USING OF TRIPLE-TREATED WASTEWATER IN AGRICULTURAL IRRIGATION IN AL-AHSA OASIS, SAUDI ARABIA.

M. N. El-Sebaei [1, 2] R. T. Osman [1] H. E.H. Mansour [1] M. A. Al-Asmari [3]

[1.] Dept. Agribus. & Consumer Sci., Coll. Agric. Sci. & Food, Univ. King Faisal, Al-Ahsa, Saudi Arabia.

[2.] Dept. Agricultural Economics, Fac. of Agric., Univ. Ain Shams, Shubra Al Khaimah, Cairo, Egypt.

[3.] General Irrigation Corporation in Al-Afalaj, Riyadh, Saudi Arabia.

melsebaei@kfu.edu.sa

ABSTRACT

The agricultural sector consumes about 84% of the total actual water consumption annually in Kingdom of Saudi Arabia, therefore, the research depends on questionnaire data that was judged before being used in the study of a random sample of 355 farms from Al-Ahsa Oasis which irrigated with two types of water (groundwater, triple-treated wastewater) to measure the economic impact of the using of triple-treated wastewater in irrigating palm and lemon crops, the results indicated a statistically significant correlation between the extent of farmers' which using of triple treated wastewater in irrigation and all of: size of the tenure, family size and the educational level of the farmer. While the relationship was negative with all of: age of the farmer, and number of years of his experience. The results showed that the productivity of dunums on farms irrigated with triple-treated wastewater increased by 0.32, 0.30, 0.22 tons, representing about 19.2%, 17.2%, 16.8% compared to which using groundwater for Alkhallas palm, Alrziz palm and lemon.

Keywords: irrigation systems, dummy variables, water unit productivity, water unit revenue, partial efficiency.

استعمال مياه الصرف الصحي المعالجة ثلاثياً في الري الزراعي بواحة الأحساء – المملكة العربية السعودية

ممتاز ناجي محمد السباعي [2،1] راضي طلعت عثمان [1] حسام الدين حامد منصور [1] محمد علي الأسمري [3]

(1) قسم الأعمال الزراعية وعلوم المستهلك، كلية العلوم الزراعية والأغذية، جامعة الملك فيصل، الأحساء، السعودية.

(2) قسم الاقتصاد الزراعي، كلية الزراعة، جامعة عين شمس، شبرا الخيمة، القاهرة، مصر.

(3) المؤسسة العامة للري بالأفلاج، الرياض، المملكة العربية السعودية.

المستخلص

يستهلك القطاع الزراعي نحو 84% من جملة الاستهلاك الفعلي للمياه سنوياً بالمملكة العربية السعودية، ونظراً لمحدودية مياه الري والتنافس الشديد بين مختلف أوجه استعمالاتها فقد استلزم الأمر زيادة المعروض منها من خلال تنويع مصادرها، اعتمد البحث على بيانات استبانة لعينة عشوائية بلغ حجمها 355 مزرعة من واحة الأحساء، تروى بنوعين من المياه (مياه جوفية، ومياه صرف صحي معالجة ثلاثياً) لقياس الأثر الاقتصادي، أشارت النتائج لوجود ارتباط طردي ومعنوي احصائياً بين مدى إقبال الزراع على الري بمياه الصرف الصحي المعالجة ثلاثياً وكل من: حجم الحيازة، وحجم الأسرة، والمستوى التعليمي للمزارع. في حين جاءت العلاقة عكسية مع كل من: عمر المزارع، وعدد سنوات خبرته. أوضحت النتائج زيادة إنتاجية الدونم بالمزارع التي تروى بمياه الصرف الصحي المعالجة ثلاثياً بمقدار 0.32، 0.30، 0.22 طن تمثل نحو 19.2%، 17.2%، 16.8% من نظيرتها التي تروى بالمياه الجوفية لكل من نخيل الخلاص والرزيز والليمون على الترتيب.

الكلمات المفتاحية: نظم الري، المتغيرات الانتقالية، إنتاجية وحدة المياه، عائد وحدة المياه، الكفاءة الجزئية.

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INTRODUCTION

Wastewater treatment is a process used to remove contaminants from wastewater or sewage and convert it into an effluent that can be returned to the water cycle with minimum impact on the environment, or directly reused (10). The agricultural sector consumes about 84% of the total actual water consumption annually in Saudi Arabia (15), due to limited irrigation water and competition between its various uses in the Kingdom, In view of the Kingdom's Vision 2030, which aims to Maintaining natural resources and achieving environmental sustainability, the government needed to focus not only on rationalizing its use in this vital sector, but also on trying to increase its supply by diversifying its resources and exploiting the largest amount of them in various ways to avoid the gap between the available quantities of water. supply and actual demand for it, In Al-Ahsa oasis, the irrigation water resources of the irrigation and drainage project have undergone a major transformation, since its inception, it has been depending on the groundwater available from 32 natural springs of the largest springs of Al-Ahsa, and after the depletion of these springs beginning in the mid-1980s, the project's share of this water decreased. They accounted for only about 50% of the total irrigation water sources and did not provide artesian wells that were drilled as substitutes for the springs and at the same level the amount obtained by the project (5). This may be due to the low water level in the formation of nuigen - the formation of underground nuigen is the main source of irrigation and drinking water in the Al-Ahsa oasis, providing about 90% of the region's needs for agricultural and domestic purposes - as well as the high salinity of groundwater in this composition in some Oasis Areas (7). The research problem in general is the increasing water deficit in Al-Ahsa region due to the depletion of natural springs in it since the mid-eighties of the last century, at a time when the demand for water is increasing as a result of the increasing population on the one hand, and the development of rates of economic and social development and the rise of Living standards and thus increasing food needs on the other hand, and to make up for this water deficit, other non-traditional sources had to be found to benefit from the water output available from the treatment plants in Al-Ahsa, and this was sought by the State Irrigation Corporation of Al-Ahsa early according to Its strategy for the conservation of natural sources of groundwater (13, 14). The principal objective of wastewater treatment is generally to allow human and industrial effluents to be disposed of without danger to human health or unacceptable damage to the natural environment (20). So the research aims mainly to compare the using of two types of irrigation water (triple-treated waste water and groundwater), using some partial efficiency criteria such as: water unit return, water unit productivity, amount of water needed to produce a unit of product, The return of the Saudi riyal from the costs, and unit Produced cost. In order to estimate the requirements of the dunum (1000 m^2) of agricultural resources according to the quality of irrigation water, to expand the use of this type of water, which contributes effectively to the sustainable development of Al-Ahsa Oasis (4).

MATERIALS AND METHODS

Data sources: The research was based mainly on primary data collected in the field in the interview of a sample of al-Ahsa farmers selected in a random sample from three regions within the irrigation and drainage project in Al-Ahsa (Al-Mansoura, Al-Hara and Jlyjela), according to the number of irrigated farms in each region. It is irrigated with two types of water (groundwater, triple-treated wastewater), the data were collected through a specially designed questionnaire, and the data were collected through a specially designed questionnaire, the questionnaire was subject to scientific evaluation and its validity and reliability were verified. The sample size is determined According to puri equation (16), as the following:

$$n = \frac{4N}{4 + \frac{(N-1)e^2}{pq}}$$

Where: n = sample size required, N = community size, e = allowable error rate, P = the proportion of farms irrigated with triple-treated wastewater, q = the proportion of farms irrigated with groundwater (wells). It was

assumed that the error rate was 5%, and that p equals q equal 0.5, in order to avoid bias and to give them equal opportunities, and in light of the available data there were 22,304 farms in Al-Ahsa Oasis, of which 11,943 were irrigated with triple-treated wastewater, an area of about 2,750 hectares in 2018, while the number of Wells water farms (groundwater) 10,361 farms with an area of about 5,207 hectares in the same year (The public irrigation corporation of Al-Ahsa, unpublished data), Accordingly, the sample size of 393 farms selected. 420 forms were distributed, 65 forms were excluded because the required data was not completed or often not in line with economic logic, so the research based its economic analysis on a sample of (355) farms representing about 90% of the sample size. In addition, some secondary data were obtained from the Department of Studies, Planning and Statistics of the Ministry of Environment, Water and Agriculture, the Ministry of Economy and Planning, the International Information Network, and studies and researches related to the study.

Research methodology: The research depends on descriptive and quantitative analysis methods, using statistical indicators such as averages, percentages and correlation coefficients. Quantitative statistical methods such as multiple regressions, t- test, and dummy variables have also been used to demonstrate the impact of irrigation quality, irrigation methods or geographical region on crops study productivity. Technically, dummy variables are dichotomous, quantitative variables (9). Their range of values is small; they can take on only two quantitative values. As a practical matter, regression results are easiest to interpret when dummy variables are limited to two specific values, 1 or 0. Typically, 1 represents the presence of a qualitative attribute, and 0 represents the absence. The number of dummy variables required to represent a particular categorical variable depends on the number of values that the categorical variable can assume. To represent a categorical variable that can assume k different values, would need to define k - 1 dummy variable (6, 8). In addition to using some partial efficiency criteria for irrigation water as a production resource (1), and to achieve research objectives, the data was statistically analyzed using SPSS ver.16 (11), and Minitab ver.14 (3).

Theoretical framework of the study

Wastewater is subject to four stages of treatment: pre-treatment, primary treatment, bilateral treatment and tri-treatment (2).**Treated wastewater:** Water coming out of the wastewater treatment plant after proper treatment in accordance with the standard of its quality according to the purpose of its use.

Bilateral treatment: is the level of treatment that can be achieved through biotherapy ending with deposition and disinfection, which aims to activate bacteria in wastewater to reduce the concentration of organic matter, and the resulting water can be used to irrigate all types of crops, Except for vegetables and plants whose fruit touches processed water (17), whether eaten fresh or cooked (9). **Tri-treatment:** The level of treatment that can be achieved through bioprocessing ending with filtration, disinfection and any other processes, the resulting water can be used to irrigate all crop species (19).

Future prospects for irrigation water sources at the Public Irrigation Corporation in Al-Ahsa: The foundation's future plans indicate that the future sources of irrigation water in Al-Ahsa irrigation and drainage project will be entirely dependent on triple-treated wastewater to provide irrigation water, which is estimated at 510 Thousand m^3 per day from the following treatment plants: Al-Hofuf, Al-Omran, Al-Ayoun, Al Khobar, with about 180,50,30,200Thousand m^3, respectively, and about 50 Thousand m^3 agricultural wastewater that can be dispensed with in the future with the aim of improving the quality and standard of irrigation water. (Five-year plan of the Irrigation and Drainage Authority of Al-Ahsa. 1430-1435 H. Department of Planning and Development, unpublished reports).

RESULTS AND DISCUSSION

1- Cropping patterns of the field sample

The results showed that there is compatibility in the larger crops with each of the crop composition according to the statistics of the Ministry of Environment, Water and Agriculture and the field study sample as described in Table 1.

Table 1. Cropping Pattern of al-Ahsa in the sample of field study for agricultural season 2018/2019

Crop	Number of farms	Total area (dunum)	Relative importance (%)
Palm	355	1826.0	78.6
Lemon	175	297.0	12.8
Figs	33	19.5	0.8
Onion	24	31.0	1.3
Zucchini	24	65.0	2.8
Okra	18	28.0	1.2
Other vegetables	75	58.0	2.5
Total	-	2324.5	100.0

Source: Collected and calculated from the sample of field study for the agricultural season 2018/2019.

The total area of the sample farms was 2324.5 dunums of which 1826 dunums of palm sat with 78.6% of the total crop area of the sample, then lemon with an area of 297 dunums with an estimated 12.8% of the best-known al-Ahsa, which represents both crops more than 91% of the compositional For the sample, this is followed by zucchini, onion, okra, figs and other vegetables with a ratio of about 2.8%, 1.3%, 1.2%, 0.8%, and 2.5%, respectively. Therefore, the study relied mainly on palm and lemon crops (13, 14).

1- **The relative distribution of farms and cultivated areas depending on the quality of irrigation water in al-Ahsa oasis**

The number of farms irrigated by underground water (wells) in al-Ahsa oasis amounted to about 11,671 farms with an area of about 26,075 dunums representing about 54%, 34.1% of the total number of farms and areas cultivated in the oasis respectively, while the number of farms irrigated with triple-treated wastewater from the State Irrigation Corporation about 9,925 farms with a cultivated area amounted to about 50,358 dunums, representing about 46%, 65.9% of the total number of farms and areas cultivated in the oasis, respectively. As show in the Table 2. It is also clear from the results of the same table of the large size of the farms that use treated wastewater for irrigation, while small farms depend on wells (groundwater).

Table 2. The relative distribution of the number of farms and the area cultivated of Al-Ahsa oasis by the quality of irrigation water. (Area: dunum)

Channels	Groundwater (wells)		Triple treated wastewater		Total	
	Number of farms	area	Number of farms	area	Number of farms	Area
A	852	1156	156	621	1008	1777
B	748	1212	1177	7932	1925	9144
C	1140	2223	1666	9638	2806	11861
D	817	1866	1441	6856	2258	8722
E	1072	2712	1128	4303	2200	7015
F	1277	2984	1887	9516	3164	12500
G	1717	4406	560	2635	2277	7041
H	2218	5117	523	2541	2741	7658
I	979	2145	360	1586	1339	3731
J	851	2254	1027	4730	1878	6984
K	11671	26075	9925	50358	21596	76433
Total	11671	26075	9925	50358	21596	76433
%	54.0	-	46.0	-	100.0	-
%	-	34.1	-	65.9	-	100
Average farm size		2.2	-	5.1	-	3.5

Source: Collected and calculated from the Public Irrigation Corporation for the agricultural season, 2018/2019

3- **The relative distribution of the units of the field sample according to the quality of irrigation water**

The study depends on preliminary data for a random sample of (355) farms distributed on the project areas approved by the State Irrigation Corporation of Al-Ahsa, namely Al-Mansoura, Al-Hara and Jlyjela according to the number of irrigated farms each, including farms irrigated from the project water (triple treated waste water), and others Irrigated from wells water (groundwater), Table 3.

Table 3. The relative distribution of the sample of field study according to the type of irrigation water

The region	Groundwater (Wells)		Triple treated wastewater		Total	
	Number of farms	%	Number of farms	%	Number of farms	%
Al-Mansoura	80	22.6	89	25.1	169	47.7
Al-Hara	54	15.2	36	10.1	90	25.3
Jlyjela	54	15.2	42	11.8	96	27.0
Total	188	53.0	167	47.0	355	100.0

Source: Collected and calculated from the sample of field study for the agricultural season 2018/2019

4- **The socio-economic characteristics of the field study sample farmers**

To clarify the extent to which farmers are interested in the use of triple-treated wastewater for agricultural irrigation purposes in accordance with their social and economic characteristics, the Pearson Correlation Coefficient Test (6, 8), where Table 4 indicates a statistically direct and moral correlation between the extent of the turnout Farmers using triple treated wastewater in irrigation: size of tenure (in dunum), family size (per capita), farm educational level (number of years of education), reverse relationship with age of the farmer (per year) and number of years of experience (per year). The high level of education is an important factor in creating a mental and material readiness for change, and this is consistent with what he said (18). The results of the survey also showed that the existence of agriculture as a secondary occupation of the farmer is evidence of its preoccupation with work other than agriculture and therefore it is preferable to use triple-treated sewage from the institution, this can be easily pursued.

Table 4. Some of the socio-economic characteristics of the study sample farmers and their interest in the use of triple-treated wastewater for agricultural irrigation

Study variables	Unit	Pearson Correlation Coefficient	Probability p value
Tenure size	Dunum	0.73	0.000
Family size	An Individual	0.63	0.000
The educational level	year	0.32	0.000
Farmer age	year	- 0.17	0.000
Experience for farmers	year	- 0.60	0.000

Where: The probability p value refers to the morale of all correlation transaction values at a moral level of 0.01
Source: Collected and calculated from the sample of field study for the agricultural season 2018/2019

5- **Quantitative measurement of the impact of the quality of used irrigation water on the productivity of the crops study**

First: T-test method

A. Impact of irrigation water quality on the dunum productivity of Alkhallas dates: The results of the statistical analysis showed that the productivity of dunum of alkhallas dates amounted to about 1.62 tons for farms irrigated with groundwater, while the productivity of the dunum for farms irrigated with triple treated sewage increased to about 1.92 tons per dunum, and this increasing is significant statistically where value of (t) calculated (5.85) (Table 5), possibly due to the low quality of groundwater because of increasing salinity due to the movement of salinity to the aquifers of the oasis, especially in the north of the oasis adjacent to the Arabian Gulf. In order to identify the difference between the average productivity of dunum according to the quality of irrigation water after the stabilization of the irrigation system and the region, It showed the superior productivity of dunums in farms irrigated with triple treated wastewater compared to farms irrigated with ground water (wells) in Jlyjela area in case of immersion irrigation only, while it was shown that the dunum productivity was higher in farms irrigated with triple treated wastewater compared to farms irrigated with ground water (wells) in modern irrigation condition at various study areas. The value of the difference coefficient in the case of triple treated sewage irrigation was found to be lower than in groundwater irrigated farms, although the difference was small.

Table 5. The results of the statistical analysis of the significance of the difference between two averages (Alkhallas dates).

The region	Irrigation system	Average dunum productivity per ton		T-test: two-sample assuming unequal variances	Significant
		Triple treated wastewater	underground water (wells)		
Al-Mansoura		1.72	1.59	1.15	-
Al-Hara	Immersion	1.80	1.79	0.07	-
Jlyjela		1.77	1.32	2.45	**
Al-Mansoura		2.28	1.64	7.11	**
Al-Hara	Modern	2.02	1.70	2.45	**
Jlyjela		1.68	1.54	1.90	*
Mean (ton/dunum)		1.92	1.62	5.85	**
Variance		0.16	0.13	-	-
Difference Coefficient %		1206.4	1218.7	-	-
Observations		102	113	-	-

Where: (*): Indicates the morale of the difference at 0.05. (**): Indicates the morale of the difference at 0.01.
Source: Collected and calculated from the sample study for the agricultural season 2018/2019

B. Impact of irrigation water quality on the dunum productivity of Alrziz dates

The results of the statistical analysis showed that the productivity of dunum of Alrziz dates amounted to about 1.74 tons for farms irrigated with groundwater, while the productivity of the dunum for farms irrigated with triple treated sewage increasing, reaching about 2.03 tons/dunum, and this increasing is significant Statistically, the value of T calculated (6.63) (Table 6), possibly due to the low quality of groundwater because of increasing salinity due to the movement of salinity to the aquifers of the oasis, especially in the north of the oasis adjacent to the Arabian Gulf. To identify the significance of the difference between the average productivity of dunums according to the quality of irrigation water after installing the irrigation system and the region, it was revealed that the productivity of dunums in farms irrigated with triple treated wastewater compared to farms irrigated with groundwater (wells) in Al- Mansoura and Jlyjela areas of immersion irrigation. While it was shown that the dunum productivity was higher in farms irrigated with triple treated wastewater compared to farms irrigated with ground water (wells) in modern irrigation condition at various study areas.

Table 6. The results of the statistical analysis of the significance of the difference between two averages (Alrziz dates).

Region	Irrigation system	Average dunum productivity per ton		T-test: two-sample assuming unequal variances	Significant
		Triple treated wastewater	underground water (wells)		
Al-Mansoura		2.04	1.54	5.23	**
Al-Hara	Immersion	1.84	1.93	0.60	-
Jlyjela		1.84	1.66	2.04	*
Al-Mansoura		2.10	1.84	2.40	**
Al-Hara	Modern	2.10	1.68	7.91	**
Jlyjela		2.28	1.88	5.20	**
Mean (ton/dunum)		2.03	1.74	6.63	**
Variance		0.07	0.07	-	-
Difference Coefficient %		3110.4	2441.4	-	-
Observations		65	75	-	-

Where: (*): Indicates the morale of the difference at 0.05. (**): Indicates the morale of the difference at 0.01.
Source: Collected and calculated from the sample study for the agricultural season 2018/2019

C. Impact of irrigation water quality on the dunum productivity of Lemon

The results of the statistical analysis showed that the productivity of the dunum of lemons amounted to about 1.31 tons for farms irrigated with groundwater, while the productivity of the dunum for farms irrigated with triple treated sewage increased to about 1.54 tons/dunum, and this increasing is significant, where value of (t) calculated estimated (6.45) (Table 7), possibly due to the low quality of groundwater due to the increased salinity due to the movement of salinity to the aquifers of the oasis, especially in the north of the oasis adjacent to the Arabian Gulf. In order to identify the difference between the averages productivity of dunums according to the quality of

irrigation water after the stabilization of the irrigation system and the region. It showed the superior productivity of donums in farms irrigated with triple treated wastewater compared to farms irrigated with ground water (wells) in different study areas and in the different irrigation systems.

Table 7. The results of the statistical analysis of the significance of the difference between two averages (Lemon).

The region	Irrigation system	Average dunum productivity per ton		T-test: two-sample assuming unequal variances	Significant
		Triple treated wastewater	underground water (wells)		
Al-Mansoura	Immersion	1.62	1.38	13.00	**
Al-Hara		1.32	1.15	2.82	**
Jlyjela		1.37	1.02	3.16	**
Al-Mansoura	Modern	1.79	1.61	8.83	**
Al-Hara		1.58	1.28	6.41	**
Jlyjela		1.42	1.29	2.69	**
Mean (ton/dunum)		1.54	1.31	6.45	**
Variance		0.04	0.06	-	-
Difference Coefficient %		3607.4	2167.2	-	-
Observations		88	87	-	-

Where: (**): Indicates the morale of the difference at 0.01.
Source: Collected and calculated from the sample study for the agricultural season 2018/2019

Second Dummy variables method

To study the impact of irrigation water quality on the dunum productivity from crops study using dummy variables, by the following statistical model: (Johnston, J., 1972).

$$\hat{Y}_i = \alpha + B_1 D_1 + B_2 D_2 + B_3 D_3 + B_4 D_4 + E_i$$

Where: $\hat{Y}_i$ Dunum productivity per ton, D_1: dummy variable that reflects water quality, taking the value (1) the state of irrigation with triple-treated sewage, the value (0) groundwater irrigation status (wells), D_2: dummy variable reflecting the irrigation system, taking the value (1) the state of irrigation by Modern systems, value (0) conventional irrigation state, D_3: dummy variable that reflects the region, taking the value (1) of the Al-Mansoura region, the value (0) for the two regions (Al-Hara and Jlyjela), D_4: dummy variable reflecting the area, taking the value (1) of the Al-Hara area, and the value (0) of the two regions (Al-Mansoura and Jlyjela), the fixed α reflect the value of Jlyjela region, E_i: the amount of random error, B_i, α, equation constants (8). By conducting the multiple regressions using the previous statistical model, the results of the statistical estimate in Table 8 indicate a correlation between dummy variable D_1 and dunum productivity per ton, which indicates increased dunum productivity in farms irrigated with treated sewage. By 0.32, 0.30, 0.22 tons representing about 19.2%, 17.2%, 16.8% of the counterpart irrigated with groundwater for both alkhallas, alrziz and lemons, respectively, possibly due to the lack of groundwater quality because of the increased salinity due to the movement of salinity to the aquifers of the oasis Especially in the north of the oasis adjacent to the Arabian Gulf, There was also a direct correlation between the dummy variable D_2 and dunum productivity per ton, which indicates that dunum productivity of dates or lemons on farms irrigated with modern systems increased by 0.20, 0.15, 0.19 tons from their counterparts irrigated by immersion irrigation (traditional), for both alkhallas, alrziz and lemons, respectively. The existence of a direct relationship between the dummy variable D_3 and dunum productivity per ton from the dates alkhallas and lemon, which indicates an increase in the dunum productivity from the alkhallas dates in Al-Mansoura region by 0.21 tons from its counterpart in Jlyjela region estimated at about 1.34 tons, and increased dunum productivity of lemon In Al-Mansoura region, 0.32 tons from its counterpart in The Jlyjela region, estimated at 1.07 tons, This may be due to the fact that the jlyjela region is located in the north of the oasis and its proximity to the Arabian Gulf, thereby increasing the salinity of its

groundwater. It also showed that there is a direct relationship between dummy variable D_4 and the dunum productivity per ton from the dates alkhallas and lemon, which indicates an increase in the dunum productivity of dates alkhallas in Al-Hara region by 0.25 tons from its counterpart in Jlyjela region, and increased dunum productivity of lemons in Al-Hara 0.06 tons higher than in Jlyjela region. However, the dummy variables D_3 and D_4 have not been significance, indicating the homogeneity of dunum productivity in the alkhallas date farms in the various study regions. The calculated (F) value also indicated the morality of the models used and their suitability for the nature of the data.

Table 8. Results of the statistical estimation of multiple regressions model using dummy variables

Alkhallas Dates		Alrziz Dates		Lemon	
Independent variable	**Coefficient and Tc value**	**Independent variable**	**Coefficient and Tc value**	**Independent variable**	**Coefficient and Tc value**
α	**1.34 **(21.7)**	**α**	**1.68 **(37.1)**	**α**	**1.07 **(42.4)**
D_1	**0.32 **(6.4)**	**D_1**	**0.30 **(6.9)**	**D_1**	**0.22 **(10.2)**
D_2	**0.20 **(4.1)**	**D_2**	**0.15 **(3.0)**	**D_2**	**0.19 **(8.7)**
D_3	**0.21 **(3.6)**	**D_3**	**- 0.02 (0.40)**	**D_3**	**0.32 **(12.3)**
D_4	**0.25 **(3.5)**	**D_4**	**- 0.03 (0.60)**	**D_4**	**0.06 *(2.0)**
R^{-2}	**0.24**	**R^{-2}**	**0.29**	**R^{-2}**	**0.67**
F	**17.5**	**F**	**14.9**	**F**	**90.33**

Where: Y_1: dunum productivity per ton, D_1: dummy variable that reflects water quality, where it takes the value (1) the state of irrigation with triple-treated sewage, while value (0) groundwater irrigation status (wells), D_2: dummy variable reflecting irrigation method, where it takes the value (1) the state of irrigation by Modern systems, while value (0) in state of immersion irrigation, D_3: dummy variable that reflects the region, it taking the value (1) of Al-Mansoura region, while the value (0) for the other (Al-Hara and Jlyjela),D_4: dummy variable that reflects the region, where it takes the value (1) of the Al-Hara region, and the value (0) for the other ways (Al-Mansoura And Jlyjela), however, the value of the fixed α reflects the Jlyjela region, R^{-2}: adjusted determination coefficient, F: refers to the significant of the model used, (**): refers to the moral coefficient of regression coefficients at the level of 0.01

Source: Collected and calculated from the sample of field study using SPSS

1- Efficiency of using irrigation water according to the partial efficiency criteria for the study crops

A. Palms of alkhallas: Table 9 shows the dunum productivity in the study sample of alkhallas palm crop, it explains the state of irrigation with triple-treated sewage (project) compared to that of wells water, both in the case of immersion irrigation and modern systems. With the amount of used water to irrigate the dunum, the productivity of unit water was about 0.57, 0.84, 0.93, 1.24 kg/m^3, respectively. At the prevailing farm price of about 2800, 3400 riyals per ton for traditional and modern irrigation systems, respectively, and in light of the total production costs of the dunum, the profitability of the spent riyal was about 0.83, 1.46, 1.77 and 2.56 riyals during the month-long shelf life of the crop, estimated at one year, while the average water unit yield was about 1.58, 2.35, 3.17 and 4.23 riyals/m^3, respectively. The cost of the unit produced was about 1528.7, 1136.4, 1227, 955 riyals/ton, respectively, indicating an increased efficiency of using triple-treated wastewater compared to groundwater (wells).

Table 9. Efficiency of using irrigation water according to the partial efficiency criteria for the Palms of alkhallas crop in the sample of field study for season 2018/2019.

Irrigation system and water quality	immersion Irrigation		Modern Irrigation	
	Underground	Treated	Underground	Treated
Productivity (ton/Dunum)	1.57	1.76	1.63	1.99
Total Revenue (SR/ Dunum)	4396	4928	5542	6766
Total costs (SR/ Dunum)	2400	2000	2000	1900
Net return (SR/Dunum)	1996	2928	3542	4866
Average amount of irrigation water (m^3/Dunum)	2775	2100	1750	1600
Return m^3 from water (SR/m^3)	1.58	2.35	3.17	4.23
Water productivity (kg/m^3)	0.57	0.84	0.93	1.24
Amount of water needed to produce a unit (m^3/ton)	1767.5	1193.2	1073.6	804.0
Riyal return of costs (riyals)	1.83	2.46	2.77	3.56
Cost of unit produced (Riyal/ton)	1528.7	1136.4	1227.0	954.8

Where: The productivity of the dunum (1,000 m^2) was calculated on the basis of a hectare (ten thousand m^2) with 250 palm trees, the net yield represents the difference between total revenue and total costs, return of m^3 water = total revenue in riyal / amount of used irrigation water m^3, production of m^3 of irrigation water = productivity in kg For dunum/ the amount of used irrigation water m^3, the amount of water needed to produce a unit of the product represents outside the division of the amount of used irrigation water m^3 / production per ton for the dunum, and the riyal's return on costs represents outside the division of total revenue in riyals / total costs in riyals, and the cost of the unit produced represents outside the division of Total costs in riyal/production per ton for dunum.

Source: Collected and calculated from the field study sample for the agricultural season 2018/2019

B. Palms of alrziz

Table 10 shows The dunum productivity in the study sample of alrziz palm crop, it explains the state of irrigation with triple-treated sewage (project) compared to that of wells water, both in the case of immersion irrigation and modern systems, With the amount of used water to irrigate the dunum, the productivity of unit water was about 0.62, 0.91, 1.03, 1.35 kg/m^3, respectively. At the prevailing farm price of about 1600, 2000 riyals per ton for traditional and modern irrigation systems, respectively, and in light of the total production costs of the dunum, the profitability of the spent riyal was about 0.14, 0.53, 0.98, 1.50 riyals during the month-long shelf life of the crop, estimated at one year, while the average water unit yield was about 0.99, 1.46, 2.26 and 2.97 riyals/m^3, respectively. The cost of the unit produced was about 1404, 1047, 1111, 880 riyals/ton, respectively, indicating an increased efficiency in the using of triple-treated wastewater compared to groundwater (wells).

Table 10. Efficiency of using irrigation water according to the partial efficiency criteria for the Palms of alrziz crop in the sample of field study for season 2018/2019

Irrigation system and water quality	immersion Irrigation		Modern Irrigation	
	Underground	Treated	Underground	Treated
Productivity (ton/Dunum)	1.71	1.91	1.80	2.16
Total Revenue (SR/ Dunum)	2736	3056	3960	4752
Total costs (SR/ Dunum)	2400	2000	2000	1900
Net return (SR/Dunum)	336	1056	1960	2852
Average amount of irrigation water (m^3/Dunum)	2775	2100	1750	1600
Return m^3 from water (SR/m^3)	0.99	1.46	2.26	2.97
Water productivity (kg/m^3)	0.62	0.91	1.03	1.35
Amount of water needed to produce a unit (m^3/ton)	1622.8	1099.5	972.2	740.7
Riyal return of costs (riyals)	1.14	1.53	1.98	2.50
Cost of unit produced (Riyal/ton)	1403.5	1047.1	1111.1	879.6

Where: The productivity of the dunum (1,000 m^2) was calculated on the basis of a hectare (ten thousand m^2) with 250 palm trees, the net yield represents the difference between total revenue and total costs, return of m^3 water = total revenue in riyal / amount of used irrigation water m^3, production of m^3 of irrigation water = productivity in kg For dunum/ the amount of used irrigation water m^3, the amount of water needed to produce a unit of the product represents outside the division of the amount of used irrigation water m^3 / production per ton for the dunum, and the riyal's return on costs represents outside the division of total revenue in riyals / total costs in riyals, and the cost of the unit produced represents outside the division of Total costs in riyal/production per ton for dunum

Source: Collected and calculated from the sample of field study for the agricultural season 2018/2019

C. Lemon

Table 11 shows the productivity of dunums in the study sample of lemon crop in the state of triple-treated sewage irrigation compared to that of wells water, both in the case of traditional and modern irrigation. With the amount of used water to irrigate the dunum, the productivity of unit water was about 0.43, 0.69, 0.79, 1.00 kg/m^3, respectively. At the prevailing farm price of about 1000, 1100 riyals per ton of lemon for traditional and modern irrigation, respectively, and in light of the total production costs of the dunum, the profitability of the spent riyal was about 0.12, 0.44, 0.70, 0.96 riyals during the shelf life of the crop on the ground and estimated for a full year. The average unit water yield was about 0.43, 0.69, 0.87, 1.00 SR /m^3, respectively. The cost of the unit produced was approximately 890, 694, 648, 563 riyal/ton, respectively, indicating an increased efficiency in the using of triple-treated wastewater compared to groundwater (wells). The above is evident in a rise in the profit margin, the total return on the productivity of the dunum, the decrease in the amount of used irrigation water, and therefore the high productivity of unit water and its return to the crops studied, which are described as triple-treated sewage compared to groundwater (wells), possibly due to the lack of groundwater quality because of increased salinity due to the movement of salinity to the aquifers, especially in the north of the oasis adjacent to the Arabian Gulf.

Table 11. Efficiency of using irrigation water according to the partial efficiency criteria for the lemon crop in the sample of field study for season 2018/2019

Irrigation system and water quality	immersion Irrigation		Modern Irrigation	
	Underground	Treated	Underground	Treated
Productivity (ton/Dunum)	1.18	1.44	1.39	1.60
Total Revenue (SR/ Dunum)	1180	1440	1529	1760
Total costs (SR/ Dunum)	1050	1000	900	900
Net return (SR/Dunum)	130	440	629	860
Average amount of irrigation water (m^3/Dunum)	2775	2100	1750	1600
Return m^3 from water (SR/m^3)	0.43	0.69	0.87	1.10
Water productivity (kg/m^3)	0.43	0.69	0.79	1.00
Amount of water needed to produce a unit (m^3/ton)	2351.7	1458.3	1259.0	1000.0
Riyal return of costs (riyals)	1.12	1.44	1.70	1.96
Cost of unit produced (Riyal/ton)	889.8	694.4	647.5	562.5

Where: The productivity of the dunum (1,000 m^2) was calculated on the basis of a hectare (ten thousand m^2) with 200 lemon trees, the net yield represents the difference between total revenue and total costs, return of m^3 water = total revenue in riyal / amount of used irrigation water m^3, production of m^3 of irrigation water = productivity in kg For dunum/ the amount of used irrigation water m^3, the amount of water needed to produce a unit of the product represents outside the division of the amount of used irrigation water m^3 / production per ton for the dunum, and the riyal's return on costs represents outside the division of total revenue in riyals / total costs in riyals, and the cost of the unit produced represents outside the division of Total costs in riyal/production per ton for dunum.

Source: Collected and calculated from the sample of field study for the agricultural season 2018/2019

2- Dunum requirements of agricultural resources: Table 12 shows a decrease in dunum requirements from the amount of used irrigation water in the case of triple-treated sewage by 18.2%, 16.7% for both palms and lemons, respectively. This may be due to the accuracy of the control of the quantities of water irrigation under modern systems that allow the provision of the necessary amount of water to the plant through automated controls. It is worth mentioning that the using of triple-treated wastewater in irrigation eliminates the use of physical additives for the purpose of supplying organic matter, nitrogen, or phosphorus, as well as not adding potassium completely, because of the fact that some of the elements necessary for the growth of plants are certain concentrations within the limit Safe, which reflects positively on farms and the environment. A farmer who uses triple-treated wastewater for irrigation can save about 35.7%, 46.2%, 66.7%, 100%, 17.1% and 30.6%, 38.9%, 71.4%, 100%, 18.2% of the total amount of manure, nitrogen fertilizer, phosphate manure, Potassium fertilizer, and the number of hours of human work. For both palm and lemon crops, respectively. Based on these results and under suitable crop-planting conditions, the economic returns on farms increase as a result of increased productivity on one hand and lower production costs on the other.

Table 12. Requirements for the dunm from agricultural resources for palm and lemon crops according to the quality of used irrigation water in the sample of field study for agricultural season 2018/2019

Irrigation system and water quality	immersion Irrigation Underground	immersion Irrigation treated	Modern Irrigation Underground	Modern Irrigation treated	Total Sample Underground	Total Sample treated	Savings Percent %
Palm crop:							
Amount of irrigation water (m^3/dunum)	**2775**	**2100**	**1750**	**1600**	**4525**	**3700**	**18.2**
Organic fertilization kg/dunum	**1200**	**750**	**900**	**600**	**2100**	**1350**	**35.7**
Nitrogen fertilization kg/dunum	**80**	**40**	**50**	**30**	**130**	**70**	**46.2**
Phosphate fertilization kg/dunum	**25**	**10**	**20**	**5**	**45**	**15**	**66.7**
Potassi fertilization kg/dunum	**70**	**0**	**60**	**0**	**130**	**0**	**100.0**
Human labor (hour/dunum)	**120**	**100**	**85**	**70**	**205**	**170**	**17.1**
Lemon crop:							
Amount of irrigation water (m^3/dunum)	**2500**	**1900**	**1700**	**1600**	**4200**	**3500**	**16.7**
Organic fertilization kg/dunum	**1000**	**750**	**800**	**500**	**1800**	**1250**	**30.6**
Nitrogen fertilization kg/dunum	**50**	**30**	**40**	**25**	**90**	**55**	**38.9**
Phosphate fertilization kg/dunum	**20**	**5**	**15**	**5**	**35**	**10**	**71.4**
Potassi fertilization kg/dunum	**50**	**0**	**40**	**0**	**90**	**0**	**100.0**
Human labor (hour/dunum)	**60**	**50**	**50**	**40**	**110**	**90**	**18.2**

Source: Collected and calculated from the sample of field study for the agricultural season 2018/2019

3- RECOMMENDATIONS

The research reached a number of conclusions from the study, the following recommendations can be proposed:

-Encourage farmers to expand the using of triple-treated wastewater for agricultural irrigation purposes to increase their economic returns as a result of increased productivity on the one hand and lower production costs on the other.

-Increasing agricultural investment in triple treated wastewater as an unconventional source of irrigation water; to make up for the water deficit and conserve groundwater for future generations; this contributes effectively to achieving sustainable development in Al-Ahsa Oasis

-Carry out detailed studies in the field of using this type of irrigation water to know its psychological effects on consumer behavior

-Conduct detailed studies on estimating the cost of treating per cubic meter of sewage and comparing it to the cost of extracting per cubic meter of groundwater (wells), as the cost may be a determining factor for the spread of agriculture using this type of irrigation water

-Increasing awareness among producers of extension and research to increase economic efficiency with using this type of irrigation water (12).

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