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IRRIGATION RESEARCH RESULTS IN THE SYRIAN ARAB REPUBLIC

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SUMMARY – Low-efficient traditional surface irrigation prevails over more than 80% of irrigated area in Syria, resulting in a loss of more than 50% of available water resources at a time these resources are facing growing pressure from all sectors. Accordingly, the Syrian government accorded an increasing consideration to the implementation of water research programme applicable for most strategic crops and farming, aiming at improving on-farm water management and, consequently, improving WUE and reduction of water loss in agricultural sector. Research and technical results showed that the use of modern irrigation methods on cotton, for example, leads to irrigation water saving by 41% as compared to traditional irrigation, average yield 30%, and improvement of WUE from 0.23 to 0.53 kg/m^3. In economic point of view, modern irrigation methods were superior to traditional irrigation, and drip irrigation ranked the first in terms of revenues and net profits per unit area. Depending on technical and economic results of modern irrigation methods the government made several decisions for transferring to modern irrigation. Areas transferred to modern irrigation estimated to 260 thousand ha during the period 2000 – 2004.

Key words: Traditional surface irrigation, research programs, modern irrigation techniques, irrigation water saving, water use efficiency, technical and economic results, irrigated area.

INTRODUCTION

Limited available water resources in Syria and their growing demand for different purposes (agricultural industrial – domestic) as well as the restricting constraints of use regulation imply the necessity of making a radical change in the current low-efficient irrigation methods and systems, and following-up ways and means that properly use water in agriculture at minimum level with high productivity.

According to the above-mentioned considerations, the scientific plans included an implementation of specialized research programmes on water management and use rationalization (water duty – irrigation methods and techniques – salt-land reclamation and drainage methods – the use of mathematical model for studying salt movement – water harvesting and spreading techniques – supplemental irrigation).

The experiments and research proved the feasibility of modern technique application in irrigation projects in particular and agriculture in general, and at all levels regarding the following two key indicators: (1) water saving and increase of available amount for horizontal agricultural expansion; and (2) increase WUE kg/m^3 or SP/m^3.

Research programmes dealt with water study of most strategic crops (cotton – wheat – maize – sugar beet) as well as water consuming vegetables and other kinds of fruit trees.

Due to the growing strategic importance of cotton over the recent years where cotton grown area ranged 250 – 270 thousand ha i.e. 18 – 19% of irrigated area in Syria, and since cotton is a summer crop consuming larger portion of irrigation water ranging 3 – 4 billion m3 i.e. 20 – 23% of annual water supply and the prevailing traditional (flooding) irrigation which has the following disadvantages: low application efficiency not more than 50% i.e. losses 50% at least; and high water table and soil salinization as in Down Euphrates Basin as a result of over-irrigation and on-farm waste, Ministry of

Agriculture/General Commission for Agricultural Scientific Research gave special importance to cotton irrigation research, aiming at improvement of water uses and irrigation efficiency, and consequently water saving and cotton yield increase by the introduction of modern irrigation methods and techniques.

Hence, this paper addressed the important cotton irrigation outcomes obtained at irrigation stations in Hama, Aleppo, Raqqa, Deir Ezzor and Hassakeh (cotton producing- governorates) which has a diversity in climate, soil and water quality.

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 amounting more than 1.4 million ha, considering that the total engineering efficiency of water uses, expressing the relation between plant consumption from water for physiological processes and water withdrawal 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 canals unsuitable for water conveyance. Gravity irrigated area of governmental irrigation systems constitutes 20% of total irrigated area.

Average water application per hectare is estimated to 14 thousand m3, and this average considerably varies from one region/basin to another depending on WUE which is identified by conveyance and delivery efficiency and on-farm irrigation techniques.

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

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

Modern Irrigation System

It comprises modern irrigation techniques (sprinkler – localized) in addition to improved surface irrigation. Using modern irrigation methods started as individual initiatives, then the government gave consideration 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 (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 period. The government has developed several decisions for facilitating transfer process and ironing out the financial and administrative constraints facing the implementation of this programme, together with their promotion of research centers for preparing the necessary research plans, conducive to reduction of traditional irrigated area and increase of modern irrigation area.

RESEARCH PROGRAMMES

The research programmes aim at improving water resource management, on-farm use optimization and WUE. A research plan was prepared in 1990 including the following four research programmes:

- Water requirements, irrigation scheduling and supplementary irrigation, including the following:
    - Study of water requirements for different crops;
    - Study of applying different irrigation rates on strategic crops;

- Study of supplementary irrigation for winter crops.

- Irrigation methods and techniques, including the implementation of the following researches:
  - Use of different irrigation techniques for irrigating field crops and vegetables, and making comparison;
  - Use of different irrigation techniques for irrigating fruit trees and making comparison.
- Salinity and drainage, including:
  - Study of salinity development phenomenon using different irrigation systems on crops.
  - Study of the effect of several levels of soil and water salinity on the yield of main crops (wheat – cotton – sugar beet – maize).
- Rainwater harvesting and spreading, including:
  - The use of contour farming for rainwater harvesting.
  - Assessment of productive efficiency of collected rainwater.
  - Runoff improvement in the Syrian steppe.
  - Vegetation regeneration and rangeland rehabilitation.

A synthesis of main research programmes and corresponding irrigation and water use stations in Syria is given in Figure 1.

TECHNICAL RESULTS

Research Results and Their Technical Feasibility

Four research programmes were implemented on a large number of field crops (including wheat, cotton, sugar beet, maize), in addition to vegetables and fruit trees. In this document, a special emphasis is given on cotton because:

- It occupies 250 – 270 thousand ha, i.e. 18 – 19% of total irrigated area.
- It is summer water-consuming crop.
- It is a strategic crop playing a significant role in socio-economic relations.

Results of water requirement and irrigation scheduling research programme

- Research implementation period: 1990 – 1995
- Implementation place: Irrigation research stations in the following cotton growing governorates (Hama – Aleppo – Hassakeh – Raqqa – Deir Ezzor), which have a diversity of pedological and climatic conditions.
- Experimental treatments:
  - 60 – 70 – 80% of field capacity in addition to the control (as farmer irrigates).
- Equations used to estimate ETo:
  - Epan – Ivanov – Blaney Kriddle – Modified Penman
- Equipment and instruments
  - Equipment for soil analysis (physical – chemical).
  - Evaporation basin.
  - Neutron probe for soil moisture measurement.
  - Various irrigation systems.
- Varieties:
  - Locally-produced varieties suitable for each governorates
- Irrigation methods: Basin irrigation

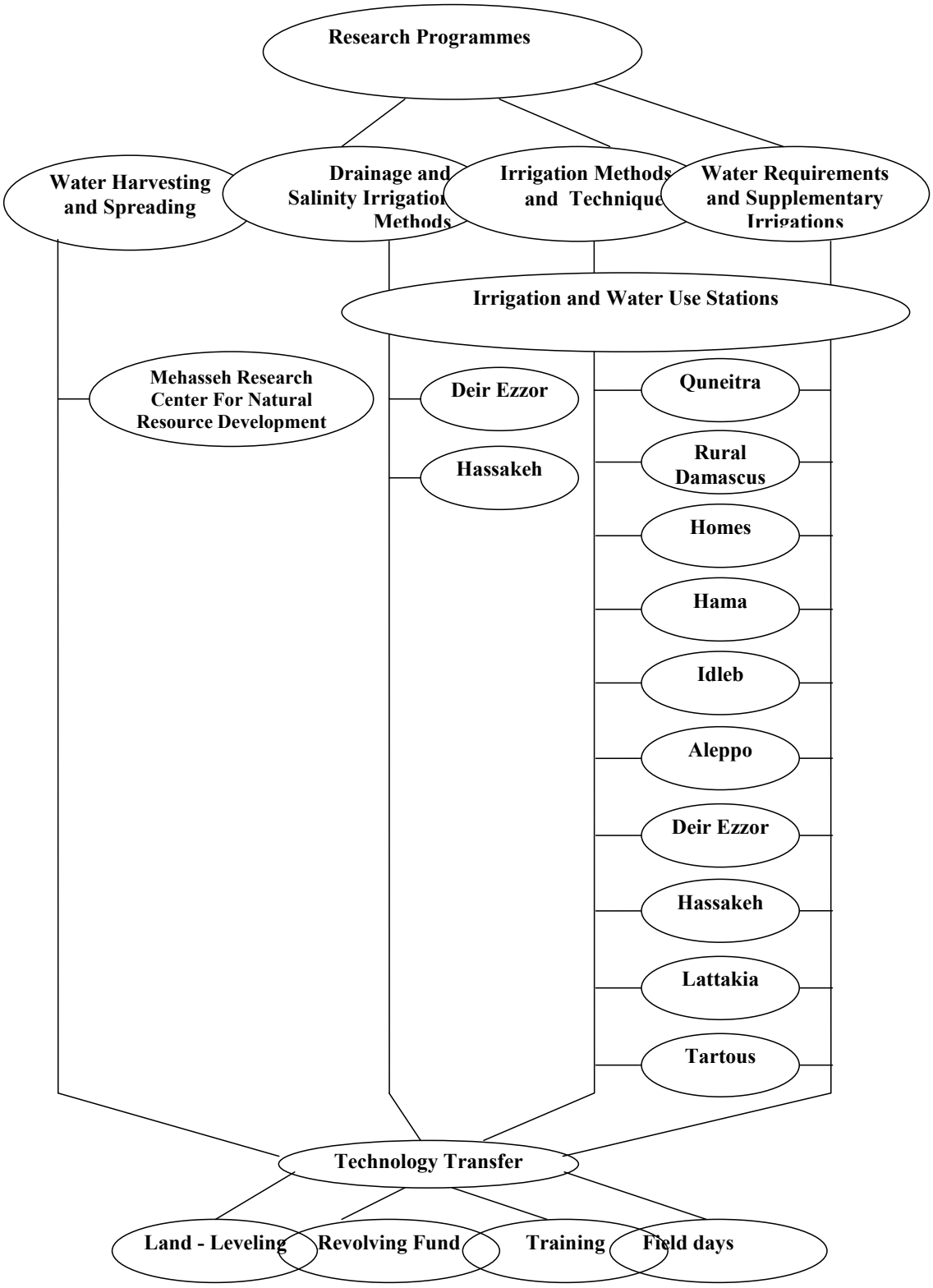

Fig. 1. Main research programs and corresponding irrigation and water use stations in Syria

Results as an average (years and regions):

- Treatment of 80% field capacity was superior to 60 – 70% and control treatments.
- Water requirement ranged 8600 – 9950 m^3/ha.
- Number of irrigations ranged 16 – 18 at irrigation rate of 400 – 600 m^3/ha/irrigation.

Results of irrigation methods and techniques research:

Programme objectives:

- Study irrigation efficiency and water uses, using modern irrigation techniques (drip – sprinkler – improved surface) vs. traditional surface irrigation.
- Make technical and economic comparison between applied irrigation methods vs. traditional irrigation.
- Assess gained net income as compared to traditional surface.
- Assess gained national production per unit area and additional national income resulting from the use of modern techniques in irrigation.

Implementation areas:

- The following governorates: Hama – Aleppo – Hassakeh – Deir Ezzor
- Implementation period: Two phases: (1991 – 1997) and (1996 – 2000).
- Varieties: Research was conducted on adopted varieties adaptable for each governorates.

Experimental treatments:

- Water treatment 80% of field capacity was adopted.

a. Drip irrigation:

- Different models of drippers at different discharges 2 – 8 l/hr were adopted.
- Filtrating pipes with discharge 7 – 8 l/hr/ linear meter.
- Two engineering layouts:
    - Irrigation line x plant row
    - Plant row & irrigation line x two plant rows.

b. Sprinkler irrigation:

Different engineering designs (sprinkler spaces) at 9 x 9 , 9 x 12, 12 x 12 were adopted, and there were three experimental treatments:

- Sprinkler irrigation throughout the season;
- Sprinkler irrigation: During germination, growth and flowering buds;
- Surface: During flowering and nut formation.

It is very important to underline that sprinkler irrigation research was conducted in impermissible ecological zones to avoid the outbreak of fungi diseases.

c. Improved surface irrigation:

It means the use of long furrow irrigation after laser land-leveling, and identification of proper slope, soil nature and composition, and discharge of on-site available water. The applied treatments were:

- Furrow length 100 – 150 – 200 m.
- Discharge 0.75 – 1 – 1.5 l/sec.
- Traditional irrigation

Results

a. Statistical:

Localized irrigation research: Drip irrigation method (one line x one row) with discharge 4 l/sec was the best at statistical function 1%.

Sprinkler irrigation research: Sprinkler irrigation method at sprinkler spacing 9 x 12 was the best in statistical function 1%.

Surface irrigation research: Long-furrow irrigation method 200 m with discharge 1.5 l/sec was the best in function of 1%.

b. Technical:

As an average for a number of years and regions (at country level):

- the localized irrigation vis-à-vis traditional surface gave the following results:
  - Applied water was 6113 m3/ha and 14446 m3/ha for localized and traditional irrigation respectively.
  - Yield increase 35%.
  - Irrigation water saving 58%.
  - WUE increase from 0.23 to 0.74 kg/m3.
  - Application efficiency increase from 25 – 50% for traditional to 88.5% for localized.

Anyway, applying the research results over the whole irrigated area estimating to 250 thousand ha grown with cotton for the year 2004 gave the following:

- Total irrigated area 250 thousand ha
- Total applied water by traditional irrigation 3.5 billion m^3
- Total applied water by localized irrigation 1.5 billion m^3
- Irrigation water saving 2 billion m^3
- Irrigated area to be increased as a result of water saving 327 thousand ha
- Foreseen production of additional area 1.48 million ton

Sprinkler irrigation vis-à-vis traditional irrigation led to the following:

- Applied water by sprinkler was 8920 m3/ha, while it was 14446 m^3/ha for traditional.
- Yield increase 31%.
- Irrigation water saving 38%.
- WUE increase from 0.23 to 0.49 kg/m3.
- Application efficiency increase from 45 – 50% for traditional to 78% for sprinkler.

Applying the results over the whole area gave the following:

- Total applied water by traditional irrigation 3.5 billion m^3
- Total applied water by sprinkler irrigation 2.225 billion m^3
- Irrigation water saving 1.275 billion m^3
- Additional area can be irrigated 143 thousand ha
- Foreseen production of additional area 616 million ton

Improved surface irrigation vis-à-vis traditional surface gave the following results:

- Applied water by improved surface was 10612 m^3/ha, while it was 14446 m^3/ha for traditional;
- Yield increase 18%;
- Irrigation water saving 27%;
- WUE increase from 0.23 to 0.37 kg/m^3;
- Application efficiency increase from 45 – 50% for traditional to 62% for sprinkler.

Applying the improved surface irrigation over the whole cotton area:

- Total irrigated area 250 thousand ha
- Total applied water by traditional irrigation 3.5 billion m^3
- Total applied water by improved surface irrigation 2.555 billion m^3
- Irrigation water saving 2 billion m^3
- Irrigated area to be increased as a result of water saving 94 thousand ha
- Foreseen production of additional area 376 million ton

The effects of modern irrigation methods on the increase of Water Use Efficiency, yield and irrigation water saving in relation to traditional surface irrigation on cotton are given in Table 1.

Table 1. The effect of modern irrigation methods on the increase of WUE, yield and irrigation water saving vis-à-vis traditional surface irrigation on cotton

Statement		*Improved surface*	*Drip*	*Sprinkler*	*Traditional surface*
Actual irrigation m^3/ha		10612	6113	8920	14446
Number of irrigations		12	17	14	11
Water saving %		27	58	38	-
Yield kg/ha		3952	4516	4376	3337
Yield increase %		18	35	31	-
WUE kg/m^3/ha		0.37	0.74	0.49	0.23
Application efficiency %		62	88.5	78	45 – 50%
Research area	Hama	94 – 99	96 – 2000	95 – 2000	95 – 2000
	Aleppo	94 – 99	91 – 2000	95 – 2000	91 – 2000
	Deir Ezzor	94 – 99	91 – 97	91 – 96	91 – 97
	Hassakeh	94 – 99	91 - 97	92 - 98	92 - 98

ECONOMIC RESULTS

Economic analysis of the research results of applied irrigation methods and techniques (improved surface – sprinkler – drip – traditional surface method)

This analysis aims at the interpretation of research results to physical data by estimating the revenues and costs per unit area as a results of productivity change and reduction of irrigation water costs. The following parameters are analyzed:

- Actual results of water requirements obtained through research;
- Achieved yields vs. water requirements of executed research;
- Actual status of production costs and product value international prices once the economic analysis is made;
- Calculation of irrigation water costs through economic analysis, considering irrigation water in Syria is used according to the established laws. Irrigation water value includes water delivery cost from the source to the field, and it was fixed according to:
    - Actual cost paid by the farmer as irrigation fees (operation and maintenance) that is estimated to 3500 SP/ha/year as a financial value, while the economic value of irrigation water from governmental irrigation projects was calculated by the depreciation of the capital used in irrigation projects according to the international prices and repair maintenance of these projects.
    - Financial and economic costs of irrigation water from other sources such as pumping from rivers and pumping from groundwater at different depths according to the current situation of groundwater were calculated financially and economically through their actual costs, divided into:
        - Fixed costs (depreciation – interests – maintenance and repair)

- Consumable costs: fuel, fats and labor wages.

The costs of well drilling and casing, pump unit and surface irrigation systems, if any, are included in this calculation. Irrigation water value was accurately calculated using pumping units at capacity 40 and 60 m^3/hr.

- Land rent was at 15% from product value.
- For accurate analysis, the productivity for farmers adopted averagely 80% of research results.

The study team wanted to give a clear picture on the economic analysis, comprising several cases:

a. Results of several research stations.
b. Economic tests on four irrigation methods: traditional, post land-leveling surface, sprinkler and drip irrigation.
c. Crop economic test on all irrigation sources, namely:
   - Irrigation from government projects.
   - Pumping from rivers.
   - Pumping at 5 – 100 – 200 m deep.
d. Excluding other affecting factors such as fertilization and varieties, considering they are the same for all irrigation techniques for showing the impact of irrigation techniques.
e. Economic test according to two kinds of pumping 40 and 60 m^3/hr, which are widely used in Syrian.
f. Economic test via the value of costs and revenues according to international prices.

The economic costs of one m^3 irrigation water by water source (river of well pumping), irrigation method (traditional surface, improved surface, sprinkler and drip) and pumping unit capacity are given in Table 2.

Table 2. Economic costs (in SP) of one m^3 irrigation water by water source, irrigation method and pumping unit capacity

Statement	Pump discharge	Government Irrigation projects	River pumping	Well pumping			
				50 m	100 m	150 m	200 m
Depreciation and maintenance of structures and pumping units (SP)/m^3	40 m^3/hr	0.13	0.05	0.10	0.26	0.20	0.27
	60 m^3/hr	0.13	0.4	0.80	0.16	0.16	0.17
Fuel and oil/SP	40 m^3/hr	0.84	0.17	0.34	0.71	1.08	1.44
	60 m^3/hr	0.84	0.23	0.47	0.98	1.46	1.95
Total cost of traditional surface irrigation/SP	40 m^3/hr	0.84	0.75	1.49	2.50	3.44	4.22
	60 m^3/hr	0.84	0.68	1.18	2.08	2.93	3.74
Total cost of improved surface irrigation/SP	40 m^3/hr	0.74	0.68	1.37	2.22	3.14	3.85
	60 m^3/hr	0.74	0.62	1.05	1.76	2.64	3.14
Total cost of sprinkler irrigation/SP	40 m^3/hr	0.65	0.80	1.30	2.33	3.29	4.25
	60 m^3/hr	0.65	0.80	1.22	2.13	2.98	3.80
Total cost of drip irrigation/SP	40 m^3/hr	0.85	1.11	1.55	2.60	3.55	4.51
	60 m^3/hr	0.85	1.11	1.47	2.40	3.25	4.39

Economic comparison of drip irrigation to traditional surface irrigation

Drip irrigation trials were carried out at four research station (Hassakeh – Aleppo – Deir Ezzor – Hama), focusing on cotton growing in Syria.

Average results at these stations for the entire period showed that applied water was 6113 and 14446 m^3/ha and yield was 4516 and 3337 kg/ha for drip and traditional irrigation respectively. And this reflected on the practical situation of economic costs and revenues and the below results were obtained:

Results of economic analysis

Economic results do not considerably differ from financial results in terms of comparing drip irrigation with traditional surface. A synthesis of results obtained per one hectare are given in Table 3.

Table 3. Production value, cost value, net profit and cost/profit ratio for tradition and drip irrigation methods in Syria

Statement	Irrigation from government projects		Pumping at 100m deep		Pumping at 200 m deep	
	40 m^3/hr	60 m^3/hr	40 m^3/hr	60 m^3/hr	40 m^3/hr	60 m^3/hr
Production value SP/ha traditional irrigation	133480	133480	133480	133480	133480	133480
Production value SP/ha drip irrigation	180640	180640	180640	180640	180640	180640
Cost value SP/ha traditional irrigation	78929	78929	113310	96842	114321	112154
Cost value SP/ha drip irrigation	74202	74202	100549	88873	101770	106527
Net profit SP/ha traditional irrigation	54551	54551	20170	36638	19159	21326
Net profit SP/ha – drip irrigation	106436	106436	80091	91767	74113	87870
Cost/profit ratio traditional irrigation	69	69	30	38	17	19
Cost/profit ratio drip irrigation	143	143	101	103	70	78

Economic comparison of sprinkler irrigation vs. traditional surface

Examination of trial results at country level showed that water applied is estimated to 8920 and 14446 m^3/ha and yield 4376 and 3337 kg/ha under the same conditions for sprinkler and traditional irrigation respectively. Adoption of these results, prevailing prices, costs and revenues for traditional irrigation and sprinkler method are estimated and presented in Table 4.

Table 4. Production value, cost value, net profit and profit/cost ratio for tradition and sprinkler irrigation methods in Syria

Statement	Traditional irrigation from government projects		Sprinkler irrigation from government projects		Increase in sprinkler irrigation %
	40 m^3/hr	60 m^3/hr	40 m^3/hr	60 m^3/hr	
Production value SP	102613	102613	134562	134562	8
Cost SP	73381	73381	74816	74816	2
Net profit SP	29232	29232	59746	59746	51
Profit/cost SP %	40	40	80	80	40

In general, economic superiority of sprinkler irrigation method in respect to traditional irrigation is evident as compared to traditional irrigation. The following economic results are analyzed also by means of production value and net profit considering different pumping depths and the results of this analysis are summarized in Table 5.

Table 5. Production value and net profit for traditional and sprinkler irrigation methods considering different pumping depths

Statement	Government irrigation projects		Pumping 50 m		Pumping 100 m		Pumping 200 m	
	40 m^3/hr	60 m^3/hr	40 m^3/hr	60 m^3/hr	40 m^3/hr	60 m^3/hr	40 m^3/hr	60 m^3/hr
Production value SP/ha traditional irrigation	133480	133480	133480	133480	133480	133480	133480	133480
Production value SP/ha sprinkler irrigation	175040	175040	175040	175040	175040	175040	175040	175040
Net profit SP/ha traditional irrigation	54551	54551	45161	49640	30751	36638	19159	21326
Net profit SP/ha sprinkler irrigation	100572	100572	88976	89690	79788	81572	62662	66676

Improved surface vs. traditional irrigation

Irrigation method in land leveled lands was superior to that of non-leveled lands, and this superiority came from two: First, reduction of applied water per unit area, and the second productivity increase. The results of economic analysis showed clear superiority of improved surface over traditional irrigation as it is reported in Table 6 for different pumping depths.

Table 6. Yield, production value, irrigation water use, irrigation value, costs, net profit and profit/cost ratio for traditional and improved surface irrigation methods considering different pumping depths

Statement	Pump capacity (m^3/hr)	Government irrigation projects		Pumping 50 m		Pumping 100 m		Pumping 200 m	
		Tradit.	Improv.	Tradit.	Impro.	Tradit.	Impro.	Tradit.	Improv.
Yield kg/ha		3194	3952	3194	3952	3194	3952	3194	3952
Production value SP		127760	158080	127760	158280	127760	158080	127760	158080
Irrigation water m^3/ha		14446	11616	14446	11616	14446	11616	14446	11616
Irrigation value SP/ha	40	12135	8538	21525	15914	36115	25788	47527	44722
	60	12135	8538	17045	12197	30048	20444	45360	36474
Costs SP/ha	40	78929	77293	88319	93207	102909	103081	114321	113015
	60	78929	77293	83840	89480	96842	97737	112154	113767
Net profit SP/ha	40	48831	80787	39441	64873	30751	54999	13439	45065
	60	48831	80787	43920	68600	30918	60343	15606	44313
Profit/cost %	40	62	105	45	70	30	53	12	40
	60	62	105	52	77	31	62	14	49

Economic comparison among different irrigation techniques on cotton:

It is essential to make a comparison among different irrigation methods by different sources, so a table including this comparison was prepared for purpose.

Relative Significance of Irrigation Techniques at Local Prices:

Through data on relative significance of irrigation techniques using financial analysis, the following can be concluded:

a. Drip irrigation ranked the first for the irrigation technique economics in terms of revenues, net profits per unit area and profit/cost ratio, followed by sprinkler irrigation for all prevailing irrigation sources in Syria.

b. Differences among irrigation techniques increase by increasing irrigation expenses i.e. high pumping level as traditional surface costs increases as a result of using higher amount of water.

c. Net profit of irrigation techniques is increasing forward with high irrigation costs as compared to traditional irrigation. For example, profit ration of drip to traditional was 153% from government irrigation projects, and it increased to 325% from well pumping at 50 m.

CONCLUSIONS AND RECOMMENDATIONS

This paper shows that low-efficient traditional surface irrigation prevails over more than 82% of irrigated area. Depending on the technical and economic findings of modern irrigation methods, the government, starting from mid-2000, took several decisions toward the movement from traditional irrigation to modern one and the necessary facilities were provided for this movement besides its support that made irrigated area exceeding 260 thousand ha. Several research programmes are applicable for most strategic crops and different farming in Syria, aiming, as a whole, at improving on-farm water management, water use efficiency and water loss reduction in the agricultural sector. This works focuses on irrigation research on cotton as it is a socio-economic crop occupying a large part of irrigated area and one of the largest water-consuming crops. It also referred to the technical and economic results that can be applied in extensive farming in farmers' lands, and these results showed the superiority of modern irrigation methods over traditional ones in the following fields:

- WUE increased from 0.23 – 0.25 kg/m^3/ha for traditional surface to 0.37, 0.74 and 0.49 kg/m^3/ha for improved surface, drip and sprinkler irrigation respectively.
- yield increased by 18 – 25%, 35% and 31% for improved surface, drip and sprinkler irrigation respectively, as compared to traditional surface. Irrigation water saving ranged 24 – 26% for improved surface irrigation.
- Drip irrigation ranked the first in terms of revenues, net profits per unit area and profit/cost ratio. In case of using pumps at discharge 40 m^3/hr, the cost/profit ratio was:
    - Government irrigation projects: 143% for economic analysis.
    - Well pumping at 50 m: 116% for economic analysis.
    - Well pumping at 100 m: 101% for economic analysis.
    - Well pumping at 200 m: 70% for economic analysis.

  Once pumps at discharge of 60 m^3/hr are used, the cost/profit ratio was as follows:
    - Government irrigation projects: 143% for economic analysis.
    - Well pumping at 50 m: 117% for economic analysis.
    - Well pumping at 100 m: 103% for economic analysis.
    - Well pumping at 200 m: 78% for economic analysis.

The following important recommendations can be drawn from this work:

1. There is a necessity to gear to the conjunctive use of groundwater as far possible by establishing regular irrigation projects on groundwater, conducive to water use rationalization on one hand, and stakeholders' potential control of groundwater abstraction on the other.
2. Encouraging the establishment of private and common companies in the field of laser land-leveling is of fundamental importance in order to improve the water use efficiency of surface irrigation method.
3. It is necessary to encourage the local manufacturing of modern irrigation equipment according to international standards.

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