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USING BENCHMARKING PROGRAM (IGRA) IN HUMID AND ARID REGIONS FOR EVALUATING IRRIGATION SYSTEMS PERFORMANCE

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ABSTRACT: *Improving the use efficiency of the available water resources for crop production in both humid and arid areas is considered one of the most important factors of irrigation water management. The aim of this study was to apply the Benchmarking IGRA program in both humid and arid areas in order to evaluate the irrigation performance in these areas. The irrigation performance was evaluated in Uelzen- Germany as an example of humid area and the study was carried out through 10 years. Egypt was divided into three zones (Kafer El-Sheikh – El-Giza – Suhag) and was considered as an example of arid region. The maximum output revenue in the humid area per unit irrigated area 2609 €/ha, while the lowest was 1987 €/ha. The highest output revenue per unit irrigated area was in arid region was 740 €/ha observed in Kafer El-Sheikh with traditional irrigation system. While, with the modified surface irrigation system, the highest value was 901 €/ha achieved in El-Giza zone.*

Key Words: *Benchmarking (IGRA) program, irrigation performance evaluation, irrigation water management in humid and arid areas*

INTRODUCTION

Egypt is one of the developing countries that faces great challenges, due to its limited water resources represented mainly by its fixed share of the Nile River water which equals about 55.5 billion cubic meters per year, out of which nearly 10 percent is outflow to the Mediterranean Sea. The agricultural sector is the major user of water in Egypt with a share amounting to 85% of the total demand of water, and in view of the expected increase in water demand from the other sectors such as municipal and industrial sector. Efficient use of all water resources in Egypt requires the formulation and implementation of appropriate water policies.

Egypt can be divided into three main agro–climatic zones: (I). Lower Egypt (Nile Delta), extending from the north of Cairo to the Mediterranean Sea and characterized by some winter precipitation. (II). Middle Egypt, extending from south of Cairo to the boundary of Minia/Assuit governorates and characterized by minimal rainfall. (III). Upper Egypt, extending southwards from the Minia/Assuit governorates boundary to the Sudanese border and characterized by almost completely absence of rainfall. The rainy period is limited mostly during the period October to March where most of its volume fall from November to February. The highest annual precipitation reaching 191.8 mm is recorded around Alexandria. Daily evaporation ranges from 1.5 to 8.5 mm with a mean daily reference Evapotranspiration ranged from 2.0 to 10.0 mm. (cited by Bader 2004).

Moghazi and Ismail (1997) evaluated the water losses for three different types of canals, which were: earthern-uncompacted canals, compacted canal bed and canal lined by jute mats coated with bitumen emulsion on both faces. They showed that, the process of compacting the canal bed reduced the rate of seepage by a considerable value and that lining of field channels by prefabricated bitumen jute mats caused a significant reduction in the seepage rate.

Osman (2003) showed that, the proper design of gated pipes together with a precision land levelling improved the water distribution uniformity and saved irrigation water in field crops (cotton, wheat, maize, and rice) by 29.6%, 29.9% ,14.5% and 19.7% respectively, and by 19.8% for horticulture (mango) compared with traditional surface irrigation.

In Egypt, different irrigation systems are used to irrigate both old lands and newly reclaimed areas. These systems are surface, sprinkler and localized irrigation. The areas irrigated with the aid of these systems are 2,746,000, 450,000, and 104,000 for surface, sprinkler and localized irrigation systems respectively. The objectives of these projects were optimal water use and greater efficiency of water use; the maintenance and operation of dams, reservoirs, barrages; reuse of drainage water; better agricultural productivity and quality; extension of newly reclaimed areas by using modern irrigation systems, such as sprinkler and stationary drip irrigation systems (International Commission on Irrigation and Drainage, ICID, 2002).

In humid climate, irrigation was generally used for supplementary water supply of crops. In the Federal Republic of Germany, as an example of humid area, the development of amelioration was continued by the production of hose reel irrigation machines which became the prevailing type of sprinkler irrigation. This type was also successfully used for waste water irrigation especially in the region north Braunschweig (Quast, *et.al* 2005).

Although efforts towards increased crop production have been focused on the field of irrigation, it declined throughout the world since the eighties due to a significant decrease of investments in this field (González, 2000).

Benchmarking is defined as a systematic process for securing continual improvement through comparison with relevant and achievable internal or external norms and standards. The overall aim of benchmarking is to improve the performance of an organization as measured against its mission and objectives (International Programme for Technology and Research in Irrigation and Drainage, 2000).

The specific aim of Benchmarking program is to identify key competitors/ comparable organizations and find best management practices for that organization. These then become standards and/or norms against which to assess an organizations own performance. Performance indicators are specifically identified to enable the comparison and to monitor progress towards closing the identified performance gap (Malano and Burton, 2001).

Using of benchmarking program in irrigation is considered as a useful tool in the management of the irrigation water. It enables evaluation of resource utilization, and to evaluate performance against a target, as well as to compare against others. However, performance indicators are the main tool in a benchmarking process by which it can determine when an irrigation district is more or less efficient than another and take the necessary measures to correct any existing deficiencies. Benchmarking the activities and processes of irrigation and drainage systems can provide valuable insight on how well the system is performing in all areas of service delivery and resource utilisation (Malano *et al.*, 2004).

The main objective of this study was to evaluate the performance of irrigation process in both humid and arid areas, by using Benchmarking (IGRA) program. Also to drive which zone needs to improve its surface irrigation system and which needs to replace it by one of the modern irrigation systems.

MATERIALS AND METHODS

1. Benchmarking (IGRA) program

The Benchmarking IGRA computer application has been developed using visual basic with a multiple document interfaces format in order to enable several windows to be used at the same time. The flow chart of the IGRA program was as presented in Figure (1). IGRA program was designed to compare the performance between different irrigated zones. It starts with the definition of the descriptors which corresponds to the irrigated zones and then lists the variables for each irrigation year. With the help of both descriptors and variables, the program has the ability to calculate the performance indicators automatically. These indicators can be stored in database and can be viewed in the form of records, charts or tables (Pe´rez *et.al*, 2003).

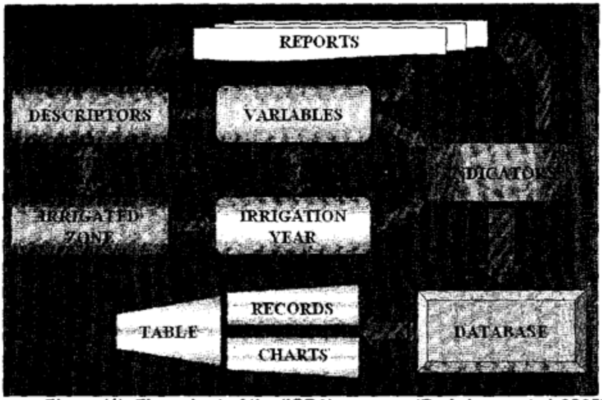

Figure (1): Flow chart of the (IGRA) program (Rodrı´guez *et.al.* 2005)

The selected performance indicators were corresponding to those outlined by International Programme for Technology and Research in Irrigation and Drainage (IPTRID) (Malano and Burton, 2001). They are divided into four different groups which are: system operation, financial indicators, productive efficiency and environmental performance indicators. Table (1) represents the four different groups including the used equation for calculating each indicator.

2. Irrigation zones

Benchmarking (IGRA) program was applied in two regions, one was humid and the other was arid region. The following is the description of the two regions which have been taken into consideration in this study:

(a) Humid region

Uelzen zone which located in lower Saxony, Germany was taken as an example of humid area. The total area for irrigation command in Uelzen is about 57534 ha and the annual irrigation area that can be irrigated varied from 41858 to 44511 ha. The main crops in Uelzen are Potato, Sugar beet, winter Rye and Barley. Most of the cultivated area in Uelzen depends on rainfall where, the average rainfall was about 543mm/year. Sprinkler irrigation (reel hose) is the common irrigation system in Germany and the irrigation process used for supplementary water supply of the crops. The ground water is the main source of irrigation water.

Table (1): Performance indicators for Benchmarking (IGRA) program as presented by (Malano and Burton 2001)

Group	Performance Indicators	Used Equation
System operation	Total annual volume of irrigation water delivered (m^3/year), (Vd)	Total volume of water delivered to water users over the irrigation/agriculture year
	Total annual volume of irrigation water supply (m^3/year), (Vis)	Total annual volume of water diverted or pumped for irrigation (not including diversion of internal drainage).
	Total annual volume of water supply (m^3/year), (Vs)	Total volume of surface diversions into the scheme and net groundwater abstraction for irrigation, plus total rainfall, excluding any recalculating internal drainage within the scheme.
	Annual irrigation water supply per unit command area (m^3/ha), (IsA)	$I_{sA} = \frac{V_{is}}{A}$
	Annual irrigation water supply per unit irrigated area (m^3/ha), (Isa)	$I_{sa} = \frac{V_{is}}{a}$
	Main system water delivery efficiency (%) (η_m)	$\eta_m = \frac{V_d}{V_s} \times 100$
	Annual relative water supply (m^3/m^3), (Rws)	$R_{ws} = \frac{V_s}{V_c}$
	Annual relative irrigation water supply (m^3/m^3), (Rwi)	$R_{wi} = \frac{V_{is}}{V_c}$
Financial indicators	Cost recovery ratio, (Cr), (%)	$C_r = \frac{R_g}{C_{mom}} \times 100$
	Maintenance cost to revenue ratio, Mr, (%)	$M_r = \frac{C_m}{R_g}$
	Total management, operation and maintenance cost per unit area (€/ha)	$C_{moma} = \frac{C_{mom}}{a}$
	Total cost per person employed on water delivery (€/person) (Ctp)	$C_{tp} = \frac{C_t}{N_p}$
	Revenue collection performance, Prc, (%)	$P_{rc} = \frac{R_g}{R_{gi}} \times 100$

Table (1): Con.

Group	Performance Indicators	Used Equation
	Staffing numbers per unit area, (person/ha), Npa	$N_{pa} = \frac{N_p}{a}$
	Average revenue per cubic metre of irrigation water supplied (€/m³), Rav,	$R_{av} = \frac{R_g}{V_d}$
	Total management, operation and maintenance cost per unit volume supplied (€/m³), Cmomv,	$C_{momv} = \frac{C_{mom}}{V_d}$
Productive efficiency	Total gross annual agricultural production, (ton/year), (Y)	Total annual tonnage of agricultural production by crop type.
	Total annual value of agricultural production (€/year), (Yv)	Total annual value of agricultural production received by producers.
Environmental performance	Salinity of irrigation water (dSm-1) (Eci)	(measured)
	Salinity of drainage water (dSm-1) (Ecd)	(measured)
	Average depth to water table (m) (dw)	Average annual depth of water table calculated from water table observations over irrigation area (measured).
	Chemical oxygen demand (COD) of irrigation water (mg l-1)	Chemical load of the irrigation supply and drainage water expressed as Chemical Oxygen Demand (COD) (measured)
	Biochemical oxygen demand (BOD) of irrigation water (mg l-1)	Biological load of the irrigation supply and drainage water expressed as Biochemical Oxygen Demand (BOD) (measured)
	Change in water table depth over time (m) (Δdw)	Change in water table depth over the last five years (measured).
	Salt balance,(t), (ds m^{-1})	Differences in the volume of incoming salt and outgoing salt (measured).

Vd = Total volume of water delivered to water users over the irrigation/agriculture year.
Vis = Total annual volume of water diverted or pumped for irrigation (not including diversion of internal drainage).
Vs = Total volume of surface diversions into the scheme and net groundwater abstraction for irrigation, plus total rainfall, excluding any recalculating internal drainage within the scheme.
A = Total command area (ha)   Vc = Total annual volume of water crop demand (m³)
a = Total irrigated area (ha)   Rg = Gross revenue collected (€)
Cmom = Total management, operation and maintenance cost (€)   Cm = Maintenance cost (€)
Ct = Total cost of personal engaged in irrigation and drainage service (€)
Np = Number of person engaged in irrigation and drainage service (€)
Rgi = Gross revenue invoiced (€)
Y = Total annual tonnage of agricultural production by crop type (ton/year)
Yv = Total annual value of agricultural production received by producers (€/year)
Eci = Electrical conductivity of irrigation water   Ecd = Electrical conductivity of drainage water
dw = Average annual depth of water table calculated from water table observations over irrigation area

(b) Arid region

Topographically, Egypt represented the arid region and divided into 3 agro-climatic zones: Lower, Middle, and Upper Egypt. Each zone is characterized by its climate and consequently its crop consumptive uses, irrigation scheduling and drainage requirements, and planting time. In this study three irrigation zones were considered and each represented one of the three agro climate.

(1) Kafer El-Sheikh zone

Kafer El-Sheikh zone has the following meteorological data: total average annual precipitation is about 62 mm, maximum temperature is about 33.3°C (in July), minimum temperature is about 6.6°C (in January), mean annual temperature is 20.2°C; maximum evapotranspiration is 6.09 mm per day in June and the minimum 1.56 mm per day in December. Average relative humidity is 59% in May and 82% in January. Wind speed ranges between 1.0m/sec in October and 1.7 m/sec in March.

(2) El- Giza zone

The meteorological data in El- Giza zone are: total average annual precipitation is 17 mm. Maximum temperature is about 34.7°C (in June). Minimum temperature is about 6.8°C (in January). Mean annual temperature is 21.3°C. Maximum evapotranspiration is 7.65 mm per day in June and the minimum is 2.06 mm per day in December. Maximum relative humidity is 74% in November and the minimum is 53% in May. Wind speed ranges between 1.8 m/sec in December and 2.9 m/sec in June.

(3) Suhag zone

In Suhag zone the meteorological data are: Almost no precipitation existed. Maximum temperature is about 38.5°C (in June). Minimum temperature is about 6.3°C (in January). Mean annual temperature is 23.5°C. Maximum evapotranspiration is 8.26 mm per day in May and the minimum 2.43mm per day in January. Maximum relative humidity is 65% in January and the minimum is 29% in May. Wind speed ranges between 1.3 m/sec in January and 2.3 m/sec in September.

3. Output data

The output data obtained from Benchmarking (IGRA) programs are presented in Table (2) followed with the used equation in the calculation of each output. The obtained results from benchmarking (IGRA) program used in differentiations between different areas at the same region. It can also be used to compare between irrigation system performance in humid and arid regions. In addition, it can illustrate the improvement in irrigation performance indicators due to applying the modified systems of irrigation.

Table (2): Output data obtained from Benchmarking (IGRA) program.

Output parameter	Used equation
1- Output revenue per unit command area, (€/ha), (Oc)	$Oc = \frac{Y_v}{A}$
2- Output revenue per unit irrigated area, (€/ha), (Oi)	$O_i = \frac{Y_v}{a}$
3- Output revenue per unit irrigation delivery, (€/m³), (Od)	$O_d = \frac{Y_v}{V_d}$
4- Output revenue per unit irrigation supply, (€/m³), (Ois)	$O_{is} = \frac{Y_v}{V_{is}}$
5- Output revenue per unit water supply, (€/m³), (Os)	$O_s = \frac{Y_v}{V_s}$
6- Output per unit crop water demand, (€/m³), (Ocw)	$O_{cw} = \frac{Y_v}{V_c}$
7- Annual relative water supply, (m³/m³), (Rwi)	$R_{wi} = \frac{V_{is}}{V_c}$
8- Annual irrigation water supply per unit command area, (m³/ha), (IsA)	$I_{sA} = \frac{V_{is}}{A}$
9- Annual irrigation water supply per unit irrigated area, (m³/ha), (Isa)	$I_{sa} = \frac{V_{is}}{a}$
10- Cost recovery ratio (%) (Cr)	$C_r = \frac{R_c}{C_{mom}} \times 100$

RESULTS AND DISCUSSION

1. Evaluation of the irrigation performance in humid area (Uelzen)

A historical series of data for a period of ten years for Uelzen irrigation zone as a humid region are used as inputs to IGRA program. All the data regarding descriptors, variables and performance indicators for irrigated zone during the studied period were stored in the IGRA database. Table 3 represents the performance indicators and the outputs which have been calculated with the help of (IGRA) program for the humid area (Uelzen). Command area was almost the same for the ten years except 1995 where it was higher because of the large amount of water supply. Limited irrigated area was varied across the studied period according to the available water and the water demand for the selected cultivated crops.

Table (3): Performance indicators and output data of the irrigation system for the humid area (Uelzen) recorded by IGRA program.

Performance indicators and outputs	Irrigation year				
	(1995)	(1996)	(1997)	(1998)	(1999)
Total annual volume of irrigation water supply, (m^3), (Vis)	56,540,640	40,217,920	33,785,810	24,049,100	52,754,170
Total annual volume of water supply, (m^3), (Vs)	251,293,100	230,216,120	252,031,530	304,926,970	243,750,871
Annual irrigation water supply per unit command area, (m^3/ha), (IsA)	809	699	587	418	917
Annual irrigation water supply per unit irrigated area, (m^3/ha), (Isa)	1107	957	804	572	1185
Annual relative water supply, (m^3/m^3), (Rws)	1.12	1.03	1.13	1.36	1.03
Cost recovery ratio, Cr, (%)	2	2	2	2	2
Maintenance cost to revenue ratio, Mr, (%)	0.23	0.27	0.32	0.45	0.22
Total management, operation and maintenance cost per unit area, (€/ha)	172	148	125	89	184
Total cost per person employed on water delivery, (€/person), (Ctp)	0.13	0.13	0.13	0.13	0.13
Staffing numbers per unit area (person/ha), (Npa)	0.0024	0.0024	0.0024	0.0024	0.0022
Total gross annual agricultural production (ton/year), (Y)	1,472,503	1,480,524	1,596,189	1,598,598	1,768,470
Total annual value of agricultural production (€/year), (Yv)	83,524,451	83,733,379	90,817,007	90,891,297	102,881,440
Output revenue per unit command area (€/ha), (Oc)	1452	1455	1578	1580	1788
Output revenue per unit irrigated area (€/ha), (Oi)	1987	1992	2161	2162	2311
Output revenue per unit irrigation supply (€/m^3), (Ois)	1.79	2.08	2.69	3.78	1.95
Output revenue per unit water supply (€/m^3), (Os)	0.33	0.36	0.36	0.30	0.42
Output revenue per unit crop water demand (€/m^3), (Ocw)	0.37	0.37	0.41	0.41	0.44
Command area, (ha), (A)	69890	57536	57557	57534	57529
Irrigated area, (ha), (a)	51076	42025	42022	42044	44518
Performance indicators and outputs	(2000)	(2001)	(2002)	(2003)	(2004)
Total annual volume of irrigation water supply, (m^3), (Vis)	43,738,430	33,625,930	18,311,710	92,283,140	31,495,650
Total annual volume of water supply, (m^3), (Vs)	247,687,832	308,970,976	399,103,315	274,574,730	253,008,186
Annual irrigation water supply per unit command area, (m^3/ha), (IsA)	760	584	318	1604	547
Annual irrigation water supply per unit irrigated area, (m^3/ha), (Isa)	983	755	411	2205	752
Annual relative water supply, (m^3/m^3), (Rws)	1.05	1.31	1.69	1.23	1.14
Cost recovery ratio, Cr, (%)	2	2	2	2	2
Maintenance cost to revenue ratio, Mr, (%)	0.26	0.34	0.25	0.12	0.34
Total management, operation and maintenance cost per unit area, (€/ha)	152	117	64	342	117
Total cost per person employed on water delivery, (€/person), (Ctp)	0.13	0.13	0.13	0.13	0.13
Staffing numbers per unit area (person/ha), (Npa)	0.0022	0.0022	0.0022	0.0024	0.0024
Total gross annual agricultural production (ton/year), (Y)	1822452	1804239	1625427	1713111	1855166
Total annual value of agricultural production (€/year), (Yv)	105434189	106331995	92788252	97184076	109204064
Output revenue per unit command area (€/ha), (Oc)	1833	1848	1613	1689	1898
Output revenue per unit irrigated area (€/ha), (Oi)	2369	2389	2085	2322	2609
Output revenue per unit irrigation supply (€/m^3), (Ois)	2.41	3.16	5.07	1.05	3.47
Output revenue per unit water supply (€/m^3), (Os)	0.43	0.34	0.23	0.35	0.43
Output revenue per unit crop water demand (€/m^3), (Ocw)	0.45	0.45	0.39	0.44	0.49
Command area, (ha), (A)	57550	57579	57548	57533	57579
Irrigated area, (ha), (a)	44495	44538	44554	41852	41883

1.1. Output revenue

Output revenue was calculated per both of unit command area, unit irrigated area and per unit volume of water supply. The obtained output revenue was plotted in Figure (2). The total command area of Uelzen zone is about 57534 ha and the annual irrigated area was about 42035, 44511 and 41858 ha for the periods of 1995 to 1998, 1999 to 2002, and 2003 to 2004 respectively. The higher output revenue recorded per unit irrigated area at 2004, where it was (2609 €/ha). While the lower was 1987 €/ha at 1995.This may be due to the increasing in the average production of all the main cultivated crops (Potato, Sugar beet, winter Rye and Barley) which lead to increase the annual amount of the agricultural production. It can also be seen a drop in the output revenue per unit command area and per unit irrigated area at 2002. The average production of all the main cultivated crops were low at 2002 besides the rainfall was higher at this year than that of the other years.

At 2004, the output revenue per unit irrigated area was higher by about 37.5% than the output revenue per unit command area. At 1995, the output revenue per unit irrigated area was higher by about 36.8% than the output revenue per unit command area. The difference was almost the same, but both of the amount of the irrigation water and crop production was varied at these two years.

The output revenue per unit water supply in (€/m^3) for the humid area (Uelzen) at the period under study reflexed the benefits of applying irrigation water. It shows that the highest output revenue per unit water supply was about 0.43 €/ha and achieved at the years of 1999, 2000 and 2004. This was because of the higher production of the main cultivated crops and the decreasing of the total annual volume of water supply during these years. It also shows that, there was a decrease in the output revenue per unit water supply during 1998 and 2002 compared with other studied irrigation years.

1.2. Annual irrigation water and annual relative water supply

The comparison between different years of irrigation in Uelzen zone, as a humid area, in annual irrigation water and annual relative water supply represented in Figure (3). The highest relative water supply was (1.69 m^3/m^3) observed at 2002, while the lowest was (1.03 m^3/m^3) at both 1996 and 1999. The lower the relative water supply the most use of the available water. Across the analysis of ten years for the recorded data, it seams that, the amount of rainfall played an important role in the humid area. Hence, the lower value of the annual relative water supply was due to the higher value of the rainfall. The higher value of annual irrigation water supply per unit irrigated area indicates that the cultivated area decreased. This was occurred at 2003 where it was 2205 m^3/ha. In contrary, when the cultivated area increased, the annual irrigated water per unit area decreased. At 2002, the cultivated area was greatest, hence, the annual irrigation water was the lowest (411 m^3/ha).

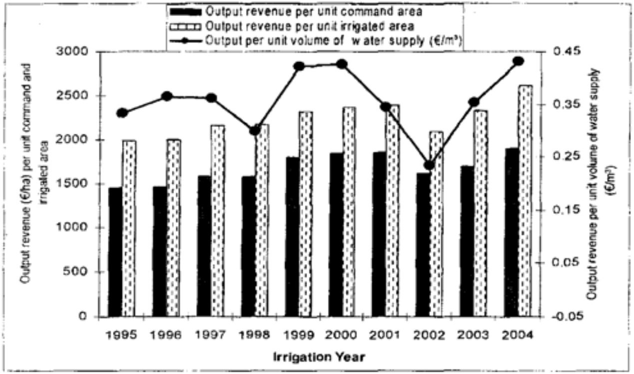

Figure (2): Output revenue per unit command area, unit irrigated area (€/ha) and unit volume of water supply (€/m^3) for the humid area (Uelzen) for each year of the studied period

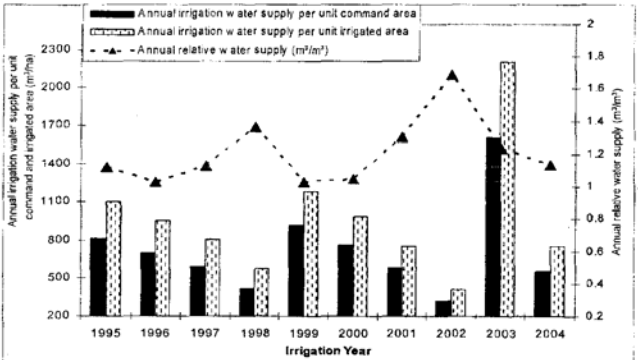

Figure (3): Annual irrigation water supply per unit command area, unit irrigated area (m^3/ha) and annual relative water supply (m^3/m^3) for the humid area (Uelzen)

2. Evaluation of the irrigation system for the arid areas

In arid areas, the evaluation of the irrigation performance in each zone was carried out two times, one with traditional irrigation system and the other with modified surface irrigation system. Table (4) represents the performance indicators in case of traditional irrigation system. The difference of the performance indicators between the three zones was due to the total annual amount of irrigation water delivered.

Table (5) represents the evaluation of the irrigation performance in case of modified system of surface irrigation. The total amount of water delivered in each zone was less than that with traditional irrigation system. Therefore, the outputs obtained with modified system will differ comparing with the outputs of the traditional irrigation system.

2.1. Annual irrigation water supply

Figure (4) indicates the annual irrigation water supply per both unit command and unit irrigated area (m^3/ha) for both traditional and modified surface irrigation systems with traditional delivery canal. The modified surface irrigation system (gated pipe or surge flow) was with improved delivery canal. The highest annual irrigation water supply in case of traditional irrigation per unit command area was 17434 m^3/ha observed with Suhag zone. The lowest annual irrigation water supply with modified irrigation per unit command area was 14275 m^3/ha observed with Kafer El-Sheikh zone. Using the modified systems led to decrease the annual irrigation water supply by about 12.85, 12.51 and 13.11% comparing with traditional system for Kafer El-Sheikh, El- Giza and Suhag respectively. Moreover, the annual quantity of water saving as a result of modified surface irrigation with improved delivery canal was (2105, 2144 and 2286 m^3/ha) for Kafer El-Sheikh, El- Giza and Suhag respectively. Water saving percent per unit irrigated area due to applying modified surface irrigation system was 12.85% in Kafer El-Sheikh, 12.5% in El- Giza and 13.12% in Suhag.

The annual irrigation water supply per unit irrigated area was lower for both traditional and modified surface irrigation systems than the annual irrigation water supply per unit command area for all irrigation zones. The modified surface irrigation system (gated pipe or surge flow) decrease the annual irrigation water supply per unit irrigated area by 1238 m^3/ha for Kafer El-Sheikh, and by 1261 m^3/ha for El- Giza and by 1345 m^3/ha for Suhag. However, the results illustrated that Kafer El-Sheikh was the lowest zone in the annual irrigation water supply per unit irrigated area because the evapotranspiration in Kafer El-Sheikh was less than the other zones.

Table: (4): Performance indicators and outputs calculated with Benchmarking (IGRA) program for arid areas with traditional irrigation system.

Indicators	Irrigation zone		
	Kafer El-Sheikh (Lower Egypt)	Giza (Middle Egypt)	Suhag (Upper Egypt)
Total annual volume of irrigation water delivered, (m^3/year), (Vd)	1,347,281,320	410,066,185	1,254,678,740
Total annual volume of irrigation water supply, (m^3/year), (Vis)	1,347,281,320	410,066,185	1,254,678,740
Total annual volume of water supply, (m^3/ year), (Vs)	1,433,977,160	416,978,555	1,254,678,740
Annual irrigation water supply per unit command area (m^3/ha)	16,380	17,144	17,434
Annual irrigation water supply per unit irrigated area, (m^3/ha), (IsA)	9,635	10,085	10,255
Annual relative water supply, (m^3/ m^3), (Rws)	1.28	1.16	1.1
Security of entitlement supply (%)	80	80	80
Cost recovery ratio (%), Cr,	56	50	48
Maintenance cost to revenue ratio (%), Mr,	36	40	21
Total management, operation and maintenance cost per unit area, (€/ha), Cmom	72	80	85
Total cost per person employed on water delivery, (€/person), Ctp	3	3	3
Staffing numbers per unit area (person/ha), Npa	0.58	0.58	0.58
Average revenue per cubic metre of irrigation water supplied (€/m^3), Rav	0.004	0.004	0.004
Total management, operation and maintenance cost per unit volume supplied (€/m^3), Cmomv	0.008	0.008	0.008
Total gross annual agricultural production (ton/year), Y	595	269	717831
Total annual value of agricultural production (€/year), Yv	103,480,078	25,154,869	72,593,208
Output revenue per unit command area (€/ha), Oc,	1,258	1,052	1,009
Output revenue per unit irrigated area (€/ha), Oi,	740	619	593
Output revenue per unit irrigation delivery (€/m^3), Od,	0.08	0.06	0.06
Output revenue per unit irrigation supply (€/m^3), Ois,	0.08	0.06	0.06
Output revenue per unit water supply (€/m^3), Os,	0.07	0.06	0.06
Output revenue per unit crop water demand (€/m^3), Ocw,	0.09	0.07	0.06
Total command area (ha), A,	82252	23919	71967
Total irrigated area (ha), a,	139832	40661	122348

Table (5): Performance indicators and outputs calculated with Benchmarking (IGRA) program for arid areas with modified surface irrigation systems.

Indicators	Irrigation zone		
	Kafer El-Sheikh (Lower Egypt)	El- Giza (Middle Egypt)	Suhag (Upper Egypt)
Total annual volume of irrigation water delivered, (m^3/year), (Vd)	1,174,205,660	358,782,091	1,090,174,513
Total annual volume of irrigation water supply, (m^3/year), (Vis)	1,174,205,660	358,782,091	1,090,174,513
Total annual volume of water supply, (m^3/ year), (Vs)	1,260,901,500	365,694,461	1,090,174,513
Annual irrigation water supply per unit command area (m^3/ha)	14,275	15,000	15,148
Annual irrigation water supply per unit irrigated area, (m^3/ha), (IsA)	8,397	8,824	8,910
Annual relative water supply, (m^3/ m^3), (Rws)	1.33	1.19	1.11
Security of entitlement supply (%)	80	80	80
Cost recovery ratio (%), Cr,	62	55	52
Maintenance cost to revenue ratio (%), Mr,	32	36	38
Total management, operation and maintenance cost per unit area, (€/ha), Cmom	61	68	72
Total cost per person employed on water delivery, (€/person), Ctp	3	3	3
Staffing numbers per unit area (person/ha), Npa	0.59	0.59	0.59
Average revenue per cubic metre of irrigation water supplied (€/m^3), Rav	0.005	0.004	0.004
Total management, operation and maintenance cost per unit volume supplied (€/m^3), Cmomv	0.007	0.008	0.008
Total gross annual agricultural production (ton/year), Y	820,695	393,646	1,017,606
Total annual value of agricultural production (€/year), Yv	112,941,003	36,653,533	102,216,359
Output revenue per unit command area (€/ha), Oc,	1,373	1,532	1,420
Output revenue per unit irrigated area (€/ha), Oi,	808	901	836
Output revenue per unit irrigation delivery (€/m^3), Od,	0.096	0.1	0.094
Output revenue per unit irrigation supply (€/m^3), Ois,	0.096	0.1	0.094
Output revenue per unit water supply (€/m^3), Os,	0.09	0.1	0.094
Output revenue per unit crop water demand (€/m^3), Ocw,	0.12	0.12	0.11
Total command area (ha), A,	82256	23919	71968
Total irrigated area (ha), a,	139836	40660	122354

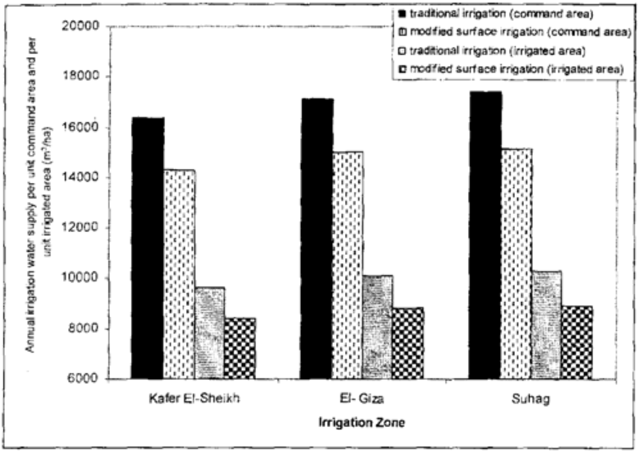

Figure (4): Annual irrigation water supply per unit command area and per unit irrigated area in (m^3/ha) for traditional and modified surface irrigation systems in arid areas

2.2. Cost recovery ratio

Cost recovery ratio is considered as a comparison parameter between different irrigation zones. Figure (5) shows the values of the cost recovery ratio under traditional and modified surface irrigation systems. The values of the cost recovery ratio in Kafer El-Sheikh were higher than El- Giza and Suhag either with traditional or modified systems. Moreover, the results show that, the modified surface irrigation system led to increase the values of cost recovery ratio by about 11%, 10% and 10% for Kafer El-Sheikh, El-Giza and Suhag irrigation zones respectively.

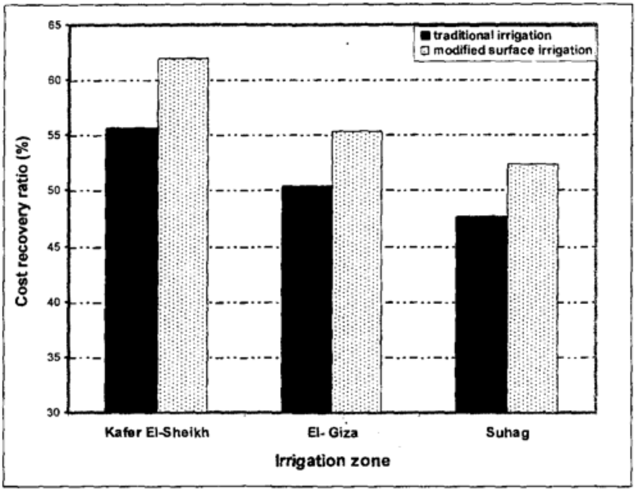

Figure (5): Cost recovery ratio (%) under traditional and modified surface irrigation systems for arid regions

2.3. Output revenue per unit irrigated area

Figures (6) illustrated that the productivity of Kafer El-Sheikh, was higher than both El- Giza and Suhag under traditional surface irrigation. This may be due to the higher production of the main crops (Wheat and Maize) and the higher total annual precipitation share in Kafer El-Sheikh which decrease the total annual irrigation need for these crops. Meanwhile, with modified surface irrigation system, El- Giza irrigation zone achieved higher value because the modified surface irrigation system led to decrease the losses of water and increase the production of the main crops (Wheat and Maize) in El- Giza irrigation zone. Moreover, the modified surface irrigation increase the output revenue per unit irrigated area (from 740 to 808, from 619 to 901 and from 593 to 836 €/ha) for Kafer El-Sheikh, El- Giza and Suhag irrigation zones respectively. This mean that, irrigation by modified irrigation system with gated pipes or surge flow increase the output revenue by 9.2% in Kafer El-Sheikh, 45.56% in El- Giza and by 40.98% in Suhag.

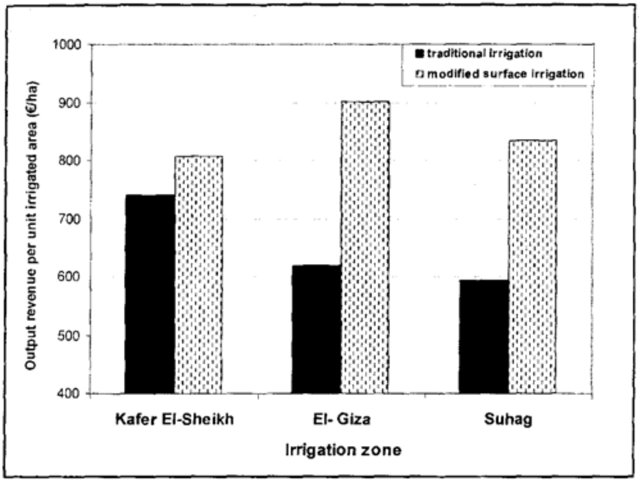

Figure (6): Output revenue per unit irrigated area (€/ha) under traditional and modified surface irrigation systems for arid regions

CONCLUSION

Appling Benchmarking (IGRA) program in irrigation as a beneficial tool in water irrigation management achieved a successful evaluation of irrigation performance in both humid and arid regions. In humid areas the higher output revenue was observed when the rainfall with large depth, where the irrigation is considered as a supplemental process. In arid areas, using the modified irrigation system (gated pipes or surge flow) instead of the traditional surface irrigation system increased the annual output revenue by 9.2, 45.56 and 40.98% in Kafer El-Sheikh, El- Giza and Suhag respectively. Also, the percent of water saved per unit irrigated area due to using modified surface irrigation system with gated pipes or surge flow was 12.85, 12.5 and 13.12% for Kafer El-Sheikh, El- Giza and Suhag respectively.

REFERENCES

Bader E. (2004). Mathematical programming models for optimising irrigation water management in Egypt. Ph.D. Thesis, Faculty of Agriculture, Kiel University, Germany.

González, F. J. (2000). Benchmarking for irrigation Systems. Experiences and Possibilities. Washington, D. C.

International Commission on Irrigation and Drainage (ICID). (2002). Sprinkler and micro-irrigation area in some member countries of ICID. ICID Working Group On Farm Irrigation Systems, Working Paper.

IPTRID International Programme for Technology and Research in Irrigation and Drainage. (2000). Benchmarking irrigation and drainage service provision.

Malano, H. and M. Burton (2001). Guidelines for benchmarking performance in the irrigation and drainage Sector. IPTRID–FAO: Rome.

Malano, H., M. Burton and I. Makin (2004). Benchmarking performance in the irrigation and drainage sector: a tool for change. Irrigation and Drainage 53: 119–133.

Moghazi, H. E. and E. S. Ismail (1997). A study of losses from field channels under arid region conditions. Irrig. Sci. 17: 105 - 110.

Osman, H. E. (2003). Evaluation of surface irrigation using gated pipes techniques in field crops and old horticultural farm. http://afeid.montpellier.cemagref.fr/Mpl2003/ AtelierTechno/Atelier Techno/ Papier%20Entier/N%C2%B054%20-%20EGYPTE_PR.pdf

Pe´rez L., JA Rodrı´guez, E. Camacho, R. Lo´pez, J. Rolda´n, M. Alcaide, JA. Ortiz and R. Segura (2003). IGRA. An approach for the application of the benchmarking initiative to irrigation areas. ICID–CIID, 54th International Executive Council, 20th European Regional Conference, Montpellier, France.

Quast, J., V. Ehlert, E. Lübbe, H. Sourell and K. O. Wenkkel (2005). Country report on irrigation management transfer in Germany. www.zalf.de/icid/countryreport_imt_germany.pdf.

Rodrı´guez J. A., L. Pe´rez, E. Camacho and R. Lo´pez (2005). IGRA. A tool for applying the benchmarking initiative to irrigated areas. Irrigation and Drainage 54:307 – 319.

إستخدام برنامج معايير الجودة Benchmarking (IGRA) فى تقييم أداء نظم الرى فى المناطق الرطبة والجافة

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الملخص العربى

أجريت هذه الدراسة بهدف تقييم أداء نظم الرى فى المناطق الرطبة والجافه وذلك بإستخدام برنامج معايير الجودة(IGRA) Benchmarking والمعروف في تقييم بارامترات الإدارة لأى نظام إنتاجى ويعتبر إستخدامه فى تقييم نظم الرى أحد ألاداوات الهامة فى تقييم إدارة مياه الرى تحت نظم رى مختلفة. أختيرت منطقة يلتسن بألمانيا كأحد المناطق التى تمثل المناخ الرطب وأختيرت جمهورية مصر العربية لتمثل المناخ الجاف. وإشتمل البرنامج على مدخلات سميت بمعايير الأداء حيث تم تقسيمها إلى أربعة معايير هى:

(١) معايير خاصة بتشغيل نظام الرى (٢) معايير خاصة بالمؤشرات الاقتصادية

(٣) معايير خاصة بكفاءة الانتاج (٤) معايير خاصة بالمتغيرات البيئية

واحتوى البرنامج على عدة مخرجات لتقييم أداء نظام الرى هى :- العائد المتحصل عليه من وحدة المساحة المرواة – والعائد لوحدة الحجم من المياه المضافة – العائد لوحدة الحجم للمياه التى يحتاجها المحصول وأيضا كمية المياه السنوية المطلوبة لوحدة المساحة المرواة.

وتم إجراء الدراسة على منطقة يلتسن بألمانيا من خلال بيانات عشرة أعوام سابقة بينما أجريت الدراسة فى جمهورية مصر العربية على ثلاث مناطق هى كفر الشيخ والجيزة وسوهاج وأدخلت البيانات الخاصة بكل منطقة وتم مقارنة مؤشرات الجودة فى مناطق جمهورية مصر العربية لنظام الرى السطحى التقليدى ولنظام الرى السطحى المطور وتوصلت الدراسة إلى النتائج الآتية:

(١) بالنسبة لمنطقة بلتسن بألمانيا والتى تمثل المناطق الرطبة حيث تعتبر فيها عملية الرى تكميلية تحقق أعلى عائد لوحدة المساحة المرواة ومقداره ٢٦٠٩ يورو/هكتار عام ٢٠٠٤ بينما أقل عائد وقيمته ١٩٨٧ يورو/هكتار تحقق عام ١٩٩٥.

(٢) تحقق أعلى عائد لوحدة المساحة المرواة فى المناطق الجافة وقيمته ٧٤٠ يورو/هكتار فى منطقة كفر الشيخ تحت نظام الرى السطحى التقليدى بينما كانت أعلى قيمة ومقدارها ٩٠١ يورو/هكتار فى منطقة الجيزة تحت نظام الرى السطحى المطور.

(٣) أوضحت النتائج أن ادخال نظام الرى السطحى المطور أدى الى زيادة نسبة التكاليف المغطاة (Cost recovery ratio) بمقدار ١١%, ١٠% & ١٠% لكل من كفر الشيخ والجيزة وسوهاج على الترتيب مقارنة بالرى السطحى التقليدى.

(٤) أدى إستخدام نظام الرى السطحى المطور (باستخدام الانابيب المثقوبة – الرى النبضى) الى زيادة قيمة العائد السنوى المتحصل عليه لوحدة المساحة المرواة بمقدار ٩,٢% بكفر الشيخ، ٤٥,٥٦% بالجيزة، ٤٠,٩٨% فى سوهاج مقارنة بالرى السطحى التقليدى.

(٥) إستخدام نظام الرى السطحى المطور (باستخدام الانابيب المثقوبة – الرى النبضى) ساهم فى توفير كمية مياه الرى السنوية بنسبة ١٢,٨٥% فى كفر الشيخ، ١٢,٥% فى الجيزة، ١٣,١٢% فى سوهاج مقارنة بالرى السطحى التقليدى.