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The economics of wheat production under different irrigation systems in the West of Nubariya region

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ABSTRACT

The study aims to evaluate the efficiency of different irrigation systems in rationalizing irrigation water in Egyptian Agriculture, particularly in the production of wheat, through improving the production efficiency in water use by converting to modern irrigation systems and expanding wheat cultivation in more suitable areas can lower water expenditure. Hence, the main objective is to evaluate the economic efficiency of wheat production under different irrigation systems in the West of Nubariya region. The average cultivated wheat area in Nubariya is about 134.85 thousand feddans representing about 4.28% of total wheat production with an average production of 346.5 thousand tons representing 4.04% of total wheat production in the period 2005/2006 to 2019/2020. The study relied on estimating production Functions and performance efficiency, in addition to analyzing production and economic efficiency using data envelopment analysis, based on field data for a stratified random sample of wheat producers in the west of Nubariya region. The sprinkler and drip irrigation systems performed better compared to surface irrigation system in reducing the value of total costs by 19% and 33% and in achieving an increase in total revenue by 1.8% and 2%. Additionally, the application of the sprinkler and drip systems was associated with an increase in the net revenue per water unit by 414% and 551% respectively.Furthermore, the results indicate a low level of production efficiency under surface irrigation system estimated at 75% for the constant returns to scale model, and about 82% for the variable returns to scale model. Meanwhile both the sprinkler and drip irrigation systems were associated with an increase in the production efficiency estimated at 24% and 12% for constant and variable returns to scale models respectively. Both modern irrigation systems (sprinkler and drip) reduce cost by 7% while maintaining the same level of production. The sprinkler irrigation system shows superiority in the allocative efficiency of different inputs used in the production of wheat crop and a low rate of waste in resources used. Moreover, the results show that the drip irrigation system is superior in cultivating wheat in the West of Nubariya region compared to other irrigation systems shown by its decrease in the waterneeded for a feddan of wheat to an average of 1307 m^3/feddan, and in the increase in the productivity to about 20 ardeb/feddan.

Keywords: Technical efficiency; Economic efficiency; DEA; Irrigation systems; wheat

INTRODUCTION

Water is a necessary and influential element for the economics and agricultural development process, as sustainable agricultural development cannot be achieved without providing a sufficient amount of water. And there is no doubt that our water supply faces plenty of challenges due to the increasing demand for water from all sectors, in addition to the waste in water during use in various sectors, especially in the agricultural sector.And nowadays the Egyptian government seeks to adopt ambitious plans seeking horizontal and vertical expansion of cultivated areas raising the necessity of adopting motivational policies to rationalize water use, and the need to switch to modern irrigation systems that raise the efficiency of field irrigation and reduce water loss.Irrigation is a vital factor in agriculture crop production that contributes to food security. Great efforts have been made in the past decades to increase the irrigated area with the same water income. Unscientific and inefficient use of water over the years has led to undesirable effects threatening long-term sustainability of agricultural production. The surface method of irrigation causes uneven distribution of water loss affect land and crop productivity. Additional food grain production from the existing irrigated area needs to maximize output crop production per water unit. (Abd-Elmabod *et al.,* 2019; Eldardiry *et al.,* 2015; El-Hagarey *et al.,* 2015; Goyal and Mansour, 2015; Mansour *et al.,* 2014; Lilienfeld *et al.,* 2007)

Wheat is one of the most important cereals crops it has become a primary crop in the Egyptian cropping pattern, as bread is considered the main part of the diet of Egyptian people, in addition, it is a strategic crop with an economic return for the Egyptian farmer. The wheat cultivated area has reached about 3.4 million feddans representing about 50.5% of the total winter crop pattern, as for the Nubariya region the cultivated area of wheat represents about 2.64% of total wheat cultivated in the year 2019/2020 (MALR, 2021).wheat productivity in the country remains low compared to its potential due to the dependency of most wheat farms on the surface irrigation system and its connection to excessive use of inputs including water, this low productivity makes importation required to meet the domestic demand of approximately 18.6 million tons per year (CAPMS, 2019). Several recent international events will affect the wheat production in the country either by the shortage of water supply caused by the filling of The Grand Ethiopian Renaissance Dam or by the Russian-Ukrainian war and its future impact on the global wheat supply and its international price. which raises the necessity to raise the self-sufficiency rate of wheat production to avoid the instability of global markets.

Improvements in wheat productivity in Egypt became an obligation for policy makers who need to reduce the import bill, forcing the agricultural sector to face a lot of difficulties and also expected to overcome challenges such as the continuous increase in the population raising the need for horizontal and vertical agricultural production to achieve food security and agricultural sustainability, limited water resources, low-efficiency irrigation systems, climate change. Furthermore, the obstacles that limit the adoption of modern irrigation systems by farmers are associated with a decrease in the productive efficiency of crops due to the misuse of water. As the surface irrigation method is the most common in Egypt it is used in about 82% of agricultural lands, drip irrigation is used in about 10% and sprinkler irrigation is used in about 8% of agricultural lands (ESIS, 2021). also, the absence of economic value of water when choosing between crops leads to a lack of interest in rationalizing water use that leads to a decrease in the efficiency of field irrigation.

MATERIAL AND METHODS

data collection:

The studywas based on primary data of a stratified random sample collected from 55 wheat producerslocated in the west of Nubariya region (20 used surface irrigation system, 15 used sprinkler irrigation system and 20 used drip irrigation system), also the study relied on published and unpublished secondary data issued by the Ministry of Agriculture and Land Reclamation, the Central Agency for Public Mobilization and Statistics, and the Nubariya agriculture directorate for new lands in EL Beheira Governorate.

Statical analysis:

The collected data was statistically analyzed by descriptive and quantitative analyses such as means, standard deviation, coefficient of variation, one-way ANOVA analysis, production function and time trend equations, stepwise regression, coefficient of determination (R2), and Data Envelopment Analysis (DEA) usingIBBM SPSS Statistics program version 21 and deapVersion 2.1 software programs

RESULTS

1. Cultivated area, yield, and production of Wheat in Egypt and Beheira Governorate:

A. In Egypt, over the period (2006/05 - 19/2020) the cultivated area of wheat has reached a minimum of 2716 thousand feddans in the year 06/2007, and a maximum of 3469 thousand feddans in 2015/14, with an average of 3,151 thousand feddans in Table (1). The time trend equation no.1 in Table (2) indicated that the area planted with wheat during the same period has taken a statistically significant increasing trend estimated at 26.1 thousand feddans, with an annual increase rate of 0.83%. Furthermore, in El Beheira Governorate the wheat cultivated area reached its minimum of 260 thousand feddans in 06/2007, and its maximum of 386.71 thousand feddans in 19/2020 with an average of 328.9 thousand feddans, which represent about 10.4% of the total wheat cultivated area. Also, the time trend equation no.2 in Table (2) indicated that the area planted with wheat during the same period has taken a statistically significant increasing trend estimated at 6.67 thousand feddans, with an annual increase rate of 2.03%. As for Nubariya, the wheat cultivated area reached its minimum of 89.77 thousand feddans in 19/2020, and its maximum of 205.3 thousand feddans in 05/2006 with an average of 134.85 thousand feddans, which represents about 9.4% of the total wheat cultivated area. And the time trend equation no.3 in Table (2) indicated that the area planted with wheat during the same period has taken a statistically significant decreasing trend estimated at 4.98 thousand feddans, with an annual decrease rate of -0.04%.

The total wheat yield has ranged between a minimum of 2.39 ton/feddan in 09/2010 and a maximum of2.88 ton/feddan in 16/2017 with an average of 2.71. Additionally, the time trend equation no.4 in Table (2) indicated that there is no significant change in the yield per feddan. Moreover, in El Beheira Governorate the yield reached its minimum of 2.62 ton/feddan in 09/2010 and a maximum of 3.05 ton/feddan in 07/2008 with an average of 2.83 ton/feddan also the time trend equation no.5 in Table (2) indicated that there is no significant change in the yield per feddan in the governorate. As well for Nubariya, the yield reached its minimum of 2 ton/feddan in 09/2010 and a maximum of 2.86 ton/feddan in 16/2017 with an average of 2.58 ton/feddan and the time trend equation no.6 in Table (2) indicated that there is a significant increase in the yield per feddan estimated at 0.02 ton/feddan, with an annual increase rate of 0.97%.

Table 1. Area, yeild and production of wheat in Egypt, El Beheira Governorate and the Nubariya for the period (05/2006 – 19/2020)

year	Area (1000 Fed.)			Yeild (ton/Fed.)			Production (1000 tons)		
	Egypt	ElBeheira	Nubariya	Egypt	ElBeheira	Nubariya	Egypt	ElBeheira	Nubariya
2006/05	3063.70	295.8	205.3	2.60	2.72	2.43	8272.4	858	499.5
2007/06	2715.52	260.2	185.4	2.72	2.89	2.59	7378.9	752.7	410.4
2008/07	2920.38	274.15	151.65	2.73	3.05	2.51	7977.05	836.85	380.80
2009/08	3147.03	332.09	129.21	2.71	2.85	2.46	8523.00	944.97	317.46
2010/09	3001.38	293.26	135.61	2.39	2.62	2.00	7169.02	767.62	271.36
2011/10	3048.60	317.56	140.40	2.75	2.83	2.43	8370.53	897.42	341.17
2012/11	3160.66	321.52	127.57	2.78	2.90	2.67	8795.48	930.94	341.00
2013/12	3377.88	345.38	138.59	2.80	2.93	2.73	9460.20	1010.24	377.95
2014/13	3393.00	354.21	136.80	2.74	2.94	2.67	9279.80	1042.43	365.25
2015/14	3468.86	360.97	145.74	2.77	2.82	2.70	9607.74	1016.31	393.50
2016/15	3353.15	377.98	143.20	2.79	2.78	2.72	9342.54	1051.17	389.22
2017/16	2921.72	308.58	114.36	2.88	2.96	2.86	8421.07	914.00	326.60
2018/17	3156.84	349.75	97.58	2.64	2.75	2.60	8348.63	961.69	253.66
2019/18	3134.95	355.66	108.53	2.73	2.71	2.65	8558.81	965.39	287.49
2020/19	3402.65	386.71	89.77	2.68	2.78	2.71	9101.76	1073.74	242.92
Aver.	**3151.09**	**328.9**	**134.85**	**2.71**	**2.83**	**2.58**	**8573.93**	**934.9**	**346.55**

Source: estimated and calculated from the publications of the Ministry of Agriculture and Land Reclamation, Economic Affairs sector,Annual Bulletin of Agricutral Statistics (separated issues).

Total production has ranged between a minimum of 7169 thousand tons in 09/2010 and a maximum of 9607.74 thousand tons in 14/2015m with an average of 8573.9 thousand tons for the same period. As for the time trend equation no.7 in Table (2) indicated thatwheat total production has taken a statistically significant increasing trend estimated at 85 thousand tons, with an annual increase rate of 0.99%. Also, in El Beheira Governorate the wheat production reached its minimum of 752.7 thousand tons in 06/2007, and its maximum of 1073.74 thousand tons in 19/2020 with an average of 934.9 thousand tons, which represent about 10.9% of the total wheat production. As for the time trend equation no.8 in Table (2) indicated that the area planted with wheat during the same period has taken a statistically significant increasing trend estimated at 16 thousand tons, with an annual increase rate of 1.71%.Additionally, in Nubariya the wheat production reached its minimum of 242.9 thousand tons in 19/2020, and its maximum of 499.5 thousand tons in 05/2006 with an average of 346.5 thousand feddans, which represents about 4% of the total wheat production. And the time trend equation no.9 in Table (2) indicated that the area planted with wheat during the same period has taken a statistically significant decreasing trend estimated at 9.47 thousand tons, with an annual decrease rate of -2.73%.

Table 2. Time trend equations for Area,Yield and Production inin Egypt, El Beheira Governorate and the Nubariya for the period (05/2006 – 19/2020)

Description	No.		Constant (a)	Coefficient (b)	Mean	Annual change rate%	R^2	F
Area (1000 Fed.)	1	Egypt	2942.5	26.1	3151.1	0.83%	0.3	*5.36
			(28.7) **	(2.31)**				
	2	ElBeheira	275.6	6.67	328.9	2.03%	0.64	**22.8
			(21.7) **	(4.78)**				
	3	Nubariya	174.7	-4.98	134.85	-0.04%	0.65	**24.38
			(19.04) **	(4.93)**				
Yeild (ton/Fed.)	4	Egypt	2.68	0.005	2.72	0.18%	0.04	--0.54
			(46.02) **	$(0.73)^{ns}$				
	5	ElBeheira	2.92	-0.01	2.85	-0.31%	0.13	--1.97
			(5.70) **	$(-1.41)^{ns}$				
	6	Nubariya	2.38	0.02	2.58	0.97%	0.31	**5.74
			(25.18) **	(2.40)*				
Production (1000 tons)	7	Egypt	7893.9	85	8573.93	0.99%	0.28	**5.04
			(22.94) **	(2.25)*				
	8	ElBeheira	806.7	16.02	934.9	1.71%	0.52	**14.36
			(20.98) **	(3.79)**				
	9	Nubariya	422.2	-9.47	346.55	-2.73%	0.39	**8.42
			(14.2) **	(2.9)**				

Note: value between braces is calculated T value

(*, **) significant at 0.05 and 0.01 level of probability, respectively.

(Ns): indicates statical insignificance

Source: estimated and calculated from Table (1).

2. Inputs of wheat production under different irrigation systems:

The results in Table (3) shows the descriptive statistical analysis and the one-way ANOVA analysis of variance which determinesthe difference between the averages of different inputs under surface irrigation, sprinkler irrigation and drip irrigation for the wheat production in west of Nubariya for the season of 2020/2021:

A. The quantity of seeds under the surface irrigation system ranged between a minimum of 60 kg/feddan, and a maximum of 70 kg/feddan, with an average of 68 kg / feddan, as for the sprinkler irrigation system ranged between a minimum of 60 kg/feddan, and a maximum of 70 kg/feddan, with an average of 66 kg/feddan, and for the drip irrigation system ranged between a minimum of 50 kg/feddan, and a maximum of 60 kg/feddan, with an average of 56 kg / feddan, and the ANOVA analysis showed a significance between Average amount of seeds used under different irrigation systems ($P \leq 0.01$).

B. As for organic fertilization under the surface irrigation system ranged between minimumof12 m^3/feddan, and a maximum of14 m^3/feddan, with an average of 13 m^3/feddan, as for the sprinkler irrigation system ranged between a minimum of 9 m^3/feddan, and a maximum of15 m^3/feddan, with an average of 12 m^3/feddan, and for the drip irrigation system ranged between a minimum of9 m^3/feddan, and a maximum of11 m^3/feddan, with an average of 10m^3/feddan, and the ANOVA analysis showed a significance between Average amount of organic fertilizer used under different irrigation systems ($P \leq 0.01$).

C. Phosphate fertilization under the surface irrigation system ranged between a minimumof30Kg P/feddan, and a maximum of60Kg P/feddan, with an average of 48 Kg P/feddan, as for the sprinkler irrigation system ranged between a minimum of 15 Kg P/feddan, and a maximum of30 Kg P/feddan, with an average of 22 Kg P/feddan, and for the drip irrigation system ranged between a minimum of 30 Kg P/feddan, and a maximum of38 Kg P/feddan, with an average of 33Kg P/feddan, and the ANOVA analysis showed a significance between Average amount of phosphate fertilizer used under different irrigation systems ($P \leq 0.01$).

D. Nitrogen fertilization under the surface irrigation system ranged between a minimumof92 Kg N/feddan, and a maximum of120 Kg N/feddan, with an average of 113 Kg N/feddan, as for the sprinkler irrigation system ranged between a minimum of69 Kg N/feddan, and a maximum of83 Kg N/feddan, with an average of 70 Kg N/feddan, and for the drip irrigation system ranged between a minimum of 70 Kg N/feddan, and a maximum of102.5 Kg N/feddan, with an average of 92Kg N/feddan, and the ANOVA analysis showed a significance between Average amount of nitrogen fertilizer used under different irrigation systems ($P \leq 0.01$).

E. Potassium fertilization under the surface irrigation system ranged between a minimumof43 Kg K/feddan, and a maximum of53 Kg K/feddan, with an average of 48 Kg K/feddan, as for the sprinkler irrigation system ranged between a minimum of 0 Kg K/feddan, and a maximum of 24 Kg K/feddan, with an average of 18 Kg P/feddan, and for the drip irrigation system ranged between a minimum of 20 Kg K/feddan, and a maximum of30 Kg K/feddan, with an average of 24Kg K/feddan, and the ANOVA analysis showed a significance between Average amount of potassium fertilizer used under different irrigation systems ($P \leq 0.01$).

F. As to the pesticides cost under the surface irrigation system ranged between a minimum of 400 EL/feddan and a maximum of 450EL/feddan, with an average of 422 EL/feddan, as for the sprinkler irrigation system ranged between a minimum of 350 EL/feddan, and a maximum of 450 EL/feddan, with an average of 420 EL/feddan, and for the drip irrigation system ranged between a minimum of 400 EL/feddan, and a maximum of430 EL/feddan, with an average of 419 EL/feddan, the ANOVA analysis showed an insignificance between the average cost of pesticides under different irrigation systems.

G. As for farm machinery used in the wheat farms undersurface irrigation system ranged between a minimum of 20 h/feddan and a maximum of 30 h/feddan with an average of 24 h/feddan, as for the farms under sprinkler irrigation system ranged between a minimum of 17 h/feddan and a maximum of 27 h/feddan, with an average of 22 h/feddan, and for the farms under drip irrigation system ranged between a minimum of 6 h/feddan and a maximum of 8 h/feddan with an average of 7 h/feddan, and the ANOVA analysis showed a significance between Average amount of hours for the field capacity of farm machines used under different irrigation systems ($P \leq 0.01$).

H. As for man labor required in the wheat farms under surface irrigation system ranged between a minimum of 20 man/feddan and a maximum of 25 man/feddan with an average of 23 man/feddan, as for the farms under sprinkler irrigation system ranged between a minimum of 16 man/feddan and a maximum of 30 man/feddan, with an average of 16 man/feddan, and for the farms under drip irrigation system ranged between a minimum of 10 man/feddan and a maximum of 20 man/feddan with an average of 17 man/feddan, and the ANOVA analysis showed a significance between Average amount of man labor required under different irrigation systems ($P \leq 0.01$).

I. As to water requirements added under surface irrigation system ranged between a minimum of 1920 m^3/feddan and a maximum of 2100 m^3/feddan, with an average of 1994 m^3/feddan, as for the farms under drip irrigation system ranged between a minimum of 1032 m^3/feddan and a maximum of 1505 m^3/feddan with an average of 1347 m^3/feddan, and for the farms under drip irrigation system ranged between a minimum of 960 m^3/feddan and a maximum of 1378 m^3/feddan with an average of 1307 m^3/feddan and the ANOVA analysis showed a significance between Average amount of irrigation water used under different irrigation systems ($P \leq 0.01$).

As for the yeild per feddan for the surface irrigation system ranged between a minimum of 15 ardeb/feddan and a maximum of 19 ardeb/feddan with an average of 17 ardeb/feddan. As for the yeild of farms under sprinkler irrigation system ranged between a minimum of 16 ardeb/feddan and a maximum of 21 ardeb/feddan with an average of 19 ardeb/feddan. And regarding the yeild of farms under drip irrigation system ranged between a minimum of 19 ardeb/feddan and a maximum of 21 ardeb/feddan with an average of 20 ardeb/feddan. and the ANOVA analysis showed a significance between Average yeild of wheat under different irrigation systems ($P \leq 0.01$).

Table 3. summarystatistics of the variables used in wheat production function under different irrigation systems in west of Nubariya for the seasonof2020/2021

Irrigation system / Inputs	Surface irrigation					Sprinkler irrigation					Drip irrigation					F
	Min	Max	Mean	Std. Deviation	C.V	Min	Max	Mean	Std. Deviation	C.V	Min	Max	Mean	Std. Deviation	C.V	
Seeds (Kg/Feddan)	60	70	68	2.8	4.1	60	70	66	3.5	5.3	50	60	56	3.5	6.3	(73.7)**
Organic Fertilizer (m^3/Feddan)	12	14	13	0.85	6.5	9	15	12	2.9	22.3	9	11	10	0.6	6	(25.6)**
Phosphate fertilizer (Kg p/Feddan)	30	60	48	8.6	17.9	15	30	22	3.9	17.7	30	38	33	2.8	8.5	(87.8)**
Nitrogen fertilizer (Kg N/Feddan)	92	120	113	6.7	5.9	69	83	70	10.3	14.7	71	102.5	92	8.5	9.2	(112.3)**
potassium fertilizer (Kg k/Feddan)	43	53	48	2.7	5.6	0	24	18	7.9	43.9	20	30	24	4.6	19.2	(164.9)**
Pesticides cost (EL/Feddan)	400	450	422	18.7	4.4	350	450	420	28.8	6.9	400	430	419	11.8	2.8	$(0.11)^{ns}$
Machinery (Hour/Feddan)	20	30	24	2.8	11.7	17	27	22	3.5	15.9	6	8	7	0.8	11.4	(272)**
Labor (man-hour/Feddan)	20	25	23	1.6	7	16	30	16	4.7	29.4	10	20	17	3.1	18.2	(21.5)**
Quantity of used irrigation water (m^3/Feddan)	1920	2100	1994	62.9	3.2	1032	1505	1347	108.3	8	960	1378	1307	295.3	22.6	(102.6)**
Yield (Ardeb/Feddan)	15	19	17	1.11	6.5	16	21	19	1.9	10	19	21	20	1.6	8	(9.9)**

Note: (C.V) Coefficient of Variance = (standard deviation / Mean) *100

(*, **) significant at 0.05 and 0.01 level of probability, respectively.

(Ns): indicates statical insignificance.

Source: estimated and calculated from the field study sample for the season of 2020/2021**.**

3.Economic indicators of wheat production under different irrigation systems in the study sample:

The results in Table (4) demonstrate the reduction in cost and the increase in net revenue for the farmers of wheat under the sprinkler and the drip irrigation compared with the surface irrigation. For wheat production under surface irrigation system, the average cost of seeds, organic fertilizer, NKP fertilizers, pesticides, irrigation, labor, and machinery was estimated at 670, 1965, 3344, 422, 1462, 2025, and 3630 EL/feddan compared with 633, 1960, 1648, 420, 1346, 1983, and 2672 for the sprinkler system achieved a decrease in cost by 1%, 0.3%, 50%, 0.5%, 8%, 2%, and 26% respectively. Likewise, for wheat production under the drip irrigation system, the average cost of seeds, organic fertilizer, NKP fertilizers, pesticides, irrigation, labor, and machinery was estimated at 560, 1466, 2229, 419, 1293, 1611, and 1043 causing a decrease in cost by 16%, 25%, 33%, 1%, 12%, 20%, and 71% respectively. As a result, the sprinkler and drip system variable cost were estimated at 10728 and 8621 El/feddan achieving a decrease rate of 21% and 36%. Also, the total cost was estimated at 11928 and 9821 causing a decrease rate of 19% and 33% respectively compared with the surface irrigation system. Moreover, the water added cost per ardeb for the sprinkler and drip was decreased by 15% and 24%. Also, the water requirements per ardeb was decreased by 47% and 43% respectively. Thus, the average net revenue of wheat production under the sprinkler and drip irrigation systems was estimated at 4972 and 7109 EL/feddan with an increased rate of 166% and 280% respectively.

Table 4. The impact of irrigation development on cost, productivity, water requirements and the net return for wheat in west of Nubariya

Description	Irrigation system			F	Abundance			
	surface	sprinkler	drip		sprinkler	%	drip	%
Seeds cost (EL/feddan)	670	663	560	(73.6) **	7	1	110	16
Organic fertilizer (EL/feddan)	1965	1960	1466	(26.6)**	5	0.3	499	25
NKP fertilizers (EL/feddan)	3344	1684	2229	(340.8) **	1660	50	1115	33
Pesticides cost (EL/feddan)	422	420	419	$(0.1)^{ns}$	2	0.5	3	1
Irrigation cost (EL/feddan)	1462	1346	1293	(12.1) **	116	8	169	12
Labor cost (EL/feddan)	2025	1983	1611	(12.8) **	42	2	414	20
Machinery cost (EL/feddan)	3630	2672	1043	(291.5) **	958	26	2587	71
Net revenue (EL/feddan)	16594	16900	16930	(3.7) *	306	1.8	336	2
Variable cost (EL/feddan)	13523	10728	8621	(251.7) **	2795	21	4902	36
Total cost (EL/feddan)	14723	11928	9821	(101.1) **	2795	19	4902	33
Net revenue (EL/feddan)	1871	4972	7109	(272.6) **	3101	166	5238	280
Net revenue per water unit (EL/1000 m^3)	12	63	80	(121.26) **	51	414	67	51
Water addedcost perardeb (EL/ardeb)	85	74	65	(26.8) **	12	15	20	24
Water requirements per ardeb (m^3/ardeb)	114	60	65	-	54	47	65	43

Note: net revenue per water unit = net revenue / water requirements per feddan.

Water requirements per ardeb = water requirements per feddan/ feddan yield. (El sayied, 2014)

(*, **) significant at 0.05 and 0.01 level of probability, respectively, (Ns): indicates statical insignificance. (Saleh, 2014)

Source: estimated and calculated from the field study sample for the season of 2020/2021.

4. Production function of wheat under different irrigation systems using stepwise analysis:

Stepwise regression is a semi-automated process of building a model by successively adding or removing variables based solely on t-statistics of their estimated coefficient. In order to remove the effect of non-effective characteristics in the regression model on wheat yield (Abderrahmane *et al.,* 2013).The multiple regression method was used in the double logarithmic form and analyzed by the Stepwise analysis method, which was more suitable for the data obtained. as its results were more logical from a statistical and economic point of view, also production elasticity indicated the change in production as a response to the change in different variables. as for the linear production function was used to estimate the performance efficiency for the variable that showed effective characteristics on wheat yield for each irrigation system.

The results in Table (5) reflect that the inputs affecting wheat yield under the surface irrigation system were the added water (X1) and the farm machinery(X8). there was a profusion in the use of water per feddan whereby every increase in the use of water by 1% led to a decrease in the production by 0.88%. however, every increase in machinery use by 1% led to an increase in production by 0.34%. Results of stepwiseregression showed that the added water and machinery with R square of 90%, had justified most of the changes in wheat yield.with a total elasticity of -0.54 which indicates that wheat producers using surface irrigationwere in the third stage of production "negative returns" according to the law of diminishing returns due to excessive use of water.Furthermore, wheat yield under the sprinkler system was mostly affected by added water (X1), nitrogen fertilizer (x5), and potassium fertilizer (x6) with R square of 96% which justified most of the changes in wheat yield according to the previous inputs. Thus, every increase in the use of these inputs by 1% led to an increase in production by 0.66%, 0.19%, and 0.027% respectively. Also, the total elasticity of the production function indicated that wheat producers using sprinklers were in the second stage of production “the economic stage”.Similarly, wheat yield under thedrip system was mostly affected by added water (X1), nitrogen fertilizer (x5), and farm machinery (x8) with R square of 85% which justified most of the changes in wheat yield according to the previous inputs. Thus, every increase in the use of these inputs by 1% led to an increase in production by 0.26%, 0.26%, and 0.3% respectively. Also, the total elasticity of the production function indicated that wheat producers using drip system were in the second stage of production “the economic stage”.

Table 5. Production functions of wheat under surface, sprinkler and drip systems

Irrigation type	Reg type	Equation	R2	F	Elasticity
Surface	Log	$\ln \hat{Y}_i = 8.47 - 0.88 \ln X1 + 0.34 \ln X8$ (4.2)** (-3.59)** (5.1)**	0.90	78.2**	-0.54
	linear	$\hat{Y}_i = 26.6 - 0.008\ X1 + 0.23\ X8$ (5.32)** (-3.66)** (5.04)**	0.90	74.05**	-
Sprinkler	Log	$\ln \hat{Y}_i = 0.78 + 0.66 \ln X1 + 0.19 \ln X5 + 0.027 \ln X6$ (-2.7)** (4.48)** (2.47)* (2.63)*	0.96	91.5**	0.87
	linear	$\hat{Y}_i = 2.53 + 0.009\ X1 + 0.059\ X5 + 0.06\ X6$ $(1.05)^{ns}$ (3.61)** (2.87)** (2.67)**	0.91	17.3**	-
Drip	Log	$\ln \hat{Y}_i = -0.82 + 0.26 \ln X1 + 0.26 \ln X5 + 0.3 \ln X8$ $(-1.14)^{ns}$(2.4)*(2.5)* (5.1)**	0.85	30.03**	0.82
	linear	$\hat{Y}_i = 7.8 + 0.005\ X1 + 0.032\ X5 + 0.21\ X8$ (0.87)* (2.3)* (0.13)* (0.18)*	0.82	14.3**	-

Note:$\hat{Y}i$:wheat yield,X1: added water m^3/fed,X5: added nitrogen Kg N/fed,X6: added potassium Kg K/fed, X8:machinery use h/fed.

(*, **) significant at 0.05 and 0.01 level of probability, respectively, (Ns): indicates statical insignificance.

Source: estimated and calculated from the field study sample for the season of 2020/2021.

5. performance efficiency for the effective variables in wheat production under different irrigation systems:

Performance efficiency indicators show whether the producers use production inputs effectively, as the P.E =1 indicates that the producer has reached the equilibrium point, and if P. E< 1 Then the used element must be reduced and vice versa. The results in Table (6) reflect on performance efficiency for the inputs that showed effective characteristics on wheat yield. As for the surface irrigation,the water added performance efficiency was estimated at -8.49 indicating that the use of this input is inefficient and advisable to reduce units added. However, for the machinery the performance efficiency was estimated at 3.53 indicating that the use of this input was inefficient and advisable to increase units added. Also, the performance efficiency of water added, nitrogen, and potassium fertilizerfor the sprinkler irrigation was estimated at 5.84, 3.01 and 2.55 respectively indicating the use of these inputswere inefficient and advisable to increase units added. As for the drip irrigation the performance efficiency of water added, nitrogen, andthe machinery was estimated at 3.83, 1.62, and 1.98 respectively indicating the use of these inputs were inefficient and advisable to increase units added.

Table 6. Performance efficiency indicators

Irrigation type	Input	Unit	Unit price	M.P	M.P Estimated value	Performance efficiency
Surface	Water added	m^3/fed.	0.73	-0.008	-6.2	-8.49
	Machinery	h/fed.	50.4	0.23	178.25	3.53
Sprinkler	Water added	m3/fed.	1.18	0.009	6.89	5.84
	Nitrogen	Kg N/fed.	15	0.059	45.19	3.01
	Potassium	Kg K/fed.	18	0.06	45.96	2.55
Drip	Water added	m^3/Fed.	0.99	0.005	3.8	3.83
	Nitrogen	Kg N/fed.	15	0.032	24.32	1.62
	Machinery	h/fed.	80.23	0.21	159.6	1.98

Note: average selling price ofoutput “ardeb of wheat” = 755,766 and 760 for surface, sprinkler and drip respectively.
M.P estimated value = marginal production value * price of output unit
Performance efficiency = M.P estimated value / input unit price.
Source: estimated and calculated from Table (5).

6. Data Envelopment Analysis:

Farrell (1957) proposed that firm efficiency consists of two components: TE, which reflects the ability of a firm to obtain maximum output from a given set of inputs, AE, which reflects the ability of a firm to use the inputs in optimal proportions, given their respective price these two measures are then combined to provide a measure of total economic efficiency or cost efficiency. As for, the DEA models have been frequently applied in agriculture due to their advantages. (Charnes *et al.,*1978) proposed a model which had an input orientation and assumed constant returns to scale (CRS). (Banker *et al.,*1984) suggested an extension of the CRS DEA model to account for variable returns to scale (VRS) situations. The use of the CRS specification when not all farms are operating at the optimal scale will result in measures of TE which are confound by scale efficiencies (SE). In this paper, the input orientation DEA model where the estimated efficiency scores indicate how much a farm should be able to reduce the use of all of its inputs as compared to the best performers.

For the farms under surface irrigation system the analysis showed that the average TE was about 75%, 82% under CRS and VRS assumptions respectively, this reflected that the current level of output can be achieved using 25%, 18% less inputs on average. As for the farms under the sprinklerirrigation system the averageTE was about 99%, 1% under CRS and VRS assumptions respectively, this reflected that the current level of output can be achieved using 1% less inputs on average. Also,for the farms under the drip irrigation system the averageTE was about 99%, 1% under CRS and VRS assumptions respectively, this reflected that the current level of output can be achieved using 1% less inputs on average.This indicates that the cultivation of the wheat under the sprinkler and drip irrigation systems helped to increase TE with a rate of 24% under CRS assumption and with a rate of 12% under VRS assumption compared to the surface irrigation system.

The average AE of inputs under the surface irrigation system was about 92% under CRS and VRS assumptions this indicates that by redistributing the inputs these farms can save about 8% of their cost. Moreover, the average AE of inputs under the sprinkler irrigation system was about 93% under CRS and VRS assumptions this indicates that by redistributing the inputs these farms can save about 7% of their cost. As for, the average AE of inputs under the drip irrigation system was about 91%, 93% this indicates that by redistributing the inputs these farms can save about 9%, 7%% of their cost under CRS and VRS assumptions respectively.

The average EE the farms under surface irrigation system was about 70%, and 75% under CRS and VRS assumptions respectively, this reflected that the current level of output can be achieved with a reduction of30%, and 25%in the current production cost. As for the farms under the sprinklerirrigation system the averageEE was about 93% under CRS and VRS assumptions this reflected that the current level of output can be achievedwith a reduction of 7%in the current production cost. Also, for the farms under the drip irrigation system the averageEE was about 90%, 93% under CRS and VRS assumptions this reflected that the current level of output can be achieved with a reduction of 10%, and 7%respectivelyin the current production cost.

Table 7. Technical, Allocative, Economic and Scale Efficiencies estimates

Irrigation type	CRS			VRS			Scale Efficiency
	TE	AE	EE	TE	AE	EE	
Surface	0.75	0.92	0.70	0.82	0.92	0.75	0.91
Sprinkler	0.99	0.93	0.93	1	0.93	0.93	0.99
Drip	0.99	0.91	0.90	1	0.93	0.93	0.99

Note: SE = TE CRS / TE VRS
EE = TE * AE
Source: estimated and calculated from the field study sample using DEAP Version 2.1 software.

7. **Average slacks in production inputs:**

The resultsin Table (8) show that farmers under the flood irrigation system were over used seeds by 3 Kg/fed, phosphate fertilizer by 3 KG p/fed, potassium fertilizer by 8 Kg K/fed, machinery by 1 h/fed, labor by 3 man-hour/fed, and water by 326 m^3/fed. As for farmers under the sprinkler irrigation system were over used seeds by 6 Kg/fed and water by 143 m^3/fed. Moreover, the farmers under the drip irrigation system were over used seeds by 1 Kg/fed,phosphate fertilizer by 3 KG p/fed, and potassium fertilizer by 4 Kg K/fed.

Table 8. Slacks and potential save in production inputs

Inputs	Surface			Sprinkler			Drip		
	Current	Targeted	saved	Current	Targeted	saved	Current	Targeted	saved
Seeds (Kg/Fed.)	68	65	3	66	60	6	56	55	1
Phosphate fertilizer (Kg p/Fed.)	48	45	3	22	22	-	33	30	3
Nitrogen fertilizer (Kg N/Fed.)	113	98	15	70	70	-	92	92	-
potassium fertilizer (Kg k/Fed.)	48	40	8	18	18	-	24	20	4
Machinery (Hour/Fed.)	24	24	-	22	22	-	7	7	-
Labor (man-hour/Fed.)	23	20	3	16	16	-	17	17	-
Water (m^3/Fed.)	1994	1668	326	1347	1204	143	1307	1307	-

Source: estimated and calculated from the field study sample using DEAP Version 2.1 software.

CONCLUSION

During the last few years, the wheat sector was characterized by rapid growth in the deficit between consumption and production. The need to improve the efficiency of wheat at farms level is accentuated because of the high level of wheat imports and the increasing importation bill. Technical, economic and scale efficiencies have been estimated for a sample of 55 wheat farmers in west of Nubariya region using the Data Envelopment Analysis method. The inputs which have influenced wheat production have been determined using the production function using the stepwise analysis. The average technical efficiency indicated that the wheat cultivated under the sprinkler and drip irrigation systems helped to achieve the same level of output using 24% under CRS assumption and 12% under VRS assumption less inputs on average compared to the surface irrigation system.The sprinkler and drip irrigation systems performed better compared to surface irrigation system in reducing the value of total costs by 19% and 33% and in achieving an increase in total revenue by 1.8% and 2%. Therefore, there is a large potential for the studied farms under the surface irrigation system to improve their wheat production efficiency throw transitioning to modern irrigation systems.

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إقتصاديات إنتاج القمح فى ظل أنظمه الرى المختلفه فى منطقة غرب النوباريه

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الملخص

استهدفت الدراسة التقييم الاقتصادي لأساليب ترشيد مياه الري في انتاج محصول القمح، بالإضافة إلي العمل علي الإرتقاء بمعايير الكفاءة الإنتاجية لاستخدام مياه الري إلي مستويات أفضل وذلك عن طريق التوسع في استخدام نظم الري المطور والتوسع في زراعة القمح بالمناطق الأكثر ملائمة والأعلي كفاءة في استخدام مياه الري، وكذلك تقدير الكفاءة الإنتاجية والاقتصادية لمنتجي القمح تحت نظم الري المختلفة بمراقبة غرب النوبارية. حيث بلغ متوسط المساحة المزروعة من محصول القمح بالنوبارية خلال الفترة (2006/05- 2020/19) نحو 134.85 ألف فدان تمثل نحو 4.28% من إجمالي المساحة المزروعة بمحصول القمح علي مستوي الجمهورية، كما بلغ متوسط الانتاج بمنطقة النوبارية نحو 346.5 ألف طن تمثل نحو 4.04% من إجمالي الانتاج علي مستوي الجمهورية لنفس الفترة.

وقد أعتمدت الدراسة علي تقدير دوال الانتاج وكفاءة الأداء، بالإضافة إلي تحليل الكفاءة الإنتاجية والاقتصادية باستخدام تحليل مغلف البيانات Data envelopment analysis وذلك إعتماداً علي بيانات ميدانية لعينة طبقية عشوائية لمنتجي القمح بمراقبة غرب النوبارية. وقد أظهرت النتائج تفوق نظامي الري بالرش والتنقيط في خفض قيمة التكاليف الكلية بنسبة 19% ، 33%، وتحقيق زيادة في الإيراد الكلي بنسبة 2% ، 1%، بالإضافة إلي تحقيق زيادة في عائد الوحدة المائية بنسبة 414%، 551% علي الترتيب عن نظيرتها بنظام الري بالغمر، بالإضافة إلي خفض متوسط احتياجات الأرب من المياه تحت نظام الري بالغمر والتي بلغت نحو 114 م3/فدان إلي نحو 71، 65 م3/فدان لنظامي الري بالرش والتنقيط علي الترتيب. كما تشير نتائج قياس الكفاءة الإنتاجية والاقتصادية باستخدام تحليل مغلف البيانات إلي انخفاض مستوي الكفاءة الإنتاجية للقمح تحت نظام الري بالغمر حيث بلغت نحو 75% في ظل نموذج العائد الثابت للسعة، ونحو 82% في ظل نموذج العائد المتغير للسعة، بينما حقق منتجي القمح تحت نظامي الري بالرش والتنقيط زيادة في الكفاءة الإنتاجية بمعدل 24%، 12% في ظل العائد الثابت للسعة ومتغير السعة علي الترتيب عما كانت عليه في نظام الري بالغمر. كذلك أدي نظامي الري بالرش والتنقيط إلي خفض التكاليف الحالية مع الحفاظ علي نفس المستوي من الانتاج بنسبة 7%. ولذا توصي الدراسة بضرورة تطبيق نظم الري الحديثة في المناطق حديثة الاستصلاح والأراضي الجديدة للمحافظة علي المياه وتقليل الفاقد منها، والإتجاه إلي تطبيق نظام الري بالتنقيط عند زراعة محصول القمح بالأراضي الجديدة لأن إنتاجيته أفضل كما أنه موفر في أغلب مستلزمات الإنتاج.

الكلمات المفتاحية : الكفاءة الانتاجية، الكفاءة الاقتصادية، تحليل مغلف البيانات، نظم ري،القمح