion becoming more onerous due in part to the growing water scarcity in many countries (ESCWA, 2020; ESCWA, 2022).

Water scarcity is the highest globally in the Arab region, with per capita annual availability below the scarcity threshold of 1000 m^3. While a few countries such as Iraq or Mauritania still exceeds this level, countries like Jordan and most Arabian Gulf countries have reached alarming scarcity levels below 100 m^3 per capita per year. Water scarcity will continue to grow as population growth remains high, water is re-allocated to other economic sectors and most importantly climate change sets in. Transboundary water resources on major rivers in Syria and Iraq are declining while in Egypt and Sudan there are concerns for the future due to the increasing upstream abstraction and climate change (Abu Zeid et al., 2019).

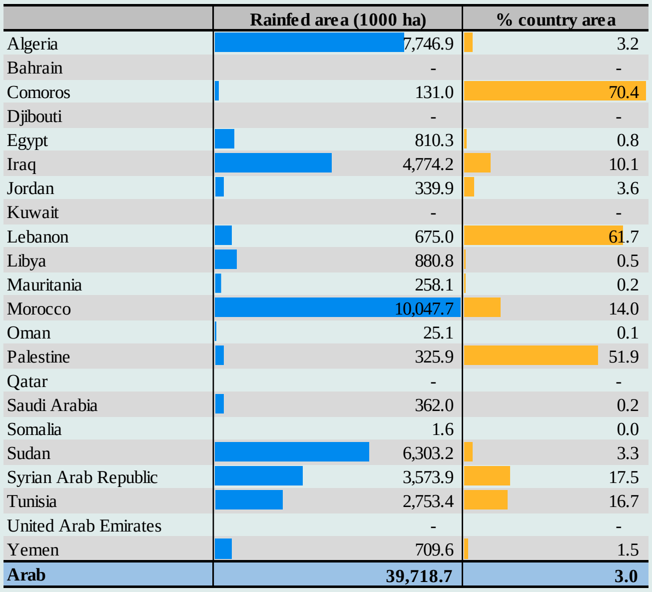
With little potential for expanding irrigated agriculture, rainfed agriculture is the best hope to enhance local production. Rainfed agriculture produces most food consumed globally particularly in poor communities of the developing world. About 80 percent of global land under cultivation and about 60 percent of crop production are rainfed. While rainfed systems occupy 7 percent of the total land of the Arab region, they contribute to about 60 percent of total production. Many countries of the region rely mainly on rainfed agriculture, which accounts for about 68 percent of the region cropland compared to 20 percent for irrigated agriculture, and 12 percent under permanent trees (FAO, 2020; AOAD, 2020).

Rainfed agriculture is essential for the Arab region and offers good potential as it requires less investment than irrigated agriculture to enhance overall productivity. Improving rainfed systems productivity and ensuring its sustainability could provide scope for poverty alleviation. However, current investment in rainfed agriculture remains limited for the needed transformation as, on average, the agriculture sector as a whole receives a disproportionately low level of investments compared to the its contribution to national economies (ESCWA, 2017; AMF, 2020).

However, strategies to upgrade rainfed systems in the region had little success as instead rainfed agriculture has experienced a decline over the last couple of decades due to natural resources degradation, while the impacts of rising water scarcity and climate change are putting additional pressure on the system. As the region seeks to increase agricultural production there is a need to shed light on the state of rainfed systems by highlighting the challenges they face to uplift productivity and by stressing on what it might take in terms of strategy change to enhance investment to unlock their potential.

2. State of the rainfed agriculture in the Arab region

2.1. Rainfed areas and rainfall characteristics



	Rainfed area (1000 ha)	% country area
Algeria	7,746.9	3.2
Bahrain	-	-
Comoros	131.0	70.4
Djibouti	-	-
Egypt	810.3	0.8
Iraq	4,774.2	10.1
Jordan	339.9	3.6
Kuwait	-	-
Lebanon	675.0	61.7
Libya	880.8	0.5
Mauritania	258.1	0.2
Morocco	10,047.7	14.0
Oman	25.1	0.1
Palestine	325.9	51.9
Qatar	-	-
Saudi Arabia	362.0	0.2
Somalia	1.6	0.0
Sudan	6,303.2	3.3
Syrian Arab Republic	3,573.9	17.5
Tunisia	2,753.4	16.7
United Arab Emirates	-	-
Yemen	709.6	1.5
Arab	**39,718.7**	**3.0**

Table 1. Areas and percentage of rainfed systems
Source: Ramankutty et al., 2008

The distribution of rainfed areas among Arab countries is provided below (Table 1). The region has about 40 million hectares of land under rainfed system. About 35 million hectares are cultivated with seasonal crops, mainly field crops such as cereals and legumes, while nearly five million hectares are covered with permanent crops, primarily tree crops. This compares with about 11 million hectares under irrigated agriculture composed of 8 and 3 million hectares of seasonal and permanent crops, respectively (AOAD, 2020). Nearly 88 percent of rainfed areas are located in 6 Arab countries: Morocco, Algeria, Sudan, Iraq, Syria, and Tunisia. The remaining Arab countries have relatively minor rainfed areas, although they might represent a large percentage of the country areas and contribute significantly to the livelihoods of rural communities (AOAD, 2020).

The growth of rainfed areas in the region is low, as most of the potentially suitable areas are already cultivated. Since the 1960s, cereals and legumes areas in the region have grown at less than 0.6 percent annually. In several Arab countries, the total rainfed area is stable though cropping pattern can change. For example, olives and other fruit trees are gradually occupying more cropped fields in the Mashreq countries.

Rainfed systems exists where annual rainfall is sufficient for permanent and economic cropping, which coincide with higher rainfall amounts (Figure 1 and Figure 2). Pockets of irrigated agriculture exist around water streams or other points of water resources within rainfed areas. In the Arab regain, rainfed systems are mainly temperate, as in North Africa and West Asia, and subtropical in Sudan and Yemen.

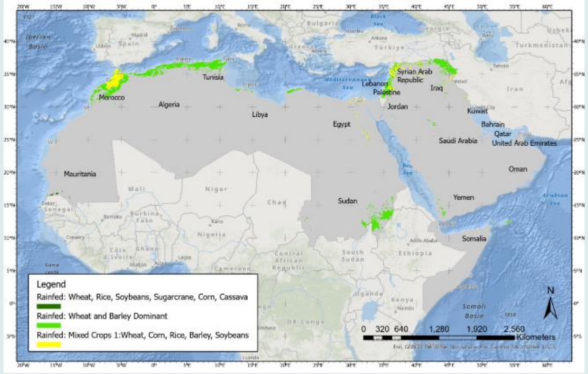


Figure 1. Rainfed agroecosystems in the Arab region.
Source: Ramankutty et al. (2008)

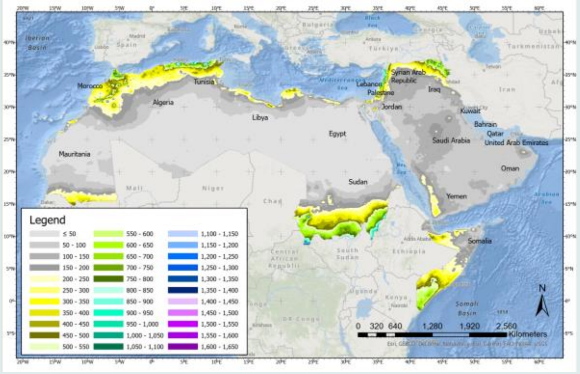


Figure 2. Isohyets of mean annual rainfall in the Arab region for the period 1981-2020
Source: Funk et al. (2015).

Note. Both maps were re-adapted by ESCWA to remove internal country borders

2.2. Rainfed Production Systems

Agricultural production systems are mainly characterized by the availability of natural resources. Water resources availability in the dry areas of the Arab regiondetermine the production system. While the availability of river and aquifer water resources define irrigated systems, rainfed agriculture is characterized by the dominance of rainfall and as such the annual amount of rainfall available defines the type of existing rainfed system (Ryan, 2011). Agriculture in dry environments could be classified into three principal agroecosystems, irrigated, rainfed, and agropastoral (Figure 3). Irrigated systems are mainly established in low rainfall areas with available surface water resources such as in the Nile basin in Egypt and Sudan, Euphrates and Tigris basin in Iraq and Syria and more limited areas in Morocco and other Arab countries. Agropastoral systems occupy most Arab land where limited rainfall is predominant, usually less than 250 mm annual. Though, some drought-tolerant crops such as barley may be grown they are known to host most livestock populations. Rainfed cropping systems start at around 250 mm annual rainfall in temperate climates and over 400 mm in tropical environments. In all cases, communities, soils, and topography impact the formation of these systems (Ryan, 2011).

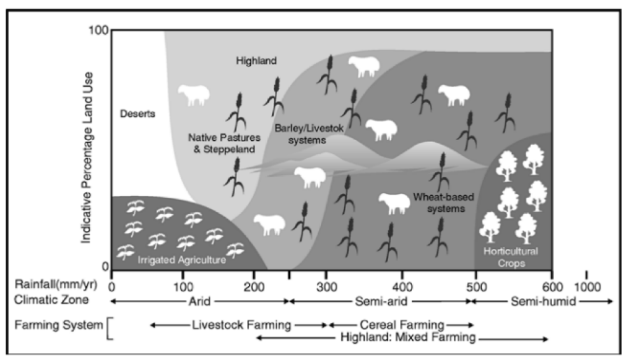


Figure 3. Farming systems across rainfall transect dry areas. Source: Ryan (2011)

Rainfed agroecosystems depend on direct rainfall to meet crops evapotranspiration requirements,. However, variations in seasonal rainfall amounts and drought spells or sequences of days without rains during the growing season imply that crops often suffer from moisture stress resulting in reduced and fluctuating production. Generally, the crops growing periods coincide with the rainfall season though farmers might also rely on residual soil moisture from the rainy season (Oweis and Hachum, 2012; Ryan, 2011).

Rainfed systems are located in two primary environments (FAO, 2015; Elhadary, 2015):

- The first rainfed farming systems is found in temperate climate-based rainfed farming systems with cold and rainy winters extending from November to April in North African and West Asian Arab countries. Rainfed systems in temperate climate are between 300-600 mm of annual rainfall at middle-latitudes with mild winters, but some are in the high-latitudes with more rainfall and cooler winters.
- The second rainfed farming systems is in semi-arid subtropical environments with warm rainy season in the summer as found in Sudan from June to September or Yemen around April-May, and again July-August. Rainfed cropping areas usually start around 500 mm annual rainfall, with the majority of cropping areas extending up to about 1000 mm.

The rainfed cropping systems change with annual precipitation levels in both climates. At lower annual rainfall, drought-tolerant crops such as barley and livestock dominate; at medium annual rainfall, wheat- and cereal based systems dominate including sorghum and millet in Sudan. Mixed cropping systems of wheat, corn, rice, and soybeans dominate at high rainfall. These characteristics lead to three dominant mixed rainfed production systems (FAO, 2015):

- The **Highland Mixed Farming System**: it prevails mainly in a small high-altitude area in Morocco, Algeria, and Yemen where annual rainfall exceeds 500 mm annually. In Morocco, it is dominated by rainfed cereal and legume cropping, with tree crops, fruits, and olives on terraces and vines while in Yemen, it includes qat and coffee. Often, livestock, mainly sheep and goats, is raised on communally managed lands under a transhumant system.

- The **Rainfed Mixed Farming System**: it is present where mean annual rainfall is between 300-500 mm on middle latitudes. It forms most of the productive rainfed areas in the region and is dominated by a wheat- and cereals-based system as well as tree crops such as olives and vines integrated with sheep and cattle. When water resources are available, summer irrigated agriculture is practiced, and limited supplementary irrigation is applied for rainfed crops to overcome drought.
- The **Dryland Mixed Farming System**: it is found in dry temperate areas, which receive an annual rainfall of between 200 to 300 mm and in subtropics from 300-400 mm at the margins of the mixed rainfed system. Population density tends to be lower than in the other farming systems resulting in larger average farm sizes. The main rainfed cereals are barley produced in a two-year fallow rotation. The livestock is mainly small ruminants, which interacts strongly with the cropping and fodder system. Low rainfall and relatively poor market linkages constrain the development of higher-value crops, such as fruits and vegetables (Oweis, 2017).

In the **Maghreb** region, almost all rainfed areas are located in the northern Mediterranean parts. Two subsystems can be found: (1) a highland mixed cropping system in higher elevations with mean annual rainfall exceeding 600 mm and very cold winters. It is dominated by cereals and legumes though some tree crops can be found, and (2) a moderately mild dryland systems at lower elevations with mean annual rainfall ranging from 300 to 600 mm. It has mixed tree crops, especially stone fruits and olives, cereals, wheat and barley, and legumes at lower elevations and rainfall amounts. These farming systems covers most rainfed areas in Morocco, 83 percent, Algeria, 88 percent, and Tunisia, 83 percent (AOAD, 2020).

In the **Mashreq** region, little highlands exist, and production systems comprise rainfed mixed farming and drylands mixed farming systems. The so-called fertile crescent extends from northern Iraq to north and west Syria with similar smaller rainfed areas found in Jordan, Lebanon, and Palestine. Mashreq countries share the same field crops in the rainfed areas, which are cereals, mainly wheat and barley, legumes, mainly lentil and chickpeas with small areas of faba bean and trees crops, olives in Syria, Jordan, and Palestine together with stone fruits and grapes and a mixure in Iraq and Lebanon. Seasonal crops occupy most of the rainfed areas in Syria and Jordan (68 percent), while permanent crops dominate in Iraq and Lebanon (56 percent) (AOAD, 2020).

In **Sudan**, the main rainfed area is in the southeast part of the country enjoys relatively high annual rainfall of 400-800 mm, in the warm summer from June to September. The main crops grown are sorghum, millet, sesame, and oil crops though it includes also transhumant livestock rearing and a significant production of of gum Arabic. In **Yemen**, there are two distinct growing seasons associated with the bimodal rainfall pattern of March-May and of July-September. Main crops include cereals, pulses, vegetables, fruit crops, and fodder that are short-term maturing and long cycle growing. Yemen faces inconsistent rainfall with farmers relying on risk-reducing strategies such as intercropping various cereals and pulses and staggered planting over time (AOAD, 2020; FAOSTAT, 2023).

2.3. Production and yields

Country records of cultivated areas, yields, and production in the Arab region are mostly aggregated for irrigated and rainfed systems. Only a few countries, such as Syria and Jordan, collect their national agricultural statistics disaggregating rainfed system production data. Aggregated crop yields and production records do not always reflect the reality of rainfed systems especially when a substantial portion of the cultivated area is irrigated with higher yields.

The region's production of cereals ranges from 50-60 million tons annually; less than half of it is rainfed. In general, rainfed yields in the region are among the lowest globally, partly due to aridity, practices, and other factors. Cereal yields in the region range from less than 1.0 to about 2.2 t/ha, with an average of about 1.9 t/ha. This is about half of the average yields in other developing countries (about 3.0 t/ha) and the world average (about 3.6 t/ha) and about a third of the developed world average (about 6 t/ha) (Figure 4). Annual cereal yields improvement rates in the region have also lagged those of the above world regions over the past three decades (ESCWA/FAO, 2016).

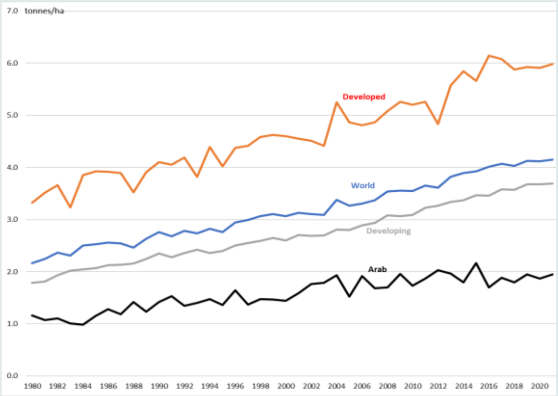


Figure 4: Trends in cereal yields.
Source: Based on FAOSTAT (accessed March 2023).

Over the last two decades, cereal yields contribution to production (35 percent) was about one-half of the contribution of the area expansion (65 percent). This is compared to 80 percent yield contribution and 20 percent area contribution for the developing countries and 95 percent yields contribution, and 5 percent area contribution for the world (FAOSTAT, 2023).

Tree crops productivity in rainfed areas of the Arab region is also low compared to other regions. Olives, grown as rainfed mainly in Morocco, Algeria, Tunisia, Syria, Jordan, Lebanon, and Palestine, have average yields of around 1.0 ton/ha, which is less than half the olive yields in other Mediterranean countries, such as Spain (2.5 t/ha), Greece (2.6 t/ha), Italy (1.8 t/ha), or Turkey (2.0 t/ha).

In the Maghreb region, the productivity of field crops, in general, is low with high fluctuation, especially in the mixed dryland systems where rainfall is lower and highly variable.

Cereal production in Morocco fluctuates greatly, depending on rainfall level with wheat yields being as low as 1 ton/ ha in dry years and reaching over 2.0 t/ha in wet years, for example in 2020-2021. The impact of rainfall was highly visible in the 2016 drought year in Morocco, with yields and production dropping below half of that in average years. Fertilizer use is still low and covers barely 50 percent of the actual need with quantities used on average well below the recommended doses. The mean consumption is about 50 kg fertilizers/ha (El Gharous and Boulal, 2016; AOAD, 2020; FAOSTAT, 2023). Similarly to Morocco, in Algeria wheat and barley dominate the cropping systems whereas grapes and olives are the major tree crops grown in rainfed areas. The agricultural sector dependence on rainwater affects its production levels, especially during droughts. Cereal harvest, for example, was severely affected by drought conditions that hit North Africa in 2000, leading to about half of normal yields only (AOAD, 2020; FAOSTAT, 2023).

In Tunisia, rainfed systems extend from the north through the central part, where rainfall exceeds 200 mm annually. The share of grains in the total cultivated land varies significantly with rainfall, especially in October and November. On average, however, field crops cover 1.7 million hectares of land distributed as 47 percent in the north and 53 percent in the central and southern parts of the country. In the wet north, the area under grain cultivation is relatively stable while it varies significantly in the central and south parts from one year to the other. Eighty-seven percent of the total area under tree crop cultivation is located in the center and south and is cultivated under rainfed conditions. Tree crops on average cover 1.9 million hectares (44 percent of total cultivated agricultural land), out of which 1.4 million hectares are under olive cultivation. Other plantations are mainly figs and stone fruits. The possibility of expanding rainfed systems in central and the south of Tunisia owes to rainwater harvesting. The annual expansion of olive cultivated areas in Tunisia is around 0.5 percent compared to 1 percent and 2.5 percent for Algeria and Morocco, respectively.

The low biophysical rainwater productivity in rainfed systems in the Maghreb region should be highlighted. Rainwater productivity is calculated based on an assumption of an average of 500 mm annual consumptive use for wheat across rainfed areas in the three countries (Figure 5). It ranges from around 2.5 to 4 kg grain/ha-mm of rainwater in the region compared to 10-20 kg/ha-mm in developed countries. The situation in other countries of the region is similar.

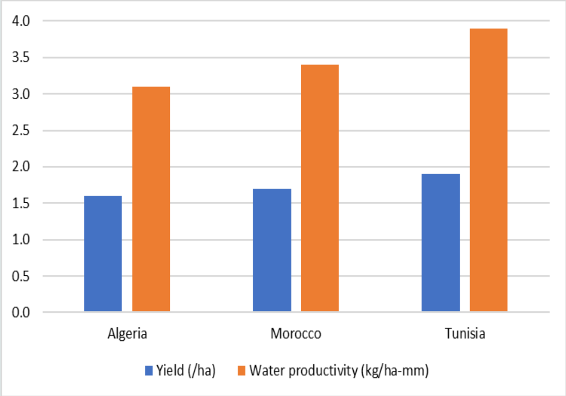


Figure 5: Yield, and rainwater productivity (WP) in the Maghreb countries.

In Mashreq, Syria and Iraq have the most rainfed areas, with small areas in Jordan, Lebanon, and Palestine. Unlike other countries, Syria disaggregates agricultural data into rainfed and irrigated in its national statistics records. Analysis of Syrian rainfed agriculture would largely represent the subregion as differences are small.

Cereals and legumes occupy the vast majority of the rainfed areas while tree crops are dominated by olives. Yields fluctuate significantly from a low of 0.1 t/ha in the extreme drought year of 2008 to over 2.0 t/ha in the very wet year of 2001 (Figure 6). Very low yields can be observed in the drought years of 2008 and 2018 drought years. But even in wet years, yields in Syria rarely exceeded 1.5 t/ha during the last 20 years (MAAR, 2020). This is compared to the yields of irrigated wheat, which range from 2.5 t/h to over 4 t/ha with much lower variability between years. Actually, it is not only the amount of rainfall that affects yields but also its distribution over the season and associated agronomic practices, including the shortage of essential inputs such as fertilizers. With supplementary irrigation, yields are much higher as they exceed 2 t/ha to reach sometimes 5-6 t/ha when other inputs such as improved varieties, nitrogen fertilizer, and other agronomic practices were applied (Oweis and Hachum 2012; FAO, 2021).

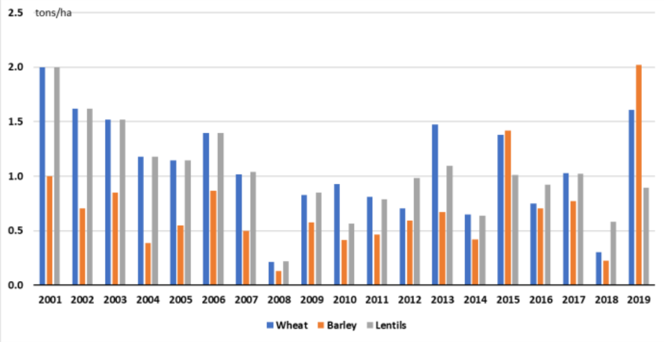


Figure 6. Wheat, barley and lentils yields in Syria. Source: MAAR (2020)

The situation regarding barley is no different. Yields ranged from as low as 0.127 t/ha in the dry year of 2008 to as high as 2.0 t/ha in the wet year of 2019. This is compared to irrigated barley yields of 2-3 t/ha. The impact of droughts in 2007, 2008, and 2018 is evident on barley yields like wheat, but as barley is more drought-tolerant than wheat yields are relatively better during severe droughts, and its variability over the years is smaller (Oweis and Hachum 2012).

Legumes are essential crops in Mashreq, especially in Syria, with lentil, chickpea, and faba beans occupying 60 percent, 40 percent, and 10 percent of the legumes area. Over the last 20 years, the yields of lentils ranged from 0.22 t/ha in the dry year of 2008 to about 2.0 t/ha in the wet year of 2001, with an average of about 1.0 t/ha.

Olives dominate rainfed trees production in Syria, Jordan, and Palestine (> 60 percent), with smaller-scale trees areas in rainfed sytems of Iraq. Olive plantations are expanding in Mashreq, taking the place of cereals, especially in mountainous areas. In Syria and Jordan, areas of olive plantations have increased at a rate of about 3 percent annually for the last 20 years. Due to its tolerance to drought and moderate inputs and services requirements that encourages farmers to replace higher-risk and lower-return field crops with olives. The yields of olives in the main producing countries of the region over the last two decades are highly volatile with those of Tunisia consistently the lowest (Figure 7).

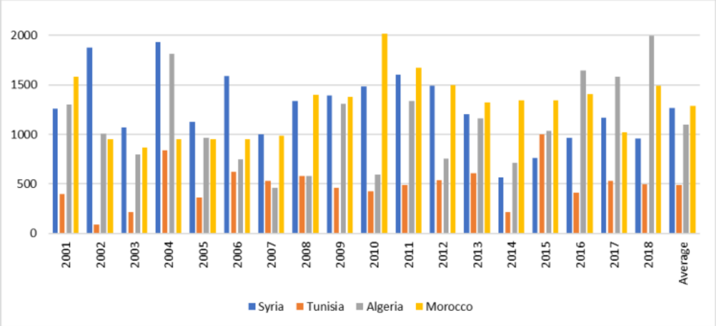


Figure 7: Olive yields (kg/ha) in major Arab producing countries. Source: AOAD, 2020

In the **Sudan** sub-tropic system, cereals are mainly produced under rainfed conditions except for wheat, which is mostly irrigated. Sorghum, millet, and sesame are the main crops grown in this system. The production of cereals fluctuates greatly depending on the rainfall amounts and distribution. Since 2015, production of cereal ranged from 6.8-8.0 million tons with over 60 percent sorghum; 30 percent millet, and 10 percent for other cereals. Cereals yields range from 0.4- 0.6 t/ha well below irrigated yields of around 2 t/ha (Figure 8). Rainfed agriculture in Sudan rarely benefits from fertilizers and other cultural practices, which leads to consistently low yields. Sorghum and sesame yields have also dropped by 70% and 64 % respectively from 1980 levels. As a result, production areas have expanded to maintain

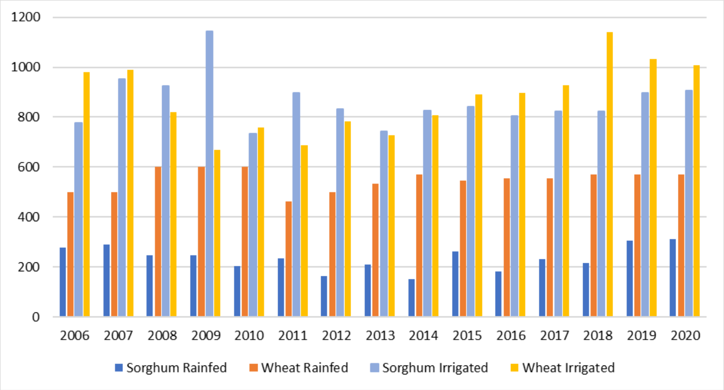


Figure 8:1. Yields of sorghum and wheat in rainfed and irrigated systems in Sudan
Source: MOAF-Sudan, accessed March 2023

production levels. Much of this expansion was towards the marginal areas, which causes further under performance (Elhadary, 2015).

In a similar environment in **Yemen**, cereals are the main rainfed crop, with small areas of legumes being grown. Sorghum and millet have grown annually on 0.3-0.4 million ha with a total production range from 0.2-0.3 million tons and yields range from 0.5-0.6 t/ha. Yemen produces also coffee and Qat in the highlands terraces using supplementary irrigation. Both are cash crops, and farmers can afford to invest in supplementary irrigation and to use more inputs (FAOSTAT, 2023).

3. Unlocking rainfed systems potential: opportunities and constraints

3.1. Opportunities to untap the potential

Area increase potential: There are few opportunities to expand rainfed cultivated areas in the region. During most of the twentieth century, the cultivated area in Arab countries grew faster than the world average. This growth has slowed since the 1990s, except in Sudan, where there are still opportunities to expand. The expansion of rainfed systems encroach on agropastoral rangelands where rainfall amounts are lower than needed for permanent and economic rainfed agriculture. Barley is already grown in this zone with high risk. Only through supplementary irrigation can this zone produce stably, requiring either reallocating groundwater resources or investing in water harvesting.

Given the impact of climate change, the future potential of rainfed areas is likely to shrink, not to expand. Rainfall is expected to decrease due to climate change at different rates across the region and over the years.

In the Moroccan highlands, for example, a reduction of the annual rainfall may reach 40 percent and in the upper Euphrates a reduction of 8-10 mm/month is projected by the end of this century. This means that some areas currently at the margins of the rainfed zone (200-350 mm annual rainfall) will be severely affected or will lose their production potential. In a scenario of 20 percent precipitation reduction occuring uniformly across the rainfed areas of the region by the end of the century, which is probably conservative, a the potential reduction in rainfed areas using satellite data wasestimated using the minimum rainfed cropping requirements of 200, 250, 300, and 350 mm annual rainfall (Funk et al., 2015). A reduction of rainfall by 20 percentwould also lead to a reduction in the potential rainfed areas in the countries affected (Table 2). The reduction could be as high as 8.4 percent (3.37 million hectares) of the areas currently being cultivated as land may be lost to other land uses. This does not mean a total loss, but those lands may be converted into rangelands or used for growing more drought-tolerant crops with lower production potential for example. The area lost may range from zero as in the case of Syria and Yemen for the zone above 200 mm to over 31 percent as in Libya for the zone above 300 mm. Knowing the shifts in the rainfall zones and the cropping systems would help strategize and plan for adaptation to the impacts of climate change.

	Minimum mean annual precipitation requirement							
Country	**200 mm**		**250 mm**		**300 mm**		**350 mm**	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Algeria	-		6,822	0.001	85,349	0.10	96,981	1.20
Jordan	14,318	4.20	32,643	9.60	55,566	16.30	89,714	26.40
Libya	2,302	0.26	180,641	20.40	277,322	31.30	120,836	13.60
Mauritania	11,235	4.20	204,880	7.70	28,258	10.50	9,913	3.70
Morocco	11,493	0.11	159,979	1.60	970,218	9.60	1,881,006	18.70
Palestine	6,565	2.00	10,503	3.20	680	0.20	9,908	3.00
Sudan	33,258	0.52	41,689	0.65	65,171	1.00	70,646	1.10
Syria	157,760	4.40	224,784	6.20	606,711	16.80	686,985	18.90
Tunisia	-	-	14,192	0.50	86,321	3.10	86,515	3.10
Yemen	-	-	72,405	10.00	217,620	30.40	299,840	41.80
Total (ha)	**236,931**	**0.60**	**941,716**	**2.40**	**2,307,867**	**5.80**	**3,370,572**	**8.40**

Table 1. Potential loss in rainfed areas estimated with a 20% reduction in annual precipitation. Source: Funk et al., 2015

Yield increase potential: Contrary to limited potential for horizontal expansion, there is considerable potential for yield increases for most rainfed crops in the region. Agricultural productivity is much lower in rainfed than it is in irrigated farming systems. Rainfed grain yields average around 1.0 t/ ha compared to about 3.0 t/ha in irrigated agriculture (Rockstrom et al., 2010evidence shows that the Arab region achieves 20-30 percent of its yield potential only with Syria, Morocco, Iraq, Jordan, and Yemen respectively at 32, 27, 19, 20, and 11 percent of their potentialt/ha (FAOSTAT, 2023; IMoA, 2020; AOAD, 2020). In Sudan's relatively higher rainfall subtropical areas, rainfed grain yields are at around 0.6 t/ha while the yield potential is 4 t/h, a gap of about 3.4 t/ha (Sederius et al. 2016). This is mainly due to low input use and poor soil-water storage capacity, as only less than 30 percent of the rainwater is stored and used by crops. Even worst results are reported for Yemen, with only 10 percent of the yield potential attained.

A large gap between rainfed actual and achievable yields in the Mediterranean basin suggests an enormous untapped potential for yield increases. Actual yields in Australia are 3-4 times the levels in this region.

In Morocco and Syria, the two primary environments for rainfed agriculture in region (Figure 9), farmers yields were compared to research station yields and the simulated potential at the specific environments. In Morocco, farmers wheat yields were about half that of the neighbouring research stations and about one-third of the simulated potential yield. In Syria, farmers wheat yields were about 54 percent of the research station yield and 44 percent of the simulated potential yields. In Tunisia, potential wheat yield is estimated at 4 t/ha with actual yields below 1 t/h or, only 25 percent of the potentiall (GYGA, 2021).

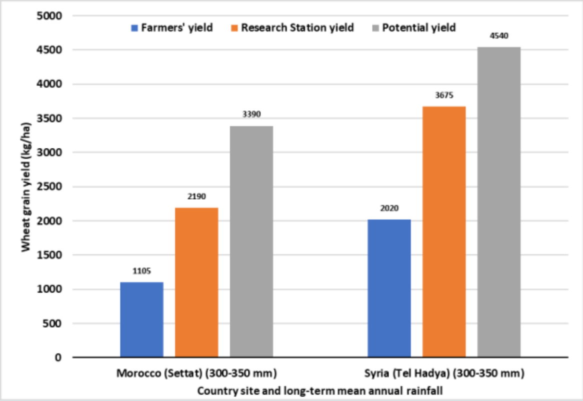


Figure 9: Average wheat yields under different scenarios in Morocco and Syria.
Source: Adapted from Oweis and Hachum 2012

The productivity gap in wheat yields has widened over time. Using currently available technologies, wheat yields could be increased by 60 percent to 150 percent in Morocco and 70 percent to 100 percent in Syria. There is a large untapped potential in rainfed agriculture in the region and ample empirical evidence indicates that yield levels in smallholder rainfed agriculture of the region can be doubled or tripled and, in many cases, even quadrupled Notably in the Arab Least Developed Countries, where yields are not only a fraction of the rest of the regions but have also remained stagnant for decades (Anderson et al., 2016).

Rainfed trees plantations also produce below their potential. Average olive yields over the last 20 years in Syria, Tunisia, Morocco, and Algeria were 1.3, 0.5, 1.1, and 1.3 t/ha, respectively. Irrigated olive plantations can produce over 10 t/ha, but the potential range is from 2-5 t/ha under rainfed areas, depending on rainfall amounts. This means a gap of over 75 percent for the region. Olives are considered drought tolerant. The yield gap in other less tolerant trees such as stone fruits and vines is even higher (MAAR, 2020; GYGA, 2021).

3.2. Constraints to untap the potential

Climatic constraints: The temporal and spatial variability of rainfall is the most critical constraint to rainfed agriculture improvement and yields, particularly in the Arab region. This factor will continue to be important for rainfed cropping systems as climate change sets in and reduces rainfall amounts and variability (ESCWA et al., 2017). The typical field crop season in the temperate climate zone of the region usually starts with rain in November-December and extends until June when most of the crops are harvested. Crop water needs often exceed total rainfall in those environments, causing absolute water scarcity. Analysis of the changes in soil moisture during the wheat growing season in a typical rainfed area in Syria showed that during winter months (December-March), when the rainfall is high and crop consumptive use is low, there is no moisture stress on the crop with average growth. Stress usually starts in March in the dry years, in April in the average years, and even in wet years when rainfall exceeds 550 mm, some stress occurs in May. This terminal drought occurs in the vast majority of the rainfed areas of the region and reduces crop yield sharply, especially when the stress occurs during the grain-filling growth stage(Oweis and Hachum, 2012).

One or more drought spells are common in the rainfed areas of most countries of the region though they are expected to increase in frequency and duration due to climate change (Verner et al., 2018). Coupled with low soil water holding capacity, drought spells cause crop failures, but their impacts will vary with the stage of the crop development, the climatic conditions and soil factors. In the semi-arid and dry sub-humid zone in rainfed zones of Sudan and Yemen, it is not always the seasonal amount of rainfall that is the limiting factor of production but rather the extreme precipitation variability, with high rainfall intensities, few rain events, and poor spatial and temporal distribution. Rainwater characteristics cannot be changed and are expected to worsen with climate change though they can be managed better and combined with farmers inadequate capacity to properly manage rainwater in the field further constraint to productivity improvement could be expected in te future.

Soils constraints: Crucial soil constraints to higher crop productivity include low soil water infiltration rates and storage capacity, poor soil fertility, and nutrient deficiency. Water storage capacity is a function of soil texture and depth, though other aspects such as soil structure and degradation processes might also affect infiltration rates and water availability for the crop. High storage capacity can keep more water in the soil to alleviate the impacts of drought spells, and in wet years, the soil can maintain more moisture to avoid terminal drought (Karrou and Oweis, 2014). Generally, soil storage capacity in the region is limited by soil depth, which varies from less than 0.5 m to slightly over one meter. Areas with higher depth soils are limited though in high rainfall areas with deep clayey soils, such as parts of Syria, Tunisia, and Morocco, rainfed yields could go up to 3-4t/ha.

Other factors that limit production in rainfed agriculture are associated with land degradation, including loss of organic matter and soil physical degradation, including nutrients and chemical degradation, erosion, and pollution. Nutrient depletion is now considered the main biophysical factor after rainfall that limit small-scale production in rainfed systems. Nutrient-poor soils limit growth even when water is not limiting. Most soils of the region have a nitrogen deficiency (Ryan, 2011) and research has shownthatapplying 50 kg N/ha would substantially increase rainfed wheat yields without any other interventions. This is because nutrients help the crop growth and uptake of water and other nutrients. In some soils, deficiency in potash and phosphorous is also apparent as an excellent response is obtained to their application in many types of soils throughout the region. Recent characterization of farmers fields in different countries across the region revealed a deficiency of micronutrients such as zinc, boron, and sulfur.

Adoption constraints: There are enough technologies and management packages available for farmers to bridge the yield gap. The problem is that most farmers in the region are not adopting thesedue to a lack of awareness or knowledge or low financial capacity, or both. The inability of farmers to invest in inputs, mainly fertilizers, improved varieties, pesticides, and disease control agents, is a problem in the region. It can be attributed to several technical, socio-economic, institutional, and policy factors. An enabling policy environment is critical to enhancing large-scale uptake and adoptionand key to the efficient use of scarce resources that could lead to farm income growth (World Bank, 2010).

Water and soil management technologies require investments that most farmers in the region cannot afford. Investments in agricultural technologies in rainfed areas is also risky. It may be attributed mainly to perceived to the low return environment facing the agriculture sector in general and rainfed systems in particular. Studies of Total Factor Productivity (TFP) show that public investments in agricultural R&D are a strong determinant of agricultural productivity growth in developed and developing countries. Governmental policies, including incentives and public investment, have been historically directed more toward irrigated agriculture because of the perceived higher returns (Siderius et al., 2016).

Weak extension systems, ineffective dissemination of new technologies, and weak seed production and delivery systems for improved crop varieties are also common issues. Adoption is also limited by labor shortages, insecure land ownership, inadequate access to capital, and limited skills and abilities. The significant inherent water-related risks in rainfed agriculture make some farmers less likely to invest in nutrients and other production-enhancing inputs even when they can do. Another issue is the small landholding in rainfed areas (0.5–2 ha), making it difficult to effectively use high inputs and appropriate agricultural technologies.

4. Unlocking the potential

4.1. Enhancing crop water availability

Strategy:

The availability of sufficient soil water for crops during the growing periods is a prominent factor in increasing crops productivity. Rainfed agriculture primarily depends on rainfall characteristics that are beyond the control of farmers. The risk of drought is also beyond thei command, and it is rising with climate change. Hence, rainfall is a critical input and a primary source of risk and uncertainty regarding production outcomes as there is always water stress with varying degrees during one or more stages of crop growth which negatively affect yields. To improve rainfed agriculture, in the absence of any control over rainfall, is to find ways to increase water availability through improved water and crop management.

Currently, there is not a sufficient focus on water resource management in rainfed areas . Rainfed systems investments tend to focus on aspects of erosion control, soil fertility improvement, pest control, and crop management to name a few. On the other hand, water is treated as an issue of in-situ water management to maximize rainfall infiltration and moisture conservation, which tend to overlood the management of available water resources to bridge periods of drought. This mismatch might be due to the lack of water allocation and management policies in rainfed agriculture. While water governing institutions addressed delivering water to households, industries, and irrigation schemes, institutions governing agriculture have focused on "dry" issues, such as soil management strategies for erosion control.

Water management in rainfed systems have to include surface water, groundwater and rainfall with the aim to increase the beneficial portion of evapotranspiration while decreasing unecessary evaporation by matching crop needs with soil water availability. Water availability in rainfed systems could be augmented through supplementary irrigation and rainwater harvestingwhich could be achieved through surface water and grwoudwater reallocation and better management of rainfall and effective use of runoff.

There are two ways to enhance soil-water status:

	In-situ	**Ex-situ**
Aim	Improving soil water storage to match crop needs	Applying supplementary irrigation at critical times to significantly increase productivities
Venues	Soil-water conservation, concentrating rainwater through runoff, and suppressing evaporation losses	Supplementary irrigation to
Reason	In semiarid areas, one-third to one-half of rainwater falling on rainfed crops is lost in evaporation without generating any benefits. Reducing this loss would increase the productive transpiration and increase yields, which would improve water productivity by shifting non-productive evaporation to productive transpiration thereby limiting also downstream water runoff by acting on physical soil conditions, soil fertility, crop varieties, and agronomic practices	Applying extra water at selected times of crop growth increases and/or stabilizes yields, i.e., drought-proofing and dry spell mitigation. Sources of water could include surface water, groundwater, treated sewage water and harvested rainwater. It has been shown that using a cubic meter of water in rainfed cropping in Morocco, Syria, and Tunisia, can bring higher net returns than using it downstream in irrigated agriculture with much lower environmental costs
Techniques/ practices	• Reducing evaporation by mulching soil surfaces with crop residues • Ensuring crop early vigor through crop genetic improvements and other cultural practices to reduce evaporation in the crop early stages • Maintaining a healthy crop increases its competitiveness in using water instead of losing it in evaporation	• Harnessing the water: ○ Diverting surface water, ○ Pumping groundwater, ○ Collecting rainwater, etc. • Irrigating: ○ Conventional surface irrigation ○ Sprinklers ○ Drip irrigation, etc.
Outcome	Concentrating rainfall in in-situ rainwater harvesting reduced evaporative losses by 40%. Eventually, increasing the ratio of Transpiration to evaporation would increase rainwater productivity	Securing water to bridge dry spells and to increase agricultural and water productivity by investing in practices like supplementary irrigation and rainwater harvesting.
Source	Oweis (2017); Oweis and Hachum (2012); Abu Zeid et al. (2019); Qadir et al. (2021)	

Practice: Supplementary irrigation:

Supplemental irrigation is a coping strategy to alleviate the negative impact of low and variable rainfall and drought spells on crop productivity. Small amounts of irrigation water are applied during the growing season when rainfall fails to cover crop water requirements. As a result, it overcomes moisture stress to increase and stabilize yields and water productivity. The critical importance of supplementary irrigation lies in its capacity to bridge dry spells thereby reducing risks in rainfed agriculture. By reducing risk, supplementary irrigation incentivizes investments in other production inputs such as varieties, fertilizer, labor, and tillage techniques and diversification. In farmer fields, yields of rainfed cereals and legumes can be doubled or tripled when small amounts of water are applied in critical periods over the season (Oweis and Hachum 2012).

To maximize gains from supplementary irrigation, an integrated package should be used. Responsive varieties, adequate fertilizers, weed control, and other cultural practices and inputs are necessary to get the best out of this practice. With such a package, yields increase by 35, 30, 25, and 10 percent were obtained for rainfed wheat through supplementary irrigation used in addition to crop variety, nitrogen, and other inputs, respectively (Oweis and Hachum 2012).

However, there are two major constraints to the wide adoption of supplementary irrigation in the region: the water source and the irrigation system.

Source of water: the amount of water needed for supplementary irrigation per unit area is only a small fraction needed compared to full-scale irrigated agriculture systems. Such small amounts can be collected from local springs, shallow groundwater, or conventional water resources and schemes during the rainy season. The reallocation of surface water and groundwater resources for supplementary irrigation may be a more beneficial and environmentally friendly option in many areas of the region as it provides higher marginal returns than irrigated agriculture (Abu Zeid et al., 2019). The other source for supplementary irrigation is rainwater harvesting as will be highlighted below. Non-conventional water sources like saline water, drainage water, and treated sewage water can also be used sustainably in for supplementary irrigation if adequately managed (Oweis, 2017; Qadir et al., 2021).

Irrigation system: When irrigation schemes are available for fully irrigated crops in the dry season, they can be used in the rainy season for supplementary irrigation with no additional investment cost. Examples include Rabea in Iraq, Tadla in Morocco, and the Euphrates river basin in Syria. Otherwise, farmers need to invest in irrigation systems to apply supplementary irrigation, which is one of the main challenges to expanding widely supplementary irrigation. Iirrigation systems might include the less efficient conventional surface irrigation including furrows, border strips, or basins, which are also labot intensive, or a mobile line source or gun sprinkler irrigation systems, which is more efficient though with a higher operational cost (Oweis and Hachum, 2012).

4.2. Enhancing crop water use

Strategy:

The aim is to increase the portion of the soil-water balance to maximize its productive part. A weak plant cannot uptake soil water even if it is plentiful. Crops need to be in good health to transform the uptaken water into transpiration and food. Often there is enough rainfall to at least double yields even in water-constrained rainfed farming environments such as in this region, but sometimes it is available at the wrong time, causing dry spells or is lost through evaporation, runoff, or deep percolation. Improving rainfed agriculture requires investing in soil, crop, and agronomic practices to maximize the ability of the crop to utilize the available water and nutrients for enhanced production. This may be done through integrated plant-soil water management to optimize transpiration

The crop itself is the first important factor to improve, which could be done through genetic improvement so it could better respond to prevailing conditions in the field. This includes developing crop varieties that are drought-tolerant and water responsive, with high transpiration efficiency, improved crop geometry including early vigor, high harvest index, and resistance to pests and diseases.

Agronomic practices that enhance crop growth and uptake of water and nutrients include proper nutrient management, optimal crop rotation, intercropping, organic matter management, pest and disease control, and conservation agriculture. These practices can increase the plant uptake of water. Appropriate planting dates, especially when supplementary irrigation is available, would ensure a crop calendar that matches good soil-water and favorable climate conditions and provide the potential to avoid unfavorable conditions such as drought and frost.

Practice:

Genetic improvements seek to improved product yield and quality, especially levels of protein in cereals and legumes. Genetic improvement relies on conventional breeding and biotechnology tools to identify and develop genotypes with wide adaptation and resistance to biotic and abiotic stresses. The improvement strategies focus on improving specific qualities such as yield and ensuring stability in highly variable environments by identifying sources of resistance genes for major pests and diseases, drought, heat, and cold tolerance. Some genetic improvement work focuses on responsiveness to inputs and water and nutrient use efficiency (Tadesse et al. 2016; Maalouf et al., 2018).

Using improved varieties of cereals and applying chemical fertilizers were the main drivers for the green revolution in the last century, mainly under irrigated systems. Many new crop varieties have been developed and released including many high-yielding varieities of wheat, barley, and legumes, which are adapted to the harsh conditions of the region. The relative performance of genotypes or crosses may vary in different environments, in which case the genotypes are said to interact with the environments and there is overwhelming evidence of this interaction under drought conditions. Critical is finding cultivars combining additional desirable traits, such as resistance to various diseases and insects and tolerance to cold and heat (Tadesse et al., 2016).

Semi-dwarf durum wheat including the cutivar “Cham” series, are widely grown in Syria with good results. The utilization and adoption of such varieties of wheat coupled with supplementary irrigation, fertilizers, and herbicides by Syrian farmers have increased wheat production significantly without a change in the area of wheat production leading to full self-sufficiency before recent events (MAAR, 2020).

4.3. Improving rainwater productivity

Strategy:

Rainwater productivity benefits from every drop of rainfall consumed, which is the yield per unit of water, and compares to land productivity as yield per unit of land. In the rainwater productivity framework, benefits include direct biophysical returns such as grain, biomass, milk and meat and other economic returns; such as income but also indirect benefits including nutrition such as protein and carbohydrate, and dietary energy; environmental benefits such as carbon sequestration, and social benefits such as employment. Unlike water use efficiency, the rainwater productivity framework is comprehensive and addresses farmer objective of maximizing economic return with all elements such as markets and value-added. Water use efficiency addresses mostly biophysical returns, especially grains while eluding economic returns per unit of rainfall and other benefits indicated earlier. The rainwater productivity framework is more comprehensive and reflects better the integration and value chain components, including markets and virtual water trade. As more water is consumed in rainfed than in irrigated agriculture, the potential to increase benefits by improving water productivity becomes more significant.

Much of the current focus is aimed at improving land productivity, with little attention devoted to increasing rainwater productivity. In rainfed dry areas, where water is more limiting than land, it is economically logical to seek maximum benefits per unit of water instead of land. However, the two indicators are not contradictory, and usually, improving one is likely to improve the other as well. When yields are low small improvements will generate large gains in water productivity. Enhancing crop yields are beneficial from both water-saving and income-enhancing perspectives. However, in many instances, such as in supplementary irrigation, adding large amounts of water in an attempt to maximize yields might lead to lower productivity and thus wastage of water.

Increasing biophysical rainwater productivity involves shifting non-productive evaporation into productive transpiration. Soil evaporation can be reduced by using adapted cropping partterns, e.g. mixed or intercropping, and agronomic practices, e.g., mulching, soil management, etc., matching crop development to water availability and genetic improvements to increase the harvest index and early vigor. Improved economic rainwater productivity requires changing cropping patterns to favor higher financial returns and maximize value-added processes. Considerations in adopting cropping patterns should include type of crop use (Oweis, 2017).

Policy change is needed at the country and regional levels to incite a modification of cropping patterns towards those that favor more water-productive crops, and creating an enabling environment for adopting water and agronomic practices. Bilateral or regional agreements can be used to emphasize on each country comparative advantage to produce crops with high rainwater productivity to enhance virtual water trade to deliver win-win arrangements.

Practice:

Agronomic practices play an important role in increasing rainfed crops productivity. Substantial differences in cereal and legumes grain yields are usually observed between neighboring farmers growing crops under the same rainfall and soil conditions but using different practices such as cropping paterrns, crop rotation or timely application of inputs and improved overall husbandry adapted for rainfed production systems. The most important practices include; nutrients management, conservation agriculture, and improved varieties.

a) **Nutrients management:** Nutrient deficiency and imbalances in rainfed soils are primarily responsible for decreasing yields and declining responses to improved soil water. Regular nutrient inputs to compensate for depleted amounts is essential to sustain crop production in rainfed areas. Fertilization is an important driver for enhancing yields and improving nutrient use efficiency. Nutrients can be biological, organic, or inorganic. Best practices promote soil organic carbon storage for optimum soil processes, maintain soil health, and enhance nutrient use efficiency for sustainable intensification. The most deficient nutrient in the regions of rainfed soils is organic matter. Consequently, nitrogen is significantly limited for growing economically cereal crops.   In many soils, phosphorus, potassium and micronutrients are also deficient, so understanding soil nutrient deficiencies and supplying them can improve rainfed systems productivity and resources efficiency.

b) **Conservation agriculture** is an important strategy for sustainably enhancing land productivity and moisture conservation. The practice is applied as an integrated package based upon three principles: i) minimum tillage and soil disturbance, ii) permanent soil cover with crop residues and live mulches, and iii) intercropping. Conservation agriculture improves many soil organic carbon content compared to conventional agricultural systems. This significantly improves soil physical, chemical, and biological properties and productive capacity thereby stabilizing yields, controlling soil erosion, increasing tolerance to drought, and improving soil nutrient levels (Page et al. 2020).

   The practice is already being used in countries such as the United States, Latin America, or Australia, but remains limited in the Arab region. However, the region has a growing interest in testing and disseminating conservation agriculture methods and some progress has been made in Syria, Morocco, Iraq and Sudan and Morocco. Nevertheless, there are challenges to adopting conservation agriculture in the region including maintaining the crop residue as mulch on the soil surface, while it is often used as animal forage as well as the need to develop alternative strategies to manage weeds, especially when farmers cannot apply herbicides, or developing low-cost planting machinery and management skill at the farm level.

c) Other **agronomic practices** might include optimal crop geometry, seeding rates, planting dates, integrated pest management, corp rotation, mixed and intercropping and integrated crop-livestock management. Most farmers in the region lack the financial or necessary knowledge to adopt optimal cultural practices.

4.4. Adopting climate-smart rainfed agriculture

Strategy:

The impacts of climate change on rainfed systems in the region are substantial on both areas and productivity. To cope with those impacts, strategic changes must be implemented to convert traditional rainfed production systems to climate-smart systems. This would be associated with mitigation measures to reduce emissions and a more critical adaptation measure and productivity enhancement (Nangia and Oweis 2016).

Climate-smart rainfed systems may sustain food production. Adaptation and climate-friendly productivity improvement may be achieved by breeding varieties that are better adapted to thermal shocks and drought. Short-term strategies take advantage of more favorable growing conditions or offset negative impacts, including shifting sowing dates, changing species, cultivars, cropping patterns, and rotations, modifying soil management and fertilization, and introducing or expanding supplementary irrigation and rainwater harvesting. The challenge is to design cropping systems in a multifunctional perspective, requiring some tradeoffs in changing crops or moving them to more favorable environments (ESCWA et al., 2017).

Practice:

Rainwater harvesting is an ancient practice whereby rainwater is directed, through runoff, to a suitable storage facility before being utilized in various beneficial uses, including agriculture. Runoff occurs naturally in watersheds because soil infiltration rates are lower than precipitation rates. Rainwater harvesting structures slow down runoff and provide enough infiltration opportunity time for storing water in the soil for direct use by plants, as the case with micro catchments, or in storing it in surface reservoirs or aquifers, as the case in macro-catchments, for later use in agriculture such as in supplemental irrigation. Slowing down runoff allows storage and better use, reduce soil erosion, and saves amounts otherwise lost in evaporation or evaporated from salt sinks. This is an important alteration of the degradation processes in the watershed and makes rainwater available for rainfed agriculture. In drier environments where rainfall is not enough to grow crops economically, rainwater harvesting allows the concentration of rain from a larger catchment into smaller agricultural plots for a higher amount of water per unit area, allowing economic agriculture and reducing risk (Oweis, 2017).

Micro catchments rainwater harvesting increase water storage in the soil profile for immediate use by plants. And because rainwater harvesting occurs during the rainfall season, it refills the soil profile as water was lost during evapotranspiration. It reduces the impact of drought spells by ensuring soil water availability at the end of the season and during dry period. Micro-catchment techniques are low cost and simple to manage, especially since they can be done within the farm.

Macro-catchments rainwater harvestinginvolves collecting runoff water from large catchments so it could be stored on surface or ground reservoirs or to recharge groundwater to be used later for supplementary irrigation. In some cases, it can be the only source of surface water and groundwater resources available for supplementary irrigation in many rainfed systems. Surface reservoirs are usually small to medium-size and are traditionally built by constructing small, often earth, dams across peripheral streams with appropriate spillways. The primary constraint is the investment and operating costs of the reservoir. Storage efficiency can be increased by adopting a strategy of emptying each fill in the soil profile of agricultural land and refilling again, keeping the last filling for later use (Oweis, 2017).

5. Creating an enabling environment for rainfed system development

Farmers in the Arab region who depend on rainfed agriculture are the poorest and have limited options to improve their livelihoods. Many try to supplement their income with nonagricultural employment, but opportunities are limited in rural areas, and as a result tend to migrate to urban areas. The development of rainfed agriculture aims to improve the quality of life of farmers. Development may focus on an integrated farming system to enhance productivity, minimize climatic variabilities, and reduce risks. This may be achieved by adopting appropriate farming system-based approaches, diversified and composite farming systems, employment opportunities, and convergence of relevant developmental programs in different sectors and institutions. Rainfed agriculture can be improved with better rainwater and fertility management to reduce rural poverty (IFAD, 2016).

5.1 Investmenting to mitigate against risk

The dryland mixed rainfed system receives less annual rainfall, having poorer soils and people and cropping have a higher risk than other rainfed systems. There are few prospects for intensification and sustainable system development without improved water resources management. Farmers in the rainfed areas of the region are generally poor and consistently lag behind in applying improved technologies, adopting advanced practices and managing resources more effectively and efficiently. At the same time, and due to the high risk associated with rainfed agriculture, investments from both the private and the public sectors are limited as priorities are geared towards irrigated agriculture. Over the past few decades, efforts were exerted to improve water management in rainfed agriculture in World Bank-supported projects in the region though they remained to less than 15 percent of those for the irrigation and drainage sector. However, returns to further investments in irrigated agriculture have plateaued meaning that similar investments in rainfed agriculture could provide better returns notably if risks associated with unfavorable rainfall characteristics are removed notably through increased water availability.

Investments in rainfed agriculture have large payoffs in yield improvements and poverty alleviation through income generation and environmental sustainability. However, there will be a need for a partial shift in water resource allocation towards rainfed farming for its stabilization and improvement. Investments in rainfed agriculture have been also mostly geared towards land management and improving drought tolerance through agronomic practices and varieties, for example, with little aimed at the most limiting resource, the water, to reduce the risk of and alleviate the impacts of drought and drought spells. Investing in supplementary irrigation, for example, has shown excellent results in Syria and in Tunisia, where they have achieved similar outputs to irrigated systems using only a fraction of the water. Applying only 50-100 mm during drought spells more than doubles yields and water productivityas increased water availability lead to better responses to fertilizers and other inputs (Oweis and Hachum 2012).

Investing in rainwater harvesting is needed as it could also help reducerisk in rainfed agriculture. In olives plantations in Tunisia, farmers developed and applied creative water harvesting practices to overcome water shortages and as a result established an economical and sustainable olive production system adapted to low and variable rainfall zones. Promoting conservation agriculture could also offer possibilities to increase in-situ crop water availability though it would decrease the crop residue for livestock feed. Highlands mixed farming systems might also offer opportunities to reduce rainfed agriculture risk though it might require heavy investments in terraces and integrated watershed management options that most farmers would not be able to afford.

With increased water availability, genetic improvement strategies may shift to responsiveness to water in addition to the current focus on drought tolerance. Making water more available to crops would offer great opportunities to maximize the benefits related to the use of other inputs. For example, the recommended dose of 50 kg/nitrogen per ha under a purely rainfed system could be increased to 100-150 kg/ha with more available water, such as in supplementary irrigation, which could enhance yields substantially. Investment in supplementary irrigation and rainwater harvesting has a large potential to increase Maghreb and Mashreq yields. Investment in integrated crop-livestock and watershed management could also help improve system returns (FAO, 2015).

5.2 Enabling policies

Solutions to upgrade rainfed agriculture appear to be technical, and several have been identified. An enabling environment to adopt those solutions and attract adequate investment is needed. Farmers cannot drive alone the change and create a better conducive environment without adequate enabling policies. Governments should consider retargeting agricultural support to give prominence to rainfed agriculture. They can focus on removing residual impediments to adoption of innovative solutions through an enabling environment where spontaneous dissemination can be expected. Government enabling policies may include providing incentives, simplifying access to credits and loans, securing land tenure and property rights, reducing land fragmentation, supporting the adoption of integrated approaches, providing modern extension services, enhancing access to markets, supporting farmers cooperatives for both inputs and outputs, providing necessary infrastructure, and strengthening sustainable natural resource management.

Payment for environmental services is an innovative approach that could help provide incentives to farmers to adopt soil and water management techniques. Groundwater resources are currently overused in most aquifers of ther egion. Groundwater tables are dropping fast, and quality is deteriorating in most Arab countries as in some cases, they are being used to produce low-value crops in fully irrigated agriculture. For example in Jordan, groundwater is used to produce barley for animal feed at a rate of 0.5 kg/per cubic meter at a value of 0.2 US$/per cubic meter at a time when the value of one cubic meter of water is 1.5 US$. There are more examples from the region where water productivity because of the crop choice. Policies are needed to better reallocate of the dwindling groundwater resources to generate the highest water productivity. This might include reallocating the water to rainfed agriculture, which would more significantly improve livelihoods in rural areas. Although strategies and policies in some Arab countries acknowledge this, appropriate regulations are still not adopted and implemented due to political consideration. However, there is an increasing realization of the need to develop policy options that address this kind of tradeoffs. For example, an innovative incentive-based policy approach could be developed that is based on a credit system to improve agricultural resources management whereby, for example, water credits could be given to interested farmers and landowners by others or other sectors as payment for increased water availability. These credits could be used for example to build terraces, water reservoirs and other rural infrastructure or to adopt beneficial agronomic practices such as mulching and others that improve soil water retention and carbon stocks

Subsidies are proven instruments to drive agricultural activities in the right direction. Unfortunately, they are usually subject to internal politics thereby leading to opposite results. For example, policies of import subsidies depress local prices and make it difficult for local producers to compete. Subsidizing animal feed inflates animal populations that overgraze and degrade natural pasture lands. Well targeted subsidies can promote the adoption of advanced technologies and sustainable practices that support rainfed systems. These include conservation agriculture machinery, supplementary irrigation systems, improved seeds and fertilizers, and rainwater harvesting infrastructure. Policies could also be used to control a range of actions and practices with significant adverse environmental impacts sucha as frequent, deep plowing, excessive use of pesticides, or excessive groundwater extraction (Searchinger et al., 2020).

Policies to support rainfed agricuture should be based on two criteria, economic efficiency and social equity, with priority being devoted to regulatory measures to improve access and use of land and water resources and technology development and dissemination for the poor. In the Arab region, these two criteria are seldom considered across the agriculture sector, meaing that rainfed systems are often excluded from major programmes and strategiesnotably when compared to irrigated agriculture and other economic sectors despite a few cases concerning supplementary irrigation in Syria and in Tunisia on a minor scale. Applying both criteria in the allocation of resources would likely result in more of the available resources being spent on rainfed systems to maximize economic returns. Particularly, a stronger emphasis on social equity would benefit poor rainfed farmers.

Creating an enabling environment to maximize private sector financing has proven more effective and sustainable than direct public funding. Essential components of an enabling environment may target agricultural finance policies, smart regulations, and well-established financial infrastructure.There is significant room for the region to improve its regulatory and policy environment noting that a combination of policies and actions would likely lead to a greater impact for an enhanced environment that support rainfed agriculture (AMF, 2020).

5.3 Institutional setups

Communities of the region have inherited a great wealth of indigenous knowledge that allows them to better cope with drought, water scarcity, and climate variability. Developing new practices for today and future conditions and adopting modern technologies require that stakeholders' organizations be supported with sufficient finance, training, and better institutional structures. Communities should lead the development and adaptation to changes, including implementing water-efficient and climate-smart rainfed practices.

There are different types of organizations for farmers and communities in rainfed areas. They address many issues of concern for their livelihoods, including for collective machinery, marketing products, facilitating credits, and sharing common natural resources. However, a common feature of these organizations is that they are generally weak with internal conflicts, and poorly financed with low capacity to manage, innovate and lead. This characteristic has been a major obstacle to upgrading rainfed agriculture. Governments strive to empower those organizations but come short of delegating them enough power to manage their business and resources so they could take major investment and finance decisions. As a result, their capacity to implement integrated packages and adopt innovative technologies is limited. It is widely reported that farmers participation is low, and a formal mecahnisms for involving them is also absent. One of the most serious issues hindering efficient rainfed systems management is the weak, if not absent, role of users' organizations in the decision-making process.

Policy frameworks can lead to successful interventions when linked to suitable institutional structures and human capacities. Rainfed agricultural management is mainly at the field scale. Interventions like rainwater harvesting, or supplementary irrigation require planning and management at the watershed scale, as utilizing runoff water may impact downstream users and ecosystems. Legal frameworks and water rights for collecting local surface runoff are required, as are human capacities for planning, constructing, and maintaining supplementary irrigation and rainwater harvesting systems and their operation and management.

A systems perspective on planning and managing activities in rainfed systems should be used and then adopted by the local planning bodies, which would benefit by extending their representative membership to include all stakeholders who can participate in decision-making. Public institutions may establish strong local farmers' institutes to develop technical interventions and improved practices. The participation of farmers in the planning and management process through their institutions can ensure equitable benefits to all producers and strengthen the ownership of natural resources. There is a need for more equitable regulations and control of shared resources that can only take place effectively with the participation of stakeholders. Older management systems may need additional measures and a modern legal basis to consider new capital financing needs.

Individual farmers may not afford the initial costs required for implementing interventions. So, investments in local institutions, such as farmers' organizations and small-scale credit schemes, are particularly important. Investments are also needed to build farmers' institutions and extension service personnel to upgrade rainfed systems. Training of extension agents is crucial for adopting new techniques to boost rainfed agriculture.

The role of women in rainfed agriculture is substantial. However, they generally take a backseat when it comes to the decision-making and leadership of farmers' institutions. Women's institutions in rural areas mainly deal with secondary issues. Reforms are needed to empower women and the young to participate in the planning and management of those institutions. Young people in rural areas are increasingly migrating to urban centers for more attractive jobs and improved income. Particular focus is needed to upgrade the capacities of young farmers and small-scale women farmers and women's labor on new technologies and practices and management, finance, and leadershipwhich requires empowering local communities which could be achieved by developing inclusive institutions for responsible and transparent delivery of services (ESCWA, 2019a).

5.4 Research for development

Enough technologies and practices to upgrade rainfed agriculture have been produced. The problem is that upscaling these solutions at a large scale is happening at a much slower rate than developing them. Focus should be directed towards overcoming adoption constraints. Farmers who are not adopting either might not know about them, their application and potential or might not afford be able to provide them. In all cases, there is a need to know the underlying cause of the low adoption rates and to develop programmes and strategies to reverse the trend. Farmers would have to be reached to to formulate with them pathways to allow them adopt and invest in already improved technologies and practices at a much greater rate. There would be a need as well to look more closely into potential institutions, livelihood strategies, and social, economic, and political that might be required to boost adoption rates.

Often interventions come in slowly and haphazardly thereby lowering their impacts and visibility even when farmers apply. Stakeholders involvement in the research and development of suitable technologies and practices is essential to ensure their suitability and the likelihood of their adoption. The integration of technical, socioeconomic, cultural, and policy aspects will be necessary for meaningful results in rainfed agriculture. As the system is subject to rainfall uncertainty, new approaches to strengthen adoption may include providing more information about local climate and weather conditions, such as the prediction of seasonal rainfall, the onset of rains, or specific rainfall events. Little is done in the region on providing near real-time data on rainfall patterns. Other lacking services and advisories include risk management, payment for environmental services, and ex-ante and ex-post impact assessments (World Bank, 2021).

The vast majority of countries of the region do not separate national data on rainfed agriculture from irrigated agricultural data. Only in seldom cases can one find data on purely rainfed systems notably in research stations. Even when rainfed systems are reported separately, as in Syria and Jordan, the indicators reported are only areas, yields, and total production. Little data is available on spatial and temporal rainfall and variability, evapotranspiration, and soil moisture levels. In rainfed systems, this is important to distinguish the pattern of variability in the different years before and after an intervention. To conduct a meaningful analysis of the barriers to improved productivity and develop a specific solution and approaches to upgrade rainfed agriculture, separate and more complete rainfed systems databases are needed. Rainfed systems are complex and thus ac omprehensive monitoring and evaluation is needed to provide assurance that enough insights is available to have a robust framework for planning future interventions.

6. Conclusions

Rainfed agricultural systems in the Arab region are not performing as they should. Yields are low due to unfavorable precipitation and land degradation but more importantly due to the low efficiency of resources management and use. Rainfed agriculture will continue to play a critical role in providing food and generating livelihoods, especially for poor rural communities. With rapid population growth and climate change, the system will not be able to cover current food needs. There is limited potential for horizontal expansion of the system, while a reduction in rainfed areas due to lower precipitation and a higher temperature is likely with climate change. The only option available is increasing the productivity and resilience of the system sustainably. This may not be possible unless the level of attention devoted to rainfed agriculture in the future is drastically increased as in the past it was only a fractions of the attention given to irrigated agriculture.

Upgrading rainfed agriculture in the region through increased productivity requires a strategic change in risk management associated with water scarcity. The key is to increase crop water availability and use through improved water management at the field and watershed levels together with the associated agricultural inputs. A strategic focus on rainwater productivity vis-à-vis land productivity would help adjust cropping patterns to maximize returns thereby converting it into a climate-smart rainfed production system. This cannot be achieved without substantial investment to alleviate production risks and upgrade the system. There are enough technologies and practices to unlock rainfed systems potential, but a good enabling environment to adopt and implement those solutions is lacking. This will include efforts involving institutional capacities, policy frameworks, knowledge generation, and finance.

Supplemental irrigation is a key practice, still underused, for unlocking rainfed yield potential and improving water and land productivities. When combined with rainwater harvesting, much of the risks associated with drought and drought spells may be alleviated with substantial productivity gains. Increasing water availability and use will also create conditions to use more inputs such as fertilizers and realize the potential of improved varieties and practices, making further productivity increases. Soil and water conservation practices have been the focus of most of the investment in rainfed agriculture with limited success. Increased investment in water management practices such as supplemental irrigation and rainwater harvesting is necessary for upgrading the system.

Strategies of water resources allocation and management do not sufficiently address increasing scarcity in the region. Rainfall is the entry point for the governance of freshwater resources, including surface water and groundwater resources. Adopting an integrated water resources management strategy would lead to better water allocation that could also benefit rainfed agriculture. The divide between rainfed and irrigated agriculture needs to be reconsidered by rethinking the governance, investment, and management paradigm, which accounts for all water use options in agricultural systems. Breaking this divide will be an important step toward re-aligning institutional priorities and increasing investments in rainfed agriculture. The reallocation of water resources, especially groundwater, to supplement rainfall may be more economical and socially equitable than using it in irrigated agriculture. Policy to keep groundwater in rainfed areas as a reserve to cope with drought should be considered.

Monitoring and assessing various indicators in rainfed agriculture are necessary to improve the system. Unlike irrigated agriculture, the significant variability in rainfall and other resources make it difficult to distinguish and evaluate those variabilities from one year to the other and before and after interventions. In most Arab countries, the accessible national records of primary agricultural indicators are not disaggregated for rainfed and irrigated systems. It is therefore difficult to evaluate the performance of rainfed systems alone. Furthermore, only a few indicators are recorded, such as yield, production, cropped areas, and farm income while data on crop water use, soil moisture changes, and drought spells is only available in research stations. Thus, it is important that annual data is collected for rainfed systems and that databases include sufficient information for proper assessment and monitoring of the system.

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