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Soil Fertility and Challenges Facing The Agricultural Sector in Jordan

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National Agricultural Research Center (NARC)

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General overview

- Jordan is a small, middle-income country with insufficient supplies of water, oil, and other natural resources (MWI, 2015).
- Jordan has a total area of 89,318 km^2 mostly desert land (MOA, 2013),
- Only 5.7 % is suitable for cultivation (El Zuraiqi, et al., 2004).
- The country is classified as semi-arid to arid region with annual rainfall of less than 200 mm in about 90% of the land.

Map of Jordan

- According to the national census conducted in November 2016, the total population is 9.5 million with an average growth rate of 2.2% which is higher than the world average of 1.7%,
- The number of Jordanians is around 6.6 million, while the non-Jordanians is around 2.9 million (30.6% of overall population) (MWI, 2015).

- The country is characterized by a relatively young population, with 37.3% of its inhabitants below the age of 15.

- The average family size is 5.4 persons, and the national unemployment rate is 12.2 %.

- Jordan has five agro-ecological zones (AEZs) based on the annual rainfall levels (MOA, 2013).
-
- The rainfall factor is the common element that determines the land use in each zone (**Table 1**).

Table 1: Jordan's Agro-Ecological Zones, Annual Rain Levels, Area and Land-use.

Agro-ecological Zone	Annual rain (mm)	Km^2	Area (%)	Land use
1. Arid	<200	79,412	89	Range, irrigated cereal & forage
2. Marginal zone	200-300	5,620	6.3	Wheat & barley
3. Semiarid	300-500	1,338	1.5	Wheat, barley & food legumes
4. Subhumid	500-800	892	1.0	Fruit trees
5. Jordan Valley	200-350	1,070	1.2	Vegetables, fruit trees, irrigated cereals
6. Water bodies		986	1.0	
Total		89,318	100	

Water Sector

- Jordan suffers a harsh water situation where the country is heavily dependent on seasonal rainfall.
- Jordan ranks as the **second** water-poorest country in the world.
- Less than 100 m^3 of annual renewable water resources is available per person (below global line for absolute water scarcity of 500m^3) (MWI, 2015; 2017).

- It is worth to mention that the water scarcity in Jordan is aggravated by two principal factors (IWM, 2015):

1. **Climate change impacts**
2. **Population growth**

Table 2: Water uses in different sectors in Jordan in the year 2017 (MWI, 2017).

Water uses	Surface water	Groundwater	Treated Wastewater	Total volume	Percentage
	MCM				
Domestic	131.3	338.4	0	469.7	45
Agriculture/ Irrigation	154.4	253.2	144.2	551.8	52
Industry	2.4	27.2	2.5	32.1	3
Total	288.1	618.8	146.7	1053.6	100

Agriculture sector

- Jordan's agriculture sector has been growing stongly and has doubled its contribution to the country’s gross domestic product (GDP) in the last years, from 2.0% to 4.0% (MOA, 2013);
- In 2016, the Jordanian agriculture exports represented approximately 18% of Jordan’s exports;
- The Gulf market is considered the main importer of the fruit and vegetables (82% of the total imported) (Jordan Investment Commision, 2017).

Agriculture sector

- The importance of the agricultural sector stems from the fact that it is:

1. The major source of **food products**,
2. One of the sources of **hard currencies** earned from exports.
3. An important source of **employment** in rural communities, where about 20% of the total poor in Jordan live in rural areas depending mostly on agriculture (MOA, 2013).

Table 3: Major Crops grown in Jordan.

Fruit trees	Field crops	Vegetables
Olives	wheat	Tomatoes
Citrus	barley	cucumbers
Bananas	maize	potatoes
Dates	Chick peas	Watermelon
Grapes	Clover	peppers
Apples	Vetch	squash
		cauliflower

Table 4: Irrigated and non-irrigated cultivated areas (ha)for fruit trees, field crops and vegetables, in 2015, 2017 and 2018, in Jordan (DOS, 2015; 2016; 2017; 2018).

Crop	Non-Irrigated Area			Irrigated Area			Cultivated Area		
	2015	2017	2018	2015	2017	2018	2015	2017	2018
Fruit Trees	38,762.7	36,268.9	36,330	47,654.4	41,794.5	42,060	86,417.1	78,063.4	78,390
Field Crops	121,724.0	65,989.0	89,290	9,682.5	7,684.2	7,240	131,406.5	73,673.2	96,530
Vegetables	2,629.6	719.6	2,870	46,143.3	36,976.2	34,580	48,772.9	37,695.9	37,450
Total	163,116.3	102,977.5	128,490	103,480.2	86,454.9	83,880	266,596.5	189,432.5	212,370

Table 5: Area and yield of major fruit, field and vegetable crops, in 2015, 2017, and 2018 in Jordan.

Crop	Area (ha)			Yield (ton)		
	2015	2017	2018	2015	2017	2018
Fruit Trees						
Olives	63,883.2	56,214.1	56,210	200,896	145,332	N/A*
Citrus	6,395.5	6,421.1	6,460	127,211	108,385	N/A
Grapes	3,830.7	2,893.9	2,980	62,265	53,509	N/A
Dates	2,669.1	3,222.6	3,370	20,141	25,419	N/A
Bananas	892.8	715.6	730.0	46,835	33,935	N/A
Peaches	1,945.0	2,749.6	2,750	37,289	69,473	N/A
Field Crops						
Wheat	25,811.5	12,190.8	13,790	21,925	12,110	N/A
Barley	95,325.6	56,458.2	77,060	40,486	48,954	N/A
Maize	939.6	1,261.6	500	26,362	37,179	N/A
Chick peas	1,286.3	463.5	950	1,708	1,509	N/A
Clover	6,011.0	2,308.5	2,320	244,223	100,935	N/A
Vetch	830.9	491.2	990	1,145	191	N/A
Vegetables						
Tomatoes	12,887.1	12,194.5	10,110	870,017	690,477	N/A
Cucumbers	2,410.2	1,654.2	1,940	231,982	190,847	N/A
Potatoes	7,255.8	4,008.2	3,800	188,326	155,639	N/A
Watermelons	2,629.4	1,488.2	1,460	116,494	95,527	N/A
Peppers	2,440.3	2,220.0	2,060	86,677	68,566	N/A
Squash	2,664.8	2,757.3	1,780	64,777	72,091	N/A
Onion	1,723.9	1,809.2	2,180	54,666	66,552	N/A
Broad beans	2,472.9	566.2	860	11,647	8,727	N/A
Cauliflower	2,300.7	1,384.4	970	72,258	46,449	N/A
Eggplants	2,323.6	1,964.1	1,610	77,015	65,319	N/A
Lettuce	1,463.4	1,364.9	870	57,751	57,934	N/A

Main cropping systems

1. **Irrigated agriculture:** It is taking place in the Jordan Valley and the highlands
2. **Rainfed agriculture:** It is occurring in areas where rainfall exceeds 250 mm, although significant production of cereals does occur in some areas where rainfall is between 200 and 250 mm.
3. **Olive trees Farming:** There are about 15 million olive trees grown in Jordan mainly under rainfed conditions.
4. **Bee keeping**

Main cropping systems

5. **Medicinal herbs and aromatic plants:** The main crops in local markets are: – mint, parsley, sage, oregano, fennel, purslane and coriander
6. **Field Crops**
7. **Vegetable Production**
8. **Fruit Production**
9. **Livestock systems:** Animal production contributes significantly to the agricultural gross domestic product (Sidahmed, 2011).

Soil fertility status

- Farmers in Jordan started to use chemical fertilizers in agriculture, primarily in irrigated areas, since 1960s (El Zuraiqi, 2004).

Soil fertility status

- In Jordan, like other arid and semiarid regions, **limiting water resources and increasing concerns for groundwater contamination** by agricultural pollutants, like nitrate, are forcing farmers to **improve irrigation and fertilization efficiency**.

- **Fertigation** is considered the most effective management tool for both nutrient and irrigation water under scarce water conditions.

- It is the technique of injecting water soluble fertilizers via irrigation water, proportionally, using modern fertilizer injectors.

- About 95% of farmers in Jordan use drip irrigation system which is the most convenient system for fertigation.

- As a modern technique, fertigation provides an excellent opportunity to:

1. maximize crop yield;
2. enhance crop quality;
3. minimize environmental pollution by controlling fertilizer application.

Fertigation techniques applied in Jordan

Fertigation techniques applied in Jordan

1. **By-pass tank (traditional injector)**
   - The common and oldest fertigation technology which is simple and cheap (**Figure 1**).
   - This injector was adopted by farmers at the end of 1970s commenced with the introduction of pressurized drip irrigation systems.

Figure 5: Fertilizer Bypass tank (a conventional injector). (A quantitative approach)

- The principal **disadvantage** linked to the use of this device, is that the concentrations of nutrients diminishwith time during the irrigation period, as there is no control over nutrient concentrations.
- This is because the dilution ratio and the injection rate are not constant.
- Thus, water soluble chemical fertilizers are added to the crops **quantitatively** using this instrument.

2. Electric Pump

- At the middle of 1990s, farmers started to inject chemical fertilizers through the irrigation system using an electric pump (**Figure 2**).
- Its **disadvantages**, there is no control over the nutrient concentration in the irrigation water (**a quantitative approach**).
- And **electricity** is needed as a power source.
- **Corrosion** from chemical fertilizers might also takeplace to the internal body of the pump.

Figure 2: An Electric pump with a suction pipe as a fertilizer injector. (A quantitative approach)

3. Hydraulic injectors

- The **new precise** hydraulic devices have been used by the Jordanian farmers since the beginning of 1990s to **control the application of nutrients more efficiently**.
- The nutrient **concentration** in the irrigation water can be **controlled** accurately by hydraulic injectors, where a **proportional** approach is followed (**Figure 3**).

Figure 3: A hydraulic injector (SuperDos 45), as a tool to inject soluble chemical fertilizers proportionally into the irrigation line.
(A proportional approach)

Hydraulic injectors

- **Irrigation water** is the source of **power** for driving these proportional injectors.

- The variation in the irrigation water flow rate does not affect the injection of the fertilizer solution, since the injector injects the solution **proportionally**, regardless of the flow rate.

Hydraulic injectors

- the high **prices** of this type of injectors and the need for high **skills** in its operation and maintenance comprise the critical issue in the adoption among farmers.

4. Venture injectors

- The venture injector type is **simple** and **cheap** (**Figure 4**).
- the concentration of the **nutrient** in the irrigation water **fluctuates** during time,
- its operation needs high **pressure difference** (33 % of the operating pressure).
- This is considered the most important drawback for this type of injectors.

Figure 4: A venture Injector as one of fertigation technologies available for farmers.

5. Automatic Injection systems

- Recently, farmers in Jordan have used programmable automatic injection systems to make **more control over nutrients concentrations** in irrigation water and **pH correctione** (reduce alkalinity).
- The optimum range for the pH of the irrigation water is 5.5 to 6.5 for plant **nutrient availability** (**Figures 5, 6 & 7**).

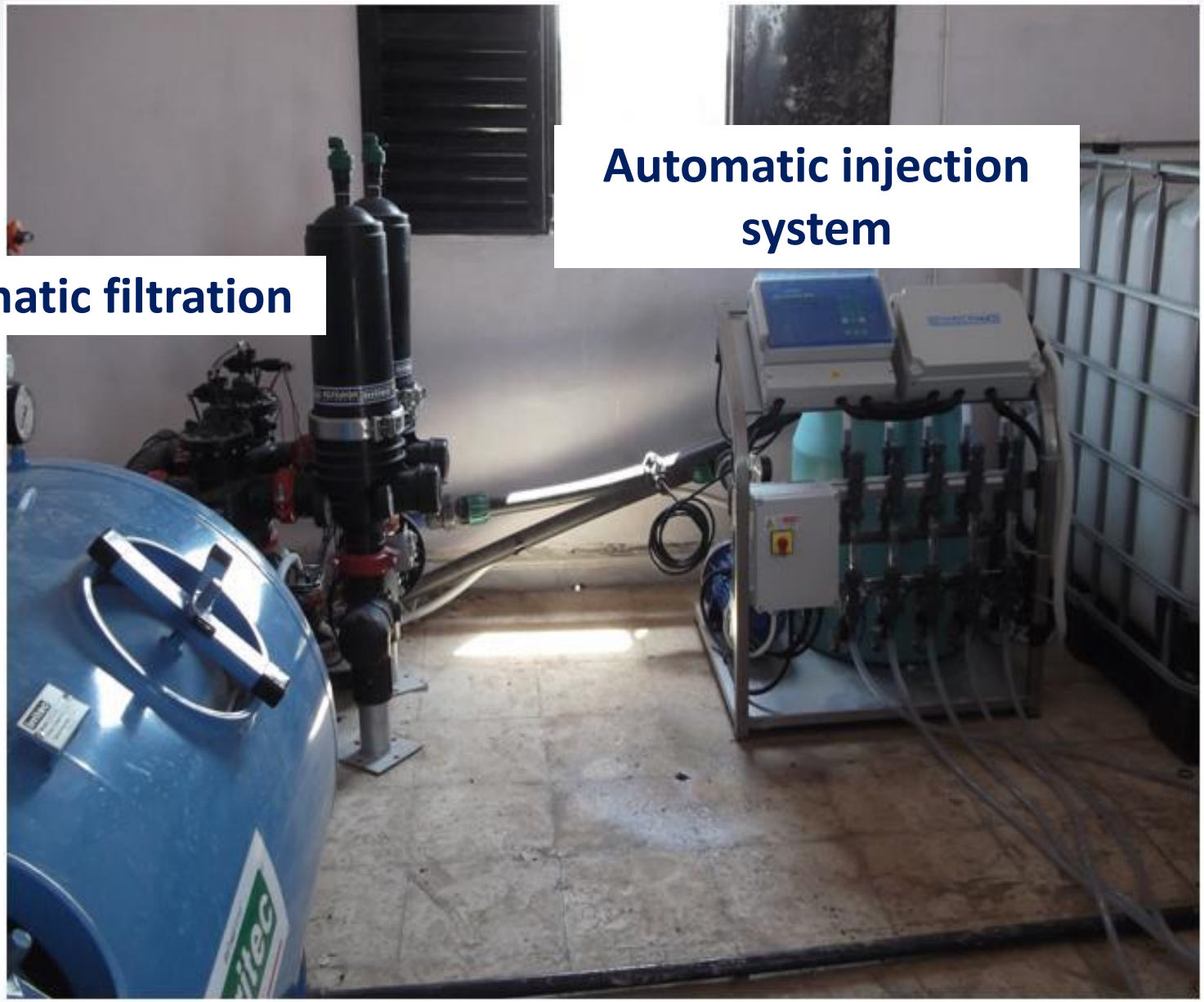

Figure 5: An automatic injection system with a full control over pH and salinity of irrigation water, and more accurate nutrient concentration.

Figure 6. A control unit of an auto injection system to make a better control over pH and salinity (nutrients concentrations) of the irrigation water.

Figure 7: An electric valve to control irrigation events.

- The system can inject the correct quantities of acid and fertilizers needed to maintain the irrigation water according to the values set by the farmer through pH and EC sensors.

- To ensure the correct supply of nutrients for optimal growth to crops.

- However, this more **advanced fertigation** technique is used mainly to **large agricultural projects and hydroponic** systems (soilless culture) for its high **cost** and **skills** needed in its operation and maintenance.

Main chemical soil properties in Jordan

1. Calcium Carbonate: 13%, in highland - 37%, in Steppe zone. Majority of soils is calcareous;
2. Clay content: 23%, in Badia (desert) - 51%, in highland);
3. PH: 7.2 - 8.4;

Main chemical soil properties in Jordan

4. Organic Matter: Low content, 0.37%, in Badia- 1.47%, in Jordan Rift Valley;
5. Soluble Salts: Generally Increase with decreasing rainfall, 2.5 dS/m, in Jordan Valley- 60.1 dS/m, in Badia;
6. Gypsum: 5.0%, in Jordan Rift Valley- 15.2%, in Badia (Alfraihat, 2015).

Environmental Challenges

- **Desertification** is considered the major environmental problems facing soil fertility in Jordan (MOE, 2014);
- Desertification is considered the main environmental problem affecting natural resources in arid, and semi-arid climatic zones, like Jordan.

Environmental Challenges

- Desertification is a process that involves a combination of:

1. Vegetation degradation,
2. Soil erosion by water and wind,
3. Increased soil salinity and alkalinity,
4. Soil compaction and crust formation.

Environmental Challenges

- Salinization occurs in conjunction with poor irrigation management that causes accumulation of salts in the root zone.

Environmental Challenges

- Most of Jordan's arid and semi-arid areas have suffered desertification, where roughly 90% of the country is classified as 'drylands (MOE, 2014).

- Irrigated highlands and the Jordan Valley have been affected by increasing soil salinity and alkalinity.

Environmental Challenges

- Among activities that have contributed to land degradation include:

1. plowing,
2. overgrazing of natural vegetation in the rangelands,
3. and excessive woodcutting in forested areas (MOE, 2014).

Environmental Challenges

- The World Bank estimated that the economic cost of environmental degradation in Jordan in 2004 was 3.1% of GDP annually.

Sustainable land management/soil conservation Projects

- There are some projects that have been undertaken which have shown some success in improving environmental conditions and combating desertification.

- These projects can be listed in the following:

Sustainable land management/soil conservation Projects

- **1-Rangelands Improving Project/ Ministry of Agriculture**
- Supervised by Forestry and Range Directorate.
- -27 range reservations have been established with total area of 75000 ha (Alfraihat, 2015).
- **2-High Land Project/ MoA:** Establishing soil conservation measures like stone walls, terraces etc.

Sustainable land management/soil conservation Projects

- **3- Zarqa River Basin Project/MoA:**
- -Covers 82.5 thousand ha of the private owned agriculture lands.
- -Proper extension, implementing the proper conservative measures and planting the proper plants.
- -Improving the range and forest lands and protecting the Zarqa River sides.

Sustainable land management/soil conservation Projects

- **4-Hammad Project/MoA:**
- - Improve the rangelands for a good livestock production and improving the water sources.
- **5-Afforestation and Forest Management projects/MoA**

National Strategy and Action Plan to Combat Desertification

- It aimed to deal with a range of associated environmental issues (MOE, 2014):

1. to combat desertification
2. to mitigate the effects of drought.

National Agricultural Research Center (NARC) role in soil conservation

- NARC with the other national institutes carry out studies and implement activities in order to:

1. improve the management of the agricultural areas,
2. increase Agricultural productivity,
3. combat desertification,
4. optimize water use,
5. improve soil conservation,
6. protect biodiversity,
7. conserve the natural resources.

Government *Subsidies*

- Combating Desertification was seen as the top national priority as it was related to improving the livelihoods of local communities.
- 'Soil Conservation Measures to Combat Desertification' has a high priority in research activities of the country.

Government *Subsidies*

- The Jordanian government provides direct subsidies to those who implement SLM **(Sustainable land management)** measures.
- These **subsidies** could be in the form of **non-monetary arrangements**, such as providing **technical** assistance, and the supply of **seeds** and **plants** (MOE, 2014).

Fertilizer Sector in Jordan

Fertilizer Sector in Jordan

- Jordan was among the world's **ten producers of phosphate rock and potash (**Taib, 2015.
- The manufacturing sector, including fertilizers production, contributed **19.2% to the country's gross domestic product** (GDP) in 2013.

Fertilizer Sector in Jordan

- There are different fertilizers producers in Jordan that produce different forms and kinds of chemical fertilizers.
- For example, **Phosphate Mines Co**. (JPMC), produces:

1. **phosphate rock**; 8.023 Mt in2018.
2. phosphate-based **fertilizers**,
3. **phosphoric** and sulfuric acids.

Fertilizer Sector in Jordan

- On the other hand, **Arab Potash Co.** (APC) which is the only producer of potash in Jordan; 2.436 Mt of **potash** in 2018 (JPM Co, 2018.).
- Other producers, like Arab Fertilizers and Chemical Industries Ltd. (**Kemapco**), produces **potassium nitrate** and **dicalcium phosphate**.

Fertilizer Sector in Jordan

- Jordan production of some phosphate and potassium fertilizers are presented in **Tables 6 and 7, respectively.**

Table 6: Production of the industrial fertilizer complex (thousands tones) during 2014-2018.

(China is the first and Jordan is the fifth in the world phosphate production in 2018).

Product	2014	2015	2016	2017	2018
DAP Fertilizer	590	344	396	379	632
Phosphoric Acid	292	238	228	264	281
Sulphuric Acid	932	780	738	839	856
Phosphate	7,144	8,335	7,991	8,688	8,000
Phosphate/China					140,000*
Phosphate/World					247,000*

Jordan Phosphate Mines Co. Annual Report 2018.

Table 7: Potash Production of Arab Potash Company (Million tones) compared with world production during 2014-2018.

Year	2014	2015	2016	2017	2018
Jordan	2.1	2.4	2.0	2.3	2.4
World	66.5	66.5	61.2	63	62.7

Arab Potash, Annual Report 2018.

- Jordan also **imports** different types of **fertilizers** (straight fertilizers and compound, solid and liquid) to cover the local market needs, as presented in **Table 8**.

Table 8: Kinds and amounts of imported fertilizers (tons) in Jordan in the years 2008-2018.

Year	Nitrogenous Fertilizers	Phosphorpus Fertilizers	Potassium Fertilizers	Compound Fertilizers	Secondary and Trace elements
2008	27,767	291,1	5,288	9,760	-----
2009	22,621.9	534,8	2,607	8,774.152	-----
2010	-----	1,451	-----	11,788.39	1,5
2011	21,175	493,2	220,1	13,410	2,186
2012	25,006	973	845	922,304	2,964
2013	20,406,997	801,9	264,35,1	8,534,845	2,180,236
2014	14,670,225	223,451	417,71	12,010,6	427,647,2
2015	10,589,897	730,700,1	931,1	17,417	678,332
2016	15,337	931,5	30,038	6,129.753	3,155.574
2017	13,113,2	1,555,5	431,48	13,092	2,301
2018	12,511,8	1,474,875	675	11,699,45	2,149,749

Ministry of Agriculture, Land and Irrigation Directorate, Annual Reports, 2008-2018.

- The value of fertilizers exports and imports during 2014 - 2018 are shown in **Table 9**.

Table 9: Jordan Fertilizers exports and imports (millions J.D.) during 2014-2018.

Year	2014	2015	2016	2017	2018
Export	303.2	151.5	137.9	148.4	189.3
Import	35.1	32.5	33.4	25.7	23.6

Department of Statistics, Statistical Yearbook of Jordan , 2018.

Official or common Fertilization recommendations (Fertilization management)

1. Fruit trees: Table 10;
2. Vegetables: Table 11;
3. Fertigation of major crops: Table 12;
4. Field Crops: Table 13.

Table 10: Nutrients recommandations for major fruit trees (kg/ha)

Crop	Age	Spacing m	N	P_2O_5	K_2O
Apples	years	4 x 5	kg/ha		
	1		60	30	100
	2-4		60-120	30-60	100-200
	5-8		120-180	60-120	200-250
	9-12		180-240	120-180	250-300
Oranges	1	5 x 5	40	25	50
	2-5		40-100	25-50	50-100
	6-10		100-200	50-100	100-200
	11-15		200-250	100-200	200-250
Olives	1	6 x 6	30	20	40
	2-4		30-60	20-40	40-80
	5-8		60-120	40-80	80-120
	9-14		120-160	80-120	120-160
Apricots	1	5 x 6	50	50	50
	2-4		50-100	50-100	50-100
	5-8		100-200	100-150	100-200
	9-12		200-250	150-200	200-250
Grapes	1	2 x 3	100	100	100
	2-4		100-200	100-200	100-200
	5-8		100-150	100-150	100-150
	9-12		150-200	150-200	150-200
Bananas	1		100	50	200
	2		200	100	250
Date Palms			120	70	330

Table 11: Nutrient recommandations for major vegetables (Kg/ha) in Jordan.

Crop	Tomatoes	Cucumber	Pepper	Eggplant	Beans
Nutrient	Nutrients requirements (kg/ton)				
N	2.8	1.8	2.1	2.9	8.7
P_2O_5	1.3	1.3	1.1	0.7	2.7
K_2O	3.8	3.0	4.2	5.0	10.7
	Expected yield (ton/ha)				
	100	50	40	60	30
	Nutrients recommendation (kg/ha)				
N	280	90	84	174	261
P_2O_5	130	65	44	42	81
K_2O	380	150	168	300	321

Table 12: Recommended average concentrations for N, P K nutrients in Irrigation water (g/m^3) using fertigation for some major crops based on local trials in Jordan.

Crop	Nitrogen (N)	Phosphorous (P)	Potassium (K)
Tomato/ protected (under greenhouse conditions)	50-60	30-50	100-150
Tomato/open field	80-100	30-50	100
Potato	80-100	35-50	100
Pepper	80-100	40-50	100-200
Egge plant	85-100	40-50	100-150
Cucumber	60-100	30-40	50-100
Squash	80-100	40-60	80-100
Citrus trees	30-50	15-30	40-60
Apples	40-60	20-30	40-60
Olives	30-50	15-25	30-50
Bananas	20-40	20-30	50-70
Date Palm	40-60	20-30	50-70

Field crops Fertilization

- **Field crops** in Jordan are grown under rainfed conditions and **rarely being fertilized (**Khattari, et al., 2011**)**.
- **Productivity** of cereal crops,**wheat** in particular, in rainfed areas in Jordan is **low**
- Wheat is grown in different **rotations**, including fallow, legumes, and summer crops.

Field crops Fertilization

- Low productivity of wheat crop is due to

1. low and poor distribution of **rainfall**,
2. inherited low **fertility**,
3. absence of crop **rotation**,
4. removal of crop residue (low **organic matter**)
5. and minimal or no use of **fertilizers**, especially nitrogen.

Field crops Fertilization

- Therefore, farmers are encouraged to fertilize wheat crop, especially in regions receiving mean annual rainfall more than 350 mm,
- This is to make sure that the soil moisture is sufficient to solubilize the added fertilizers and there is no problem regarding osmotic stress.

Table 13: Wheat crop recommended fertilization program in Jordan.

Fertiliser	Di Ammonium Phosphate (DAP) $(NH_4)_2HPO_4$ 18-46-0	Urea $(NH_2)_2CO$ 46-0-0	Sulfate of Potash K_2SO_4 0-0-50
Application Rate (kg/ha)	55	100	60
Time of application	Before seeding	At tillering stage	Before seeding

Fertilizer use challenges facing farmers and the country

- **At the farmers level**

I. **Drought/rainfed** areas/lack of adequate soil moisture in rainfed areas to solubilise chemical fertilizers (drought and water scarcity);

II. **Economic** issue/fertilizers cost and availability

III. Fertilizers **quality/salt** index;

IV. Lack of appropriate fertilizers **recommendations** (rate of application) based on soil and plant **analyses**- farmers' conviction;

Fertilizer use challenges facing farmers and the country

V. Method of fertilizers application: soil **application** (least efficient), via irrigation water (fertigation, the most efficient);

VI. Soil **alkalinity** (high pH) and high calcium carbonate contents (calcareous)-P and micronutrients **availability/fixation**.

Fertilizer use challenges facing farmers and the country

- **At the country level**

1. **Economical** issue/Import, export and production-hard currencies;
2. **Environmental** issue: soil degradation (salinization and alkalinisation), soil and water resources pollution (heavy metals, nitrate), GHGs emissions associated with fertilizers production and use.

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