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IRRIGATION SYSTEM PERFORMANCE: SYRIAN COUNTRY REPORT

A. Kaisi[*], M. Yasser[**] and Y. Mahrouseh[***]
[*]ANRR/GCSAR, Ministry of Agriculture and Agrarian Reform, Syria, E-mail: ak-gcsar@scs-net.org
[**]Dept. of Geology, University of Damascus, Syria, E-mail: yasser-m@scs-net.org
[***]General Union of Peasants, Syria

SUMMARY: In this work are presented the most important aspects of irrigation practices and irrigation systems performances in Syria including the data and information about water availability and use, water resources development and application of modern techniques in irrigation. The impact of rapid population growth and socio-economic development to the qualitative and quantitative changes of water resources is highlighted. In order to mitigated with the water shortage problems, an emphasis should be given to the use of more efficient irrigation techniques, construction of new accumulations, and use of non-conventional water resources. Guidelines for the policies and measures of sustainable development in water sector are given comprehending all necessary actions: from water resources assessment and comprehensive water plan to water use rationalization, modernization of water legislation and promotion of sustainable water use and establishment of water user associations. A necessity for the rehabilitation of already existing irrigation systems and delivery networks is also underlined.

Key words: water resources availability, water resources development, irrigation systems performance, Syria.

INTRODUCTION

Over the last 30 years of socio-economic development, the Syrian natural resources particularly water and land resources had an increasing attention since the agricultural sector will remain the mainstay of development process and a source for people food at a time food security is one of the most complicated problems at national, regional and international levels.

Population growth and socio-economic development for all various activities started to create a growing pressure on water resources, leading to qualitative and quantitative changes of these resources. These resources form the most complicated and difficult circle due to their limitedness as compared to the increasing and rapid demand on water by all human activity sectors (agriculture, domestic uses, industry,….etc.), considering that the country as other East Mediterranean countries is characterized by low rainfall with annual and seasonal variations together with low use efficiency in agriculture that consumes more than 80% of total water uses.

Hence, it is necessary to take a range of integrated measures for keeping the equilibrium between the available resources and their demand under the framework of resource conservation from pollution and depletion and in the manner that ensures the sustainable development of all economic activities.

Accordingly, several guidelines and decisions related to water conservation and maintenance, and good operation and utilization of water projects and expansion were issued. Emphasis was on vertical and horizontal expansion by constructing dams and drilling wells in renewable-water areas.

Additionally, great emphasis is given to water use rationalization through the use of modern irrigation techniques, expansion of dam construction, use of closed circuit in industrial water and factories, and use of non-conventional water resources like drainage water and wastewater was largely emphasized.

Due to the growing role of water in Syria's socio-economic development. The government paid attention for unifying the supervision agencies over water sector, so the Ministry of Irrigation had been established since 1982 to undertakes the following responsibilities:

- Study of water resources: their development, protection, pollution control and uses.
- Study and design of irrigation projects and land reclamation and what relates to these projects in terms irrigation and drainage structures and dams, and implementation or supervision over the implementation of these projects.
- Operation and maintenance of irrigation and wastewater systems and pumping stations.

In 1986, a law in which the country was divided into seven water basins was issued. Accordingly, general directorates were established for these basins.

To maximize WUE, the Water Research Center was established to conduct specialized research on water resource development and improvement, irrigation projects development and establishment of Administration of Natural Resource Research (ANRR) for implementing research aiming on-farm water resource management rationalization and improvement.

NATURAL CONDITIONS IN SYRIA

Location and area

Syria, which population estimated at /18.392/ million on annual rate 2.7%, lies on the eastern coast of the Mediterranean Sea between longitude 36 – 42 east and latitude 32 – 37 north. It is bounded by Turkey to the north, Iraq to the east, Palestine & Jordan from the south and by Lebanon & the Mediterranean Sea to the west.

Syria's total area is 185,180 km^2, of which 61,000 km^2, equal to 32.9%, are cultivable land. The rangelands and forests cover about 89,000 km^2 i.e. 48% and the remained is uncultivable land.

Population

Syria belongs to the high-rate population countries as indicated in the following census:

- 2.3 million in 1921;
- 4.6 million in 1960;
- 6.3 million in 1970;
- 9 million in 1981;
- 13.8 in 1994;
- 18.392 in 2003, with a growth rate ranging between 2.7 – 2.45%.

Climate

Mediterranean Sea's climate prevails in Syria, where three climatic areas can be mentioned:

- *the costal area,* directly affected by the Mediterranean Sea and characterized by moderate climate and heavy rainfall;
- *the mountainous inland area,* characterized by moderate climate and moderate rainfall;
- *the desert region,* characterized by low rainfall and high temperature in summer and coldness in the winter season.

Rainfall (Tables 1 and 2 and Figure 1)

In Syria, precipitation starts between October and May. Rainfall varies from one region to another; in the coastal western mountains the rainfall is regular while it is varied and semi-regular in the inland regions. In the steppe, the rainfall is often irregular and forms rainy storms in Autumn or Spring. Rainfall amount varies from one year to another. Annual precipitation ranging 700 – 1000 mm in the coastal and western heights, and they gradually decreases as of 500 mm in the wet region to 100 mm in the eastern-south steppe. This is attributable to the morphological situation of Syria, so that coastal heights hinders the wet winds coming from the Mediterranean sea and the same for Toros mountains that hinder northern wet winds.

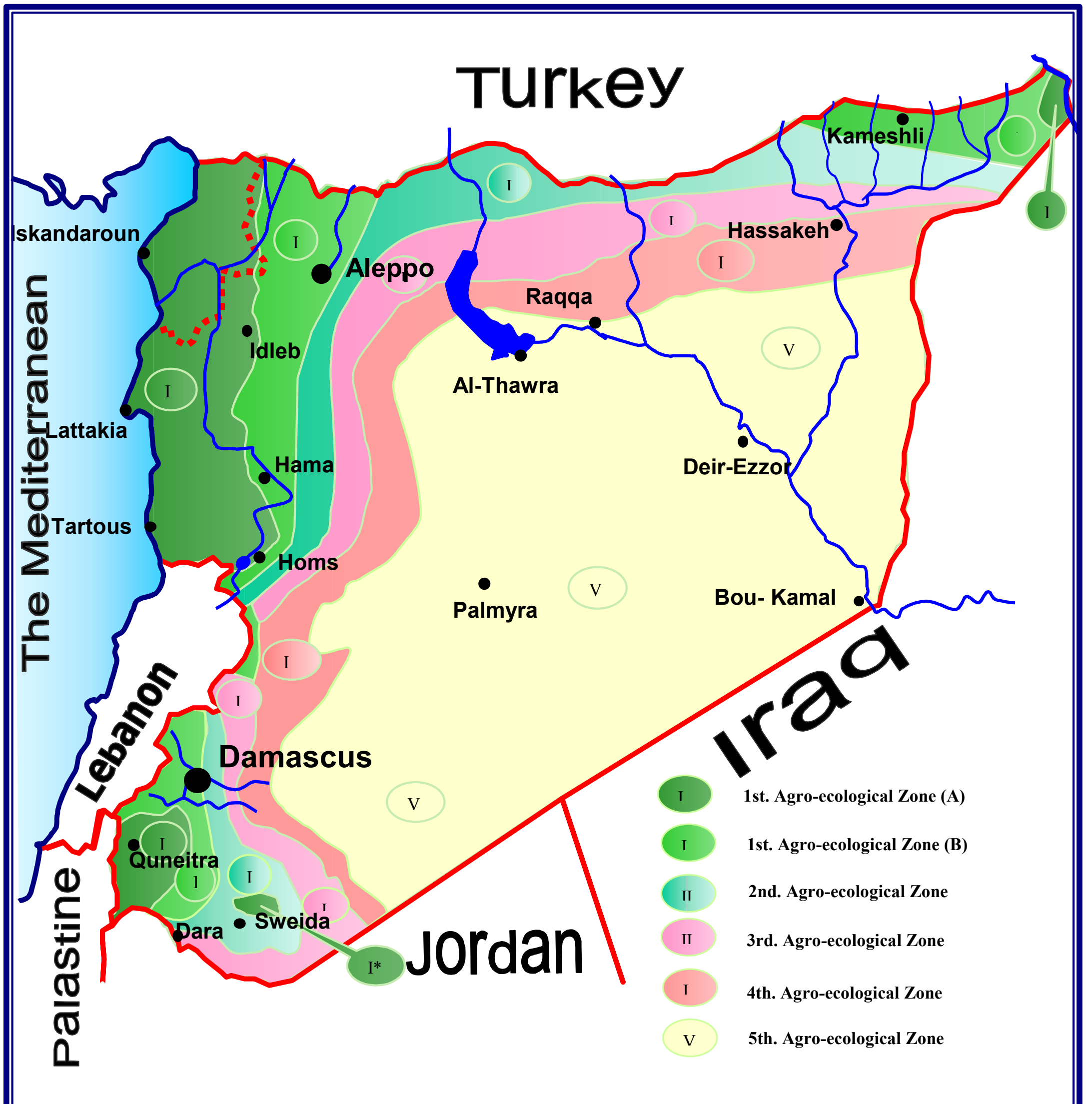

Figure /1/:Distribution of Agro-ecological Zones in Syria

Fig. 1. Distribution of Agro-ecological zones in Syria

Accordingly, precipitation decreases from the west to the eastward, and from the north to the southward and this variability affects water resources. Spring and rivers prevails in the western part of Syria and their number decreases whenever one goes toward inland region where no springs at all.

In general, most Syrian lands are dry or semi-dry and more than half Syria's area has rainfall less than 220 and this rainfall is irregular from one year to another. Syria sometimes faces dry years. Average precipitation is more than 46.0 billion m^3, one third of which falls on 60% of the total surface area, the second third on 15% of the area and the remained third on 25%.

Table 1. Annual rainfall rates (mm) and rainfall amounts (m.m^3) by agro-ecological zone for the seasons 1989 – 2000

Zone		*1st*	*2nd*	*3rd*	*4th*	*5th*	*Total*
Area/ha		2701251	2470066	1306292	1829079	10211283	18517971
Annual rate for the period 1960 - 1985		617.90	308.20	263.10	223.20	141.40	249.80
		16691.03	7612.74	3436.85	4082.50	14438.75	46257.89
Annual rainfall rate (mm) and rainfall supplies for agro-ecological zones (m.m^3)	*1989–1990*	438.70	237.30	210.40	174.80	120.10	194.00
		11850.39	5861.47	2748.44	3197.23	12263.75	35921.28
	1990–1991	477.49	242.56	215.41	186.48	123.37	203.65
		12898.20	5991.39	2813.88	3410.87	12597.66	37712.00
	1991–1992	749.70	341.70	311.80	223.80	113.90	261.90
		20251.28	8440.22	4073.02	4093.48	11630.65	48488.65
	1992–1993	594.62	322.70	300.41	296.74	141.21	258.15
		16062.18	7970.90	3924.23	5427.61	14419.35	47804.27
	1993–1994	541.10	276.90	215.80	213.60	127.90	222.72
		14616.47	6839.61	2818.98	3906.91	13060.23	41242.20
	1994-1995	608.34	300.85	279.99	230.48	168.00	264.03
		16432.75	7431.19	3657.49	4215.66	17154.96	48892.05
	1995–1996	623.40	326.50	265.10	282.90	135.70	256.00
		16839.60	8064.77	3462.98	5174.46	13856.71	47398.52
	1996–1997	598.00	312.00	271.40	246.30	174.80	268.74
		16153.48	7706.61	3545.28	4505.02	17849.32	49759.71
	1997–1998	664.50	321.50	271.30	221.20	201.00	291.60
		17949.81	7941.26	3543.97	4045.92	20524.68	54005.64
	1998-1999	464.58	182.86	140.25	110.15	56.21	143.93
		12549.47	4516.76	1832.08	2014.73	5739.76	26652.80
	1999-2000	513.50	194.00	167.60	131.50	67.20	162.64
		13870.92	4791.93	2189.35	2405.24	6861.98	30119.42
	1989 - 2000	570.36	278.08	240.86	210.72	129.95	229.76
		15406.78	6868.74	3146.33	3854.29	13269.56	42545.70

Table 2. Rainfall rate by agro-ecological zone in Syria

Zone	*Area /thousand ha/*	*% out of total country area*	*Annual rainfall rate*	*Rainfall amount billion m^3/year*
1st	2682.5	14.5	<350 mm (1)	14.752
2nd	20460.5	13.3	350	8.612
3rd	1332	7.2	250	3.330
4th	1905.5	10.3	> 250 mm	4.763
5th	11119.5	54.7	> 200 mm (2)	15.179
Total	18500	100%	-	46.636

(1) Rainfall amount is calculated in 1st agro-ecological zone at a rate of 550 mm/year.
(2) Rainfall amount is calculated in 5th agro-ecological zone at a rate of 150 mm/year.

Rainwater resources for an average year are estimated at 46.258 billion m^3 (1960 – 1985), while average rainwater supply rate was 42.546 billion m^3 during the period (1989 – 2000) distributed irregularly on Syrian territory within the range between 100 and 1650 mm/year. By discussing available water resources depending on different sources, it is worthwhile to underline that rainfall supply is an important source for groundwater recharge (7 – 9% of rainfall forms renewable groundwater supplies) and constitutes soil moisture storage and runoff in inland basins.

Relative Humidity and Evaporation

The main source of humidity in Syria is the Mediterranean Sea. In summer relative humidity is clearly decreases from the west to the eastward whenever we go away from the marine influence, and it decreases as of the coastal region toward the east in winter. Relative humidity decreases by increasing elevation above sea level due to low temperature.

In Syria, evaporation rate varies from one region to another due to variation in temperature and humidity. Potential evaporation rate increases from the west to north-west down to east and south-east. It is 1200 – 1400 mm/year in coastal and mountainous regions, while it ranges between 2600 – 3000 mm/year in eastern and south-eastern regions.

Water amounts lost by evaporation from water bodies and basins are annually estimated at 1962 million m^3, distributed as follows:

- Barada and Awaj basin: 6 million m^3;
- Yarmouk basin: 31 million m^3;
- Steppe basin: 15 million m^3;
- Orontes basin: 148 million m^3;
- Coastal basin 16 million m^3;
- Khabour basin 132 million m^3;
- Euphrates and Aleppo basin: 1614 million m^3.

WATER RESOURCES

Syrian water resources have special importance since they are limited and depletable resources in addition to their effect on all sectors (agriculture – industry – tourism). As for geographical distribution of water resources, Syria is divided into seven main water basins depending on the hydrographical network limits and hydro-geological criteria (Table 3).

Available water resources

Discussing available water sources by different resources, rainwater supplies are considered as sources for groundwater recharge, and formation of soil moisture storage and surface runoffs. Depending on the prevalent climatic conditions of each basin, average annual water supplies were calculated as follows:

Total traditional water supplies

Total average water supplies are estimated to 16,556 million m^3/year of which:

- Surface water 10,923 million m^3/year
- Groundwater 5,633 million m^3/year

Total natural water resources calculated by taking into account percent surface runoff and groundwater recharge corresponding to rainfall at 50% probability and annual and mathematical runoff averaged 15,890.8 million m^3/year were as follows:

- Surface water 10,635 m.m^3/year
- Groundwater 5,256 m.m^3/year

However, regular water resources corresponding to rainfall probability 50% taking into account regulation degree in all seven water basins were 14,218 million m^3/year.

Non-conventional water resources

Due to the growing pressure on water resources, reliance on non-conventional water resources (drainage water and urban and industrial wastewater) is increasing, and their amounts are related to management and organization level, and effectiveness and nature of infrastructures (conveyance and distribution systems – urban and industrial wastewater systems – drainage water systems).

Table 3. Water balance for years at rainfall probability 75% (for population number and actually cultivated areas in 2002)

Water balance elements			Unit	Hydrological basins							Total
				Barada & A 6waj	Yarmouk	Steppe	Orontes	Coastal	Tigris & Khabour	Euphrates & Aleppo	
Average water resources		Surface water	m.m^3	20	180	163	1110	1557	788	7105	10923
		Groundwater	m.m^3	830	267	180	1607	778	1600	371	5633
		Total	m.m^3	850	447	343	2717	2335	2388	7476	16556
Rainfall proportion at probability 50% to average annual rainfall			%	83.7	83.7	83.7	83.7	83.7	83.7	83.7	83.7
Runoff proportion at 50% to average annual runoff			%	67.1	67.1	67.1	67.1	67.1	67.1	67.1	67.1
Available water resources	Natural	Surface water	m.m^3	13	121	109	745	1.045	529	6.948	9.510
		Groundwater	m.m^3	557	179	121	1.078	522	1.074	249	3.780
		Total	m.m^3	570	300	230	1.823	1.567	1.602	7.197	13.289
	Organization degree		%	90	85	60	85	65	95	98	
	Organized water resources		m.m^3	513	255	138	1.550	1.018	1.522	7.053	12.049
	Wastewater and industrial effluents		m.m^3	254	85	35	352	0	102	172	1.000
	Drainage effluents		m.m^3	75	37	0	222	72	404	728	1.536
	Total water resources available for use		m.m^3	842	375	173	2.124	1.090	2.028	7.953	14.585
Water uses	Agricultural irrigation	Area on groundwater	1000/ ha	59.440	17.641	6.800	142.095	12.289	339.338	193.347	770.950
		Area on surface water	1000/ ha	17.067	19.144		112.060	56.272	91.175	287.263	582.981
		Total area	1000/ ha	76.507	36.785	6.800	254.155	68.561	430.513	480.610	1.353.931
		Groundwater consumption	m.m^3	785.80	211.80	68.00	1.137.20	99.50	4.305.00	1.440.70	8.048.00
		Surface water consumption	m.m^3	0.197994	188.60		954.90	466.80		4.314.80	5.925.10
		Total agricultural water uses	m.m^3	785.80	400.40	68.00	2.092.10	566.30	4.305.00	5.755.50	13.973.10
	Domestic uses	Population till 2001	Million	3.670	1.128	0.592	3.200	1.516	1.238	5.309	16.653
		Water use	m.m^3	269	76	44	240	81	38	322	1.070
	Industry		m.m^3	76	38	2	229	85	45	86	561
	Evaporation losses		m.m^3	6	31	15	148	16	132	1.614	1.962
	Total water resources use		m.m^3	1136.8	545.4	129.0	2.709.1	748.3	4.520.0	7.777.5	17.566.1
Water balance			m.m^3	-294.5	-170.5	44.1	-585.5	342.1	-2.491.8	175.2	-2.980.7

- Drainage water: is partially reused in regions increasing in number and area. Its total percent constitute 15% of irrigation water amount discharged to surface water streams or going to recharge groundwater storage. Drainage is estimated to 1.5 billion m^3.
- Wastewater and industrial water: constitute nearly 70 – 75% of total water used for industry and domestic use. It is estimated to one billion m^3 that should be reused for agricultural purposes of treatment processes.

WATER RESOURCE DEVELOPMENT

The water resources development is characterized by several phases described here below.

Dams

Government plan for expansion in dam construction for rainwater conservation and surface waters in order to be utilized in agricultural irrigation projects and drinking water and electrical power supply started of the necessity for benefiting from the water supply nature and recharge conditions of related region. Number of dams reached 159 dam end 2003 with total storage 19,160 $m.m^3$ (including dead amounts of storage lakes). These dams are distributed according to their purpose as follows:

- 75 Irrigation dam at 47% of total dams.
- 24 drinking water dam at 15% of total dams.
- 32 sheep drinking at 20% of total dams.
- 28 multi-purpose dam at 18% of total dams.

Government Irrigation Projects

By increasing attention to water in agricultural projects, the government established a number of irrigation projects conducive to food production increase. Water resource uses were developed as a response to demand increase. This had been achieved through a range of measures as the construction of a number of dams and drilling a large number of wells for irrigation, drinking and industrial purposes. Irrigated area increased from 670 thousand ha in 1990 to 1.420 million ha in 2003, leading to an increase in agricultural product value and attainment of food security.

- In 2003, total planned irrigated area on all water sources was 1.420 million ha, constituting 7.67% of Syria's area and 24.2% of total cultivable area (Table 4).
- Irrigated area covered by government irrigation systems is estimated at 341774 ha, constituting 24% of total irrigated area in Syria and distributed on basins as follows:
  - Coastal basin: 37679 ha — 17 government irrigation system
  - Orontes basin: 112370 ha — 17 government irrigation system
  - Steppe basin: 950 ha — 3 government irrigation system
  - Khabour basin: 45650 ha — 12 government irrigation system
  - Euphrates basin: 122606 ha — 9 government irrigation system
  - Yarmouk basin: 22519 ha — 1 government irrigation system
- Application efficiency changes according to project components. Through the experiment, it has been indicated that the efficiency of large irrigation projects equipped with cement canals is nearly 75% for localized irrigation, 50 – 65% for sprinkler irrigation, and 45 – 50% for surface irrigation depending on the climatic conditions.

If the conveyance and distribution canals are earth, the total project efficiency will be about 55% for localized irrigation and 35% for surface irrigation.

The government irrigation project comprise irrigation systems composing of main, secondary and tertiary canals. These canals are trapezoid and case-like lining cement ones with different sizes; linear slopes and edge slopes varying according to the topographic situation of lands passing by. They are designed to provide specific water duty according to areas and crops that will be irrigated. In addition, there are quadric canals (field), and they are earth canals with changing and irregular sections.

Canals (I – II – III) are conveyance and distribution ones with an efficiency ranging 75 – 95%, while the quadric canals are earth ones with low efficiency ranging 45 – 50% due to the losses of water conveyance to the field by infiltration in addition to the grass and weed growth in the canal bottom, ridges or sides.

Table 4. Development of total irrigated areas and those irrigated by groundwater source during the period 1985 – 2003

Year	Total irrigated area [thousand ha]	Increase of irrigated area [thousand ha]	Groundwater irrigated area [thousand ha]	Percent groundwater irrigated area [%]
1985	652.0		318.0	48.8
1990	693.0	41.0	342.0	49.4
1994	1082.0	389.0	694.0	64.1
2000	1210.0	128.0	698.0	57.7
2002	1350.0	140.0	832	61.62
2003	1420.0	70.0	852	60.0

Through water and irrigation projects executed in Syria whether for dams or irrigation system, it has been shown that water policy considers water a natural source that should be save to meet the socio-economic needs. Water policy ensures several principles aiming at:

- Increasing water from rivers supply by implementing large water structures.
- Reconnaissance and development of groundwater.
- Increasing water from valleys and temporary streams by establishing storage dams and storage lakes for using water for agricultural purposes directly or for groundwater recharge.

IRRIGATION SYSTEMS AND PRACTICES APPLIED IN SYRIA

Traditional irrigation system

Traditional surface irrigation (flooding irrigation) prevails in irrigated agriculture because it is very early used since it is low-cost, easily implemented and doesn't need skilled labor or advanced techniques. Traditionally irrigated lands are estimated to 82% of total irrigated area, considering that the total engineering efficiency of water uses, expressing the relation between plant consumption from water for physiological processes and water abstraction from the source, is not more than 50% at best as the water is taken from irrigation systems (government & private) by gravity or pumping from wells or rivers via earth canal s unsuitable for water conveyance. Gravity irrigated area constitutes 20% of total irrigated area.

Average water application per hectare is estimated at 14 thousand m^3, and this average considerably varies from one region to another or from one basin to another depending on WUE which is identified by conveyance and distribution efficiency and on-farm irrigation techniques.

Project irrigation efficiency is related to its components. If it is possible to achieve canal conveyance and distribution efficiency 80 – 95%, this figure will decline to 40 – 50% by surface irrigation which is characterized by several negative features:

- Losing a large portion of irrigation water in conveyance and distribution canals;
- Wasting irrigation water at farm level due to low field irrigation application efficiency;
- High water table level and soil salinity as in Down Euphrates basin.

Modern Irrigation System (Table 5)

It comprise modern irrigation techniques (sprinkler – localized) in addition to improved surface irrigation. Using modern irrigation methods started as individual initiatives, then the government paid attention to the introduction of these techniques and encouragement of farmers to possess and use these techniques through the national programme for transferring to modern irrigation which was started late 2000 (depending on the technical findings of irrigation methods and techniques). This programme aims to transfer the whole irrigated area from traditional methods to modern ones during a specific time period. The government developed several decisions for facilitating transfer process and ironing out the financial and administrative constraints facing the implementation of this programme.

Table 5. Irrigated areas by modern irrigation methods as of the 4th quarter of 2002 till end 2003

Provinces	Rural Damascus	Sweida	Quneitra	Deraa	Homs	Hama	Al-Ghab	Idleb	Aleppo	Tartous	Lattakia	Raqqa	Hassake	Deir Ezzor	Total
Drip	13327	852.2	2330	17140	11427.1	1890	1211.3	3723	3380.5	4602	3478	653.5	2607	300	66921.6
Sprinkler	6063.9	-	77	4001	8267	38273	10571.1	35988	22344	251	183	6167.4	41486	900	174572.4
Improved surface	7	-	-	-	164	200	552	85	1200	-	-	1120	625	950	4903
Total	19391.3	852.2	2407	21141	19858.1	40363	12514.4	36496	28424.5	4853	3661	7940.9	44718	2650	246397

Accordingly, total area irrigated by modern methods (drip – sprinkler – improved surface) reached 246 thousand ha end 2003 i.e. 18.7% of total irrigated and actually cultivated area and 28.2% of total area irrigated by groundwater by pumping.

TECHNICAL AND RESEARCH FINDINGS FOR THE USE OF MODERN TECHNIQUES IN CROP IRRIGATION

Research findings

Research stations 'findings (Table 6)

Toward the improvement of water resource management and on-farm use rationalization, a research plan was developed in 1990 covering five research programmes including a programme on irrigation method and technique research for irrigated cultivation. Through this programme several findings were obtained and they were considered the scientific basis for government's decision for the implementation of the national programme for moving modern irrigation.

A. Cotton: Modern techniques as compared to traditional irrigation lead to:

Statement	Drip	Sprinkler	Improved surface	Traditional surface
Irrigation water saving %	58	38	24	
Yield increase %	35	31	19	
WUE kg/m^3	0.74	0.49	0.40	0.23

B. Wheat: Modern techniques as compared to traditional irrigation lead to:

Statement	Sprinkler	Improved surface	Traditional surface
Irrigation water saving %	36	17	
Yield increase %	23	30	
WUE kg/m3	1.09	0.89	0.56

C. Sugar beet: Modern irrigation techniques lead to:

Statement		Drip	Sprinkler	Improved surface	Traditional surface
Irrigation water saving %		50	37	31	
Yield increase	Roots %	38	44	27	
	Actual sugar %	47	54	24	
WUE kg/m3	Roots %	8.1	6.63	5.4	0.36
	Actual sugar %	0.99	0.81	0.59	0.37

D. Maize: Modern irrigation techniques lead to:

Statement	Drip	Sprinkler	Improved surface	Traditional surface
Irrigation water saving %	59	49	43	
Yield increase %	53	50	28	
WUE kg/m3	1.98	1.48	0.90	0.37n

Table 6. Technical comparison among irrigation methods applied for crop irrigation at country level

Statement	*Crop*		*Irrigation method*			
			Drip	*Sprinkler*	*Improved surface*	*Traditional surface*
Total water requirement [m^3/ha]	Cotton		6113	8920	10612	14446
	Wheat		-	5807	7527	9092
	Sugar beet		7500	9581	10488	13995
	Maize		3572	4491	5065	8844
Water saving as compared to surface irrigation [%]	Cotton		58	38	24	-
	Wheat		-	36	17	-
	Sugar beet		50	37	31	-
	Maize		59	49	43	-
Yield [kg/ha]	Cotton		4516	4376	3952	3337
	Wheat		-	6329	6699	5141
	Sugar beet	Roots	60830	63830	56170	44170
		Sugar	7430	7800	6230	5040
	Maize		7090	6640	4578	3290
Yield increase [%]	Cotton		35	31	19	-
	Wheat		-	23	30	-
	Sugar beet	Sugar	38	44	27	-
		Roots	47	54	24	-
	Maize		53	50	28	-
WUE [kg/m^3]	Cotton		0.74	0.49	0.40	0.23
	Wheat		-	1.09	0.89	0.56
	Sugar beet	Sugar	8.1	6063	5.4	3.2
		Roots	0.99	0.81	0.59	0.36
	Maize		1.98	1.48	0.90	0.37
Application efficiency [%]	Cotton		88.5	78	62	51.5
	Wheat		-	79	64	49
	Sugar beet		93	73	63	49
	Maize		92	79	67	42

E. Fruit trees: (Table 7)

Olives: The use of localized irrigation on olives as compared to the traditional surface irrigation lead to an increase of yield at 29% fruit and 41% oil, and an increase in WUE from 0.47 kg/m^3 to 1.9 kg/m^3 and water saving at 50%.

Almonds: As an average the results showed the following:
- Yield increase at 18% as compared to the traditional.
- Irrigation water saving at 36%.
- WUE increase from 0.84 to 1.58 kg/m^3 for localized irrigation.

Grapes: Average results showed:
- Yield increase at 41% as compared to the traditional.
- Irrigation water saving at 38% as compared to the traditional.
- WUE increase from 2.9 to 6.7 kg/m^3 for localized irrigation.

Results of demonstration fields

A number of farmers' fields using modern irrigation techniques were under the control, supervision and following-up of irrigation and extension staff. Accordingly, positive results for using modern techniques for irrigating different crops as compared to traditional irrigation were obtained.

a. Sprinkler irrigation led to:

- Irrigation water saving: 31%.
- Yield increase: 27.7%.
- WUE increase from 0.31 to 1.1 kg/m^3

b. *Localized irrigation led to:*
- Irrigation water saving: 45%.
- Yield increase: 32%.
- WUE increase from 0.31 to 1.24 kg/m^3

c. *Improved surface irrigation led to:*
- Irrigation water saving: 22%.
- Yield increase: 25%.
- WUE increase from 0.31 to 0.58 kg/m^3

Table 7. Technical comparison among irrigation methods applied for fruit tree irrigation at country level

Statement	*Tree*		*Irrigation method*	
			Localized	*Surface*
Total water requirement [m^3/ha]	Almonds		7194	11678
	Grapes		5318	8646
	Olives		2697	5669
Water saving as compared to surface irrigation [%]	Almonds		38	-
	Grapes		28	-
	Olives		52	-
Yield [kg/ha]	Almonds		10590	8690
	Grapes		35753	25320
	Olives	Fruit	5120	3974
		oil	958	678
Yield increase [%]	Almonds		22	-
	Grapes		41	-
	Olives	Fruit	29	-
		oil	41	-
WUE [kg/m^3]	Almonds		1.470	0.74
	Grapes		607	209
	Olives	Fruit	1.9	0.7
		oil	0.36	0.12
Application efficiency [%]	Almonds		95	57
	Grapes		92	60
	Olives		94	50

Technical results of irrigation methods and techniques

The application of modern techniques on the whole irrigated area for different crops may lead to water saving conducive to meet the water shortage in water balance.

a. Sprinkler irrigation:

The use of sprinkler irrigation for crop irrigation saves irrigation water as follows:

- 36% equivalent to 1.743 billion m^3 at country level/ 690 thousand ha wheat.
- 49% equivalent to 326.6 million m^3 at country level/ 64 thousand ha maize.
- 37% equivalent to 113.5 million m^3 at country level/ 28 thousand ha sugar beet.

b. Localized irrigation:

Localized irrigation is used to irrigate:

- Cotton: irrigation water saving 58% equivalent to 1.750 billion m^3/average area of 210 thousand ha.
- Grapes: irrigation water saving 38% equivalent to 35.7 million m^3 at country level/ irrigated area 1340 ha.

- Olives: water irrigation saving 50% equivalent to 78 million m^3 at country level/ irrigated area 29 thousand ha.

c. Improved surface irrigation

The improvement of surface irrigation by accurate laser-land leveling leads to water irrigation saving ranging 23 – 35% from applied water as compared to traditional surface irrigation for most agricultural crops. For cotton, for instance, the use of this technique saves 815 million m^3/year for the area mentioned in paragraph /b/.

GUIDELINES FOR THE POLICIES AND MEASURES OF SUSTAINABLE DEVELOPMENT

In addition to dam construction, government irrigation projects establishment and ironing out the difficulties facing the national programme of movement to modern irrigation, the government through Ministries of Agriculture and Irrigation, aiming at sustainable development of resources by taking a range of important measures as described here below.

Water resource assessment

The goal of water resources assessment is to prepare modern water balances showing the movement and hydrochemistry of water, reconnaissance of deep aquifers, clarification of groundwater discharge and recharge, etc.

Comprehensive water plan

Development of a comprehensive water plan aims at:

- Assessing present and future uses up to the year 2020;
- Assessing, collecting, treating and reusing non-conventional water;
- Controlling water quality and quantity;
- Establishing training and qualification programmes.

Operation and maintenance of irrigation projects

Operation and maintenance of irrigation projects is necessary for:

- Giving importance to the operation and maintenance works in terms of equipment provision;
- Developing and rehabilitating old irrigation projects.

Water use rationalization

The activities on water use rationalization aim at:

- Minimizing losses and waste in water distribution systems by applying advanced irrigation techniques;
- Conducting studies for reducing evaporation;
- Selecting high-specification lands for appropriate irrigation and cropping rotations;
- Preventing violations and encroaching upon water structures.

Modernization of water legislation

The activities on modernization of water legislation aim at:

- Optimal management of water resources for multi activities;
- Addressing water use rights and their protection from pollution;
- Keeping pace with technological progress and its reflection on water resource process.

Promotion of WUAs role by issuing necessary laws

Gearing toward the promotion of WUAs role by issuing necessary laws is important for:

- Identification of water users bodies;
- Identification of WUAs role in water distribution process;
- Identification of WUAs in irrigation projects maintenance.

CONCLUSIONS

The following conclusions can be drawn from the above mentioned data and information:

- Syrian water resources are limited as compared to the increasing demand size by different economic sectors;
- Agricultural sector is the largest consumer of water resources;
- Syrian government's attention to water resources and considering it a natural resource that should be saved to meet the necessary needs by constructing dams and governmental irrigation projects;
- Increase of water loss percent due to:
  - Evaporation
  - The dominance of low-efficient traditional irrigation on 80% of irrigated areas.
  - The use of earth canals in on-farm water distribution (quadric canals).
- There is a strong necessity to rehabilitate old irrigation projects and to develop the modern ones by transferring them to piped canals in conveyance and distribution, conducive to the use of modern techniques in on-farm irrigation;
- Adoption of a range of measures and polices by the government is necessary aiming at the sustainable development of water resources and the orientation toward WUAs establishment and the activation of existing ones.

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