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EVALUATION OF BARLEY CULTIVATED AREAS' ACTUAL STATUS IN EGYPTIAN NEWLY RECLAIMED LANDS

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ABSTRACT

Barley is a globally important strategic cereal crop, which grows well under various climatic and drought-stress conditions. In Egypt, barley is a major winter crop cultivated in old and newly reclaimed lands that suffer from a lack of irrigation, low soil fertility, and salinity of both soil and water. However, there is a lack of awareness of the nutritional role of barley for both humans and animals. Therefore, this paper aims to evaluate the actual status of cultivated areas of barley, especially in newly reclaimed lands in Egypt during the period (2004/2005–2018/2019). The study is based on descriptive and quantitative analysis using means, growth rates, relative importance, and robust regression. Results show that barley cultivated areas in newly reclaimed lands represented about 76.9% of total cultivated areas during (2004/2005–2018/2019). It means that barley is more adaptable in dry and marginal areas, meaning it is a sustainable plant that can face drought, land degradation, and climate change. Also, production costs, farm prices, and net return of barley are the most important factors that affect the producer's decision to cultivate barley during the study period. In addition, there is excessive use of some variables during the study period; after estimating the production function of barley using robust regression, it is shown that it is necessary to reduce these variables in the production process to achieve economic efficiency.

Contribution/Originality: This study contributes to existing literature by evaluating the actual status of cultivated areas of barley in Egypt to improve awareness of the nutritional role of barley, both for humans and animals.

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1. INTRODUCTION

Recently, the Egyptian government launched a 1.5 million feddan[1] project in the marginal areas around the Nile Valley. The major goal of this project is to achieve sustainable development by boosting agricultural production and increasing economic growth (Moghazy & Kaluarachchi, 2020). The project's newly reclaimed lands are located in the desert, specifically the western desert region, which has sandy and calcareous soils (Food and Agriculture Organization (FAO), 2005). To accomplish the significant economic and environmental aims of this project, challenges must be faced, such as changing the agricultural system pattern, using unusual water sources (wastewater and reuse of drainage water), and cultivating plants with a shorter growth duration and lower water needs (Food and Agriculture Organization (FAO), 2005). Barley (*Hordeum vulgare*) is one of the oldest cultivated plants and is a globally important strategic cereal crop needed to achieve food security (Elbasyoni et al., 2020; Kumar et al., 2014). After wheat, maize, and rice, barley is the world's fourth-largest cereal crop (Idehen, Tang, & Sang, 2017). According to FAOSTAT (2020), global barley-cultivated areas covered 46.9 million hectares, producing about 141 million tons in 2019–2020. The Russian Federation is the world's leading barley producer, with a yearly production of 17.9 million tons, then Germany, France, Ukraine, Australia, and Canada with about 10.7, 10.3, 9.4, 8.9, and 8.7 million tons, respectively.

In Egypt, barley is a major winter crop, which is planted from late November to mid-December and harvested in April and May (MALR, 2020). It grows well under various climatic and drought-stress conditions (Ahmed & Hassan, 2019; Idehen et al., 2017; Kumar et al., 2014), although its cultivation is concentrated in rainfed areas in the northern coastal regions of about 250-300 thousand feddans. Also, it is grown in both old and newly reclaimed lands that suffer from lack of irrigation, salinity of both soil and water, and low soil fertility (Grando & Macpherson, 2005; Hassanein, 2019). It is considered a restorative crop that improves soil properties, consumes low amounts of fertilizer, and tolerates thirst and salinity (Kumar, Verma, Singh, Sharma, & Devi, 2020; MALR, 2020). It is recommended that barley is grown in rainy desert areas that do not have the water needed for wheat production. So, barley is considered a more efficient use of water than wheat (MALR, 2020). Barley is used mainly for animal feed (about 65%), malting (33%), and human nutrition (2%) (Idehen et al., 2017; Kumar et al., 2020; Sullivan, Arendt, & Gallagher, 2013).

Lately, barley is becoming more popular as a food ingredient because of its high nutritional fiber content (Aly et al., 2021). Compared to other cereals, barley grains have about 20% dietary fiber and 3–7% beta-glucan, which is healthy due to its ability to minimize blood cholesterol and reduce the risk of developing chronic diseases (Elbasyoni et al., 2020; Idehen et al., 2017; Oscarsson, Andersson, Salomonsson, & Åman, 1996; Theander, Westerlund, Åman, & Graham, 1989; Ullrich, Clancy, Eslick, & Lance, 1986). Several experimental studies have reported that the cultivated soils in Egypt are affected by varying degrees of salinity. The development of barley genotypes for irrigation agriculture would be a cost-effective and efficient strategy to expand irrigated farming, which involves poor-quality water, because barley has shown tolerance for saline conditions and improved water use efficiency (Ahmed & Hassan, 2019; Byrne et al., 2018; Grando & Macpherson, 2005; Mansour et al., 2018).

Recently, Egypt's Ministry of Agriculture and Land Reclamation (MALR) has started an awareness program for farmers in newly reclaimed and marginal lands to spread newly approved and registered varieties of barley (thirteen varieties) to suit each barley production region (MALR, 2020) and to mix barley flour with wheat flour (by about 15–20%) in bread production in an attempt to reduce the annual import of wheat (Elbasyoni et al., 2020; MALR, 2020).

However, there is still a lack of awareness about the nutritional role of barley for both humans and animals. Previous studies have shown that the development of new barley genotypes in newly reclaimed lands may be considered the most cost-effective approach to expand cultivation. However, there has been a continuous decline in barley's total cultivated area, which reached about 53.6 thousand feddans and produced about 84.2 thousand tons in 2018/2019 (Egyptian Ministry of Agriculture and Land Reclamation, 2004/2005- 2018/2019b) across about 14.3% old and 85.7% newly reclaimed lands. Therefore, this research aims to evaluate the actual status of barley cultivated areas in Egypt, especially in newly reclaimed lands, during the period (2004/2005–2018/2019).

The objectives of this research are to evaluate (in Egypt):

1. The actual cultivated areas of barley.
2. The most significant factors influencing the production of the barley crop.
3. The geographical distribution of barley in newly reclaimed lands.
4. The production functions of barley using Robust Regression.

2. MATERIALS AND METHODS

2.1. Data Resources

This work relied on both available and unpublished data from the Egyptian Ministry of Agriculture and Lands Reclamation (Agricultural Statistics Bulletin (Egyptian Ministry of Agriculture and Land Reclamation, 2004/2005-2018/2019b), Cost Bulletin (Egyptian Ministry of Agriculture and Land Reclamation, 2004/2005-2018/2019a)), the national project for developing and serving the lands of young graduates in the new lands, Nubaria, FAOSTAT (2020) and the data of the International Network and prior studies connected to the study's topic.

2.2. Analytical Methods

This work relied on economic analysis, both descriptive and quantitative, using means, growth rates, relative importance to the geographical distribution of newly reclaimed lands, and robust regression (Jajo, 2005) to estimate the production function of barley. Therefore, several statistical tests were conducted on the data, such as Jarque-Bera (Jarque & Bera, 1980), White test, LM Test (Godfrey, 1978), multicollinearity, and Cook's Distance Measure (Cook,

[1]One feddan is 0.42 hectare.

1977), to ensure the accuracy of data, as suggested in the agricultural production function analysis of Hayami and Ruttan (1970). The production function describes the relationship between independent variables (X_n) and the dependent variable (Y) (Shafei, Khairy, & Mansour, 2009), after conducting some statistical tests on the data, such as normality distribution, homogeneity, autocorrelation, multicollinearity, and outliers.

The production function is an exponential function in its normal form (Shafei et al., 2009) but is linear in its logarithmic form (1, 2):

$$Y = \beta_0 X_1^{\beta 1} X_2^{\beta 2} \ldots \ldots \ldots X_K^{\beta K} \quad (1)$$

The production function of barley in newly reclaimed lands in Egypt is expressed in the following logarithmic formula using Robust Regression:

$$ln\, \hat{Y}_t = \alpha + \beta_1 lnX_1 + \beta_2 lnX_2 + \cdots + \beta_K lnX_K + \cdots \varepsilon t \quad (2)$$

Where:

$ln\, \hat{Y}_t$ = Estimated production of barley at time t.

$ln\, X_{1, 2, \ldots, K}$ = Production cost of barley.

α = The intercept term.

$\beta_{1, 2, \ldots, K.}$ = Parameters of independent variables.

ε_t = Random error.

Economic efficiency describes the relationship between inputs and output in the production process. It represents the ratio between the marginal production value of a variable and the marginal cost of that variable (Habib, Ismail, & Abidel, 2013; Shafei et al., 2009).

By studying some derivatives of the production functions of barley using Robust Regression, the economic efficiency of the variables could be estimated. The estimated derivatives are calculated by:

1. Average Product = Yield / Number of Units from Variables.
2. Marginal Product Value = Marginal Product × Farm Price.
3. Economic Efficiency (EE) = Marginal Product Value / Price of Variables

If EE is more than one, this indicates that economic efficiency has not been achieved and the amount of the variables should be increased.

If EE is less than one, this indicates that economic efficiency has not been achieved and the amount of the variables should be reduced.

Economic efficiency is achieved when EE = 1; this indicates each variable is used at its maximum efficiency.

3. RESULTS AND DISCUSSION

3.1. Actual Cultivated Areas of Barley

Table 1 (Egyptian Ministry of Agriculture and Land Reclamation, 2004/2005-2018/2019a, 2004/2005-2018/2019b, 2004/2005-2018/2019c) shows the total barley cultivated areas in Egypt, which occupied about 84.9 thousand feddans during the period 2004/2005–2018/2019. The maximum cultivated area was in 2005/2006 with about 147.2 thousand feddans, while the minimum area was 53.6 thousand feddans in 2018/2019. This indicates a continuous decrease in cultivated areas during this period at a rate of about 6.4%.

These cultivated areas were divided into old and newly reclaimed lands; barley grows in limited areas in the old lands, especially those with salinity problems of either soil or water. Also, it is grown on lands located at the ends of canals, where there is not enough water for irrigation (Hassanein, 2019; Kumar et al., 2020).

The areas cultivating barley in these lands reached 19.6 thousand feddans during the study period. Barley cultivation was concentrated in the old lands in Beheira, Sharkia, Ismailia, Fayoum, and Sohag (MALR, 2020).

In addition, barley was cultivated in newly reclaimed lands, which are characterized by either sandy or salty soils. (Grando & Macpherson, 2005; Hassanein, 2019). The areas where barley was cultivated in these lands reached about 65.3 thousand feddans, representing about 76.9% of the total cultivated area during the study period (2004/2005–2018/2019). The results showed that barley is more adaptable in dry and marginal areas (Food and Agriculture Organization (FAO), 2002). So, barley is a plant that can withstand drought, land degradation, and climate change. Also, barley is better able to resist heat stress than wheat (Elbasyoni et al., 2020). Table 1 (Egyptian Ministry of Agriculture and Land Reclamation, 2004/2005-2018/2019a, 2004/2005-2018/2019b, 2004/2005-2018/2019c) shows that the maximum cultivated area was about 112.9 thousand feddans in 2005/2006, while the minimum area was about 45.9 thousand feddans in 2018/2019. This indicates a continuous decrease in the cultivated areas in newly reclaimed lands at a rate of about 5.4% per year during the study period. Nonetheless, barley cultivation is concentrated in newly reclaimed lands because it has a high ability to withstand different environmental conditions (Elbasyoni et al., 2020). The productivity of these lands decreased continuously during the study period, leading to a decrease in quantity produced to about 91.3 thousand tons. It decreased at a rate of about 1.8% per year from 114.1 thousand tons in 2009/2010 to 73.7 thousand tons in 2018/2019, as shown in Table 2. According to the Food and Agriculture Organization (FAO) (2002), due to the arid climate of Egypt, rainfall is very low (5–200 mm/year) and evaporation is very high (1500–2400 mm/year). However, these conditions are exacerbated by the poor soils in the East and West Nile Valley. These soils are generally characterized as relatively low fertile soils with low organic matter, a high calcium carbonate content (30–80%, $CaCO_3$), and salinity (Food and Agriculture Organization (FAO), 2005; Wahba, Fawkia, & Zaghloul, 2019).

3.2. The Most Significant Factors Influencing the Production of Barley

The factors affecting barley production are important indicators for agricultural policy and should be considered during future barley cultivation with a view to the appropriate allocation of available agricultural economic resources (MALR, 2020). So, production costs, farm prices, and the net return of barley are among the most important factors that affect producers' decisions to grow a specific crop. Production cost: Table 1 (Egyptian Ministry of Agriculture and Land Reclamation, 2004/2005- 2018/2019a, 2004/2005- 2018/2019b, 2004/2005- 2018/2019c) shows that the production costs increased during the study period by about L.E 3.5 thousand, with a significant annual growth rate of about 8.7% (Table 2). The total cost increased from L.E 1.7 thousand in 2004/2005 to L.E 5.7 thousand in 2018/2019. This means that increases in costs affected production decisions, which may be the reason for the decrease in cultivated areas of barley in newly reclaimed lands during the study period. Hamed, Eljadi, and Delawi (2020) confirmed that merging farmers who own small farms is considered an effective way to reduce production costs and achieve the most significant returns. Farm price: Table 1 shows that the farm price increased during the study period by about L.E 0.97 thousand, with a significant annual growth rate of about 6% (Table 2). It increased from L.E 0.50 thousand in 2005/2006 to L.E 1.4 thousand in 2018/2019. Despite the increasing farm prices during the study period, it is not considered sufficiently profitable for farmers to increase cultivated areas of barley in newly reclaimed lands. Salama (2019) concluded that harvesting barley in the late winter season led to a high price of the barley forage, optimized the forage quantity and quality, and increased grain yield. Net return of barley: Table 1 shows that the net return decreased during the study period by about L.E 0.63 thousand, with a significant annual rate of decrease of about 6.2%, as shown in Table 2. It decreased from L.E 0.88 thousand in 2008/2009 to L.E 0.35 thousand in 2017/2018. This indicates the main reason for farmers' reluctance to cultivate barley, which led to a decrease in barley cultivated areas in newly reclaimed lands during the study period. Singh, Saxena, Sarkar, and Dogra (2016) concluded that increasing barley production in the arid zone by adopting improved technology would substantially increase farmers' income. Additionally, Wollie, Zemedu, and Tegegn (2018) confirmed that most farmers prefer to cultivate barley because it is drought-resistant and offers a stable income over time.

3.3. Geographical Distribution of Barley in Newly Reclaimed Lands

Identifying suitable areas for the cultivated varieties of barley could increase the cultivated areas and hence the amount of barley produced (Gomaa, Radwan, Moselhy, El-Sadek, & Abdelkader, 2014). Therefore, this section will present the geographical distribution of newly reclaimed lands both outside and inside the Nile Valley areas, in which barley cultivation is possible.

a) Areas outside the Nile Valley

Table 3 (Egyptian Ministry of Agriculture and Land Reclamation, 2004/2005-2018/2019b) shows the five main areas of barley cultivation on newly reclaimed lands outside the Nile Valley during the study period. These areas represented about 58.6% of newly reclaimed lands. New Valley was the primary area for barley cultivation with about 19.4 thousand feddans, representing about 50.8% of the total outside the Nile Valley areas and about 29.8% of the newly reclaimed lands. Matruh comes second, followed by Noubaria, North Sinai, and South Sinai with about 6.74, 6.58, 5.1, and 0.44 thousand feddans, respectively, and representing about 17.6%, 17.2%, 13.2%, and 1.15% of the total outside the Nile Valley areas and about 10.3%, 10.1%, 7.75%, and 0.67% of the newly reclaimed lands, respectively.

Table 1. The variables of the barley crop in new lands during (2004/2005–2018/2019) (Egyptian Ministry of Agriculture and Land Reclamation, 2004/2005-2018/2019a, 2004/2005-2018/2019b, 2004/2005-2018/2019c).

Years	Cultivated Area (10^3 Fed)		Production (10^3 Ton)	Yield (Ton/Fed)	Farm Price	Total Costs	Net Return
	Newly	Total			(L.E./feddan)		
2004/2005	95.31	141.5	88.37	0.93	665	1710	752
2005/2006	112.9	147.2	107.7	0.95	500	1810	750
2006/2007	83.44	106.0	97.33	1.17	605	2051	780
2007/2008	60.15	83.39	98.00	1.63	1060	2202	819
2008/2009	63.83	85.55	97.70	1.53	930	2576	881
2009/2010	75.75	95.44	114.1	1.51	660	2900	777
2010/2011	65.75	88.11	83.54	1.27	835	3131	769
2011/2012	67.69	84.76	95.46	1.41	1010	3344	740
2012/2013	50.21	66.09	82.36	1.64	1050	3702	686
2013/2014	63.12	78.68	104.5	1.66	1074	4151	548
2014/2015	46.79	63.42	78.30	1.67	1127	4408	363
2015/2016	51.14	62.19	82.32	1.61	1179	4581	386
2016/2017	49.96	59.85	83.65	1.67	1232	4815	370
2017/2018	47.71	57.81	83.31	1.75	1284	5050	354
2018/2019	45.94	53.60	73.68	1.60	1420	5674	506
Mean	65.31	84.91	91.35	1.47	975	3474	632
Minimum	45.94	53.60	73.68	0.93	500	1710	354
Maximum	112.9	147.2	114.1	1.75	1420	5674	881

Table 3 also shows that the contribution of these areas to barley production amounted to about 34.6, 10.9, 4.4, 2.75, and 0.67 thousand tons, representing about 37.8%, 12%, 4.8%, 3%, and 0.73% of the production from newly reclaimed lands in New Valley, Noubaria, Matruh, North Sinai, and South Sinai, respectively. Gomaa et al. (2014) showed that farmers in Egypt's northwestern coastal zone selected barley cultivation for animal feed in summer. On the other hand, most farmers in the coastal zones of Egypt's Western and Eastern Deserts depend on groundwater. The major cause of soil salinity in these areas is the excessive use of groundwater, which causes a significant drop in the water table. So, infiltration of seawater, irrigation with low-quality (saline) water, and insufficient field drainage are the reasons for soil salinity (El Raey, 2010). The high soil salinity limits water and nutrient absorption and simultaneously promotes Na^{+} and Cl^{-} ion accumulation. In turn, this increases osmotic stress and ionic toxicity in the plant cell, which leads the plants to suffer from physiological thirst and damaged cell membranes and metabolic activities, leading to reduced photosynthesis and growth (Alharby, Colmer, & Barrett-Lennard, 2018).

Table 2. Variables' growth functions for barley during the period (2004/2005–2018/2019).

Variables	Equation	R^{-2}	F	Mean	Growth Rate (%)	T
Cultivated area	$\hat{Y}_{t} = e^{4.6 - 0.054\ Xt}$	0.76	44^{***}	65.31	(5.4)	$(6.6)^{***}$
Production	$\hat{Y}_{t} = e^{4.6 - 0.018\ Xt}$	0.37	9.2^{*}	91.35	(1.8)	$(3.03)^{*}$
Yield	$\hat{Y}_{t} = e^{0.08 + 0.035\ Xt}$	0.57	19.2^{**}	1.47	3.5	4.3^{**}
Total Cultivated area	$\hat{Y}_{t} = e^{4.9 - 0.064\ Xt}$	0.86	88.5^{***}	84.91	(6.4)	$(9.4)^{***}$
Farm Price	$\hat{Y}_{t} = e^{6.4 + 0.060\ Xt}$	0.74	39.8^{***}	975	6	6.3^{***}
Total Costs	$\hat{Y}_{t} = e^{7.4 + 0.087\ Xt}$	0.98	781^{***}	3474	8.7	27.9^{***}
Net Return	$\hat{Y}_{t} = e^{6.9 - 0.062\ Xt}$	0.66	27.9^{***}	632	(6.2)	$(5.3)^{***}$

Notes: $\hat{Y}$ dependent variable X_t time by years; ( ) brackets indicate minus values.
(***) Statistically significant at 0.001.
(**) Statistically significant at 0.01.
(*) Statistically significant at 0.05.

It can further be noted that the yield rank of barley-producing areas was different. Table 3 shows that the yield of New Valley, Noubaria, South Sinai, Matruh, and North Sinai was about 1.78, 1.66, 1.52, 0.65, and 0.54 tons/feddan, respectively. It suggests that the selection of appropriate varieties of barley for the area led to an increase in yield during the study period. Gomaa et al. (2014) found that the adoption of new genotypes effectively improved crop production in marginal areas of Egypt. Also, Tokhetova, Umirzakov, Nurymova, Baizhanova, and Akhmedova (2020) confirmed that genotypes of hull-less barley showed high adaptability to climatic conditions that increased efficiency and productivity. Ayers and Westcot (1985) and Moghazy and Kaluarachchi (2020) reported that the maximum yield of barley was found at an EC (Electric Conductivity) level of 5.3 dS/m; the yield decreased to 50% when irrigation water salinity increased to 12 dS/m.

In addition, the changes in climate conditions in Egypt – the continually rising temperatures and decreasing rainfall – affected agricultural productivity. Mostafa et al. (2019) concluded that 80% of the days in a year would be hotter than the 90^{th} period. Furthermore, some studied scenarios predict that precipitation could significantly decrease during the 2010 to 2100 period from -0.48 to -0.9 mm/y and from -0.95 to -1.40 mm/y for Representative Concentration Pathway RCP45 and RCP85 scenarios, respectively, especially in the north of Egypt. However, the yield in Near East North Africa has been reduced by about 30% due to the negative impact of climate change (Abdel & Radojevic, 2020; El Raey, 2010). Increasing temperatures lead to elevated soil evaporation and increasing soil salinity. It is reported that about 35% of the agricultural lands in Egypt suffer from salinity.

Table 3. Geographical distribution of barley outside the Nile Valley areas during (2004/2005–2018/2019) (Egyptian Ministry of Agriculture and Land Reclamation, 2004/2005-2018/2019b).

Areas Outside the Nile Valley	Cultivated Areas (10³ fed)	Cultivated Areas (%)	New Lands (%)	Production (10³ ton)	New Lands (%)	Yield (ton/fed)	Rank
New Valley	19.44	50.8	29.8	34.58	37.8	1.78	1
Noubaria	6.58	17.2	10.1	10.93	12.0	1.66	3
Matruh	6.74	17.6	10.3	4.41	4.83	0.65	2
North Sinai	5.06	13.2	7.75	2.75	3.01	0.54	4
South Sinai	0.44	1.15	0.67	0.67	0.73	1.52	5
Total outside the Nile valley	38.25	100	58.6	53.34	58.4	1.39	-
Total new lands	65.31	-	100	91.35	100	1.47	-

b) Areas within the Nile Valley

Table 4 shows the areas with the highest levels of barley crop production in newly reclaimed lands in the Nile Valley during the study period. These areas represented about 43.6% of newly reclaimed lands.

Barley cultivated areas were concentrated in Lower Egypt with about 21.4 thousand feddans, representing about 75.1% of the total area in the Nile Valley areas and about 32.8% of the area of newly reclaimed lands. Sharkia, Port Said, Alexandria, and Ismailia are the most cultivated areas in the Nile Valley with about 24.9%, 21.9%, 13.4%, and 12.8%, respectively. In these areas, barley production increased by about 10.8, 9.5, 4.4, and 5.2 thousand tons, representing about 11.8%, 10.4%, 4.8%, and 5.7% of the newly reclaimed lands' production of Sharkia, Port Said, Alexandria, and Ismailia, respectively.

Table 4 also shows that the Middle and Upper Egypt areas had the smallest cultivated area of barley on newly reclaimed lands during the study period, with about 4.2% and 6.6%, respectively.

Selecting appropriate barley varieties could increase cultivated areas, especially outside the Nile Valley areas, which represent the largest areas of newly reclaimed lands during the study period. Byrne et al. (2018) confirmed that the efficient utilization of plant genetic resources (cultivars, breeding, materials, landraces, and wild relatives) is the future of crop improvement.

Table 4. Geographical distribution of barley within the Nile Valley areas during (2004/2005–2018/2019) (Egyptian Ministry of Agriculture and Land Reclamation, 2004/2005-2018/2019b).

Areas within the Nile Valley		Cultivated areas (10^3 fed)	Cultivated areas (%)	New Lands (%)	Production (10^3 ton)	New Lands (%)	Yield (ton/fed)
Lower Egypt	Alexandria	3.83	13.4	5.9	4.36	4.8	1.2
	Behairah	0.35	1.2	0.54	0.58	0.63	1.5
	Sharkia	7.06	24.9	10.9	10.8	11.8	1.5
	Ismailia	3.64	12.8	5.6	5.24	5.7	1.4
	Port Said	6.23	21.9	9.5	9.48	10.4	1.1
	Suez	0.26	0.91	0.40	0.46	0.50	2.1
	Total	21.4	75.1	32.8	30.9	33.8	1.4
Middle Egypt	Giza	0.67	2.4	1.03	1.14	1.2	2.3
	Beni Suef	0.15	0.53	0.23	0.24	0.26	1.6
	Fayoum	1.1	3.9	1.7	1.25	1.4	1.0
	Menia	0.84	2.9	1.3	1.46	1.6	1.8
	Total	2.76	9.7	4.2	4.1	4.5	1.5
Upper Egypt	Assuit	0.15	0.53	0.23	0.20	0.22	1.1
	Suhag	0.31	1.1	0.47	0.16	0.17	0.9
	Qena	0.35	1.2	0.54	0.51	0.56	1.4
	Luxor	0.15	0.53	0.23	0.17	0.19	0.9
	Aswan	3.34	11.7	5.1	3.80	4.2	0.9
	Total	4.3	15.1	6.6	4.8	5.3	1.13
Total within the Nile Valley		28.5	100	43.6	39.8	43.6	1.4
Total new lands		65.31	-	100	91.35	100	1.47

3.4. Production Function of Barley using Robust Regression

The variables of the production function show a normal distribution, homogeneity, and no autocorrelation, but there are multicollinearity and outliers. So, this part uses Robust Regression to estimate the barley production function to obtain accurate estimates. It is the best solution if multicollinearity and outlier problems exist between variables (Jajo, 2005; Shafei et al., 2009). An accurate production function helps in selecting different production variables and knowing when variables are productive and economically efficient (Shafei et al., 2009).

The production function was estimated after using stepwise regression to determine the variables with the greatest effect on barley production. It was found that during the study period, the most relevant variables were labor wages (X_1), machinery (X_2), seeds (X_3), fertilizers (X_5), and insecticides (X_6).

The GRETL program was used to estimate the production function of barley in newly reclaimed lands in logarithmic form (Cottrell & Lucchetti, 2008):

$$Ln\hat{Y}_t = 0.17 + 0.92\ LnX_1 + 2.3\ LnX_2 - 1.8\ LnX_3 + 0.49\ LnX_5 - 0.51\ LnX_6 \qquad (3)$$

Equation 3 shows that the productivity elasticity of labor wages (X_1) and fertilizers (X_5) were positive and less than one. This indicates that these variables are located in the second or economic stage of production. At this stage, it is necessary to stop increasing these variables in the production process. Also, it shows that the productivity elasticity of machinery (X_2) was positive and higher than the one. This indicates that this variable is located in the first stage of the production process. It is necessary to increase this variable until it reaches the second stage of production.

In contrast, the productivity elasticity of seeds (X_3) and insecticides (X_6) were negative. This proves that these variables are located in the third stage of production, meaning that it is necessary to decrease these variables to return them to the second production stage.

Ikram et al. (2020) reported that the inefficient use of inputs is one of the major constraints to crop yield in arid and semi-arid climates. Also, Al-Enizy and Al-Kaisy (2017) found that the technical methods used in barley production are the most essential factors that affect the production function. However, Wollie et al. (2018) concluded that input variables such as fertilizer and labor input have considerable effects on barley production.

3.5. Economic Efficiency of Barley

Equation 3 was used to estimate the most efficient use of the relevant variables in the barley production process by studying some derivatives of production functions.

Table 5 shows that economic efficiency was less than one for labor wages, machinery, and fertilizers. Marginal product values were L.E. 117, 400, and 107, respectively, for these variables, which were less than their prices of about 712, 507, and 405, respectively. This indicates that these variables are used excessively and it is necessary to reduce them in the production process. Habib et al. (2013) applied this method to orange crops to achieve economic efficiency. Hamed et al. (2020) concluded that merging small farms allowed optimal production to be reached and cultivated areas to achieve economic efficiency. Also, Ahmed and Hassan (2019) concluded that using improved surface irrigation techniques, such as raised beds, led to increased barley yield and reduced irrigation water, consequently increasing water use efficiency. Additionally, Ikram et al. (2020) found better economic returns were achieved by using a barley-Egyptian clover intercropping system and improving water use efficiency in arid and semi-arid climates.

The variables with negative coefficients estimated by the Robust Regression of barley do not achieve economic efficiency in their use, and the concentrations of these variables should be reduced so they reach the second stage of production. Wollie et al. (2018) found that the input variables of barley displayed non-economic efficiency, and improved barley seeds should be used.

Table 5. Economic efficiency of variables used in barley production in new lands.

Derivatives	Variables		
	X_1	X_2	X_3
Elasticity	0.92	2.3	0.49
Average products	0.13	0.18	0.23
Marginal products	0.12	0.41	0.11
Marginal product values	117	400	107
Price of variables	712	507	405
Economic efficiency	0.2	0.8	0.3

Source: Calculated from production function and (Table A – see appendix).

4. CONCLUSION

Based on the results, this work concludes that expanding the cultivation of barley in newly reclaimed lands, especially outside the Nile Valley areas, is associated with low costs, efficient water consumption, and high economic returns due to barley's great importance as a sustainable food and fodder crop. The study of the geographical distribution outside and within the Nile Valley areas has shown that selecting appropriate barley varieties could increase the cultivated area, especially outside the Nile Valley areas, which represent the areas with the most newly reclaimed lands during the study period. However, during the period of study, there was excessive use of many variables during the barley production process, which may indicate a lack of economic efficiency in their use. Therefore, concentrations of variables should be reduced to ensure the second or economic stage of production is reached.

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APPENDIX

Table A. Descriptive statistics of production costs during (2004/2005–2018/2019) (Egyptian Ministry of Agriculture and Land Reclamation, 2004/2005-2018/2019c).

Costs (L.E./feddan)	Mean	Standard Deviation	Minimum	Maximum	Growth Rate%	%
Labor Wages	712	243	319	1007	8.2***	29.0
Machinery	507	185	290	859	8.1***	20.7
Seeds	250	138	80	501	12.9***	10.2
Manure	293	177	55	628	16.4***	11.9
Fertilizers	405	213	99	748	14.1***	16.5
Insecticides	83.1	33.2	23	141	10.5***	3.39
Other expenses	203	37.9	137	261	3.6***	8.28
Variable costs	2453	999	1027	4121	9.9***	70.6
Fixed costs	1020	271	650	1553	5.9***	29.4
Total cost	3474	1268	1710	5674	8.7***	100

Note: L.E.: Egyptian currency. (costs have been measured by Egyptian pound per feddan).
(***) statistically significant difference at the 0.001 level.