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ESTIMATION OF ECONOMIC EFFICIENCY OF MAIZE CROP USING DATA ENVELOPMENT ANALYSIS IN EGYPTIAN RECLAIMED LANDS

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Abstract

Maize is considered as a strategic crop in Egypt and it is suitable to be cultivated in reclaimed lands as a reason of its climate-resilient and water shortages. Data Envelopment Analysis (DEA) according to input- oriented model is applied to estimate economic efficiency of inputs that used in cultivation of maize in Egyptian reclaimed lands during the period of (2001-2018). During last mentioned period of time maize production value increased by about LE 1154 million with a significant annual growth rate of 14.4 %. This increase was stuck to an increase in costs from LE 2588 in 2001 to LE 6356 in 2018, which led farms to refrain from cultivating it and that led to decrease of yield by about 3.1 tons / feddan. Estimated percentage by about 87% for Variable Returns-to-Scale model (VRS) and 44% for Constant Returns-to-Scale model (CRS) less than 1 and scale efficiency was about 50% led to non-economic efficiency result. That means using of inputs was not efficient and costs should be reduced by 13% for VRS and 56% for CRS to reach the optimum size. So the scale could increase production by reducing amount of inefficient inputs by 50% without affecting their current output levels. DEA helped in estimating the optimum values of inputs that achieve efficiency by about LE 874, 440, 435, 349, 237 and 211, respectively from labor wages, fertilizers, machinery, manure, seeds and insecticides in reclaimed lands.

Keywords : Economical Efficiency, Maize, Data Envelopment Analysis, Reclaimed lands.

Introduction

Cereal crops are considered as one of the most strategic food crops in the world. Maize is considered as one of the maximum essential cereal crops after wheat and rice all over the world, supplying nutrients for people and animals and serving as a primary material for the manufacturing of starch (fao.org, 2018 and Manal, 2018).

Economic efficiency considers one of the most important of economic analysis method, which could control efficiency of production units in use of available resources, it means maximizing production with minimal costs, or increasing profits and decreasing costs (Nassar et al., 2018) and estimating resource uses in agricultural production which is an important issue for sustainability factor of view, because it offers information for decision makers, resource allocations (ICAR Report, 2017), and major challenges facing agriculture include excessive consumption of an agricultural resources, leading to low input use efficiencies (Sara et al., 2020). Therefore, optimum use of maize crop inputs, especially in reclaimed lands, to achieve efficiency through utilizing the correct combination of productive inputs to accomplish food sustainability (Shamsudeen et al., 2018).

So, sustainable development aims at efficient use of resources in a manner that ensures continued long-run use effectively. According to the Food and Agriculture Organization (FAO) definition of sustainable agricultural development is "the management and conservation of the natural resource base and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations (http://www.fao.org/3/u8480e/U8480E0l.htm). This could be achieved through optimal exploitation of human and natural resources.

In Egypt, maize crop occupies the 2nd order strategic food crops after wheat, where it is used in the dry feed industry about 70% and bread production by 20% (Shehata et al., 2018). It can be grown in reclaimed lands, where climate-resilient and water shortages. Reclaimed lands helped in increasing of agricultural production and reached about 3.2 million feddans expressed in 34.8% from total cultivated areas in Egypt during 2018 (CAPMAS, 2018). The cultivated areas of maize reached about 188 thousand feddans, represented about 9.6% from total cultivated area of maize in Egypt and about 8% from total cultivated area in reclaimed lands during the period of

2001-2018 (CAPMAS, 2001-2018).

Recently, Egypt has become an importer of maize crop by about 5.5 million tons by about LE 17 billion pounds in 2018 because there is a gap between production and consumption about 8.6 million tons in 2018 (CAPMAS, 2018) as a result of increasing population. This research exposed to challenges facing agriculture in reclaimed lands economically for expense due to low soil fertility and lack of water resources. At the same time, it was necessary to increase cultivated areas of maize crop to reduce the food gap. Therefore, the research will measure production costs used in producing maize crop, which may affect its yield in reclaimed lands and will cover aspects of effect of inputs on the yield decline, misuse of inputs available in reclaimed lands and determination the target size of inputs.

So, the main aim of this research is to estimate economic efficiency of inputs that used in cultivation of maize in reclaimed lands during the period of (2001-2018) as an attempt to achieve sustainability from these inputs through determine the optimal size of inputs without extravagance and input slacks using Data Envelopment Analysis (DEA) that determines efficiencies and inefficiencies years and scale efficiency.

Some research findings have emphasized that using DEA to help decision makers in choosing appropriate economic decisions by measuring level of technical and economic efficiency, where it was found that specific farms have had the most significant levels of technical efficiency compared to mixed farms, and increasing the technical efficiency to financial subsidies that allocated by agricultural policy in Bulgarian countryside according to (Nicola, 2018) and using to assess the performance of every European country by the output-oriented model that some countries tend to lower eco-efficiency scores because of the different tax effects and the policy makers should revise taxes effects in these countries (Moutinho et al., 2017 and Pierluigi et al., 2017). Majority of EU countries have a more effective and optimized crop production process in terms of resource savings and output maximization and this is probably because of the use of the regular agricultural policy. Using limited natural resources in saving of basic goods for society by measuring eco-efficiency at miniature focusing on little scope family farms in Spain as the key decision-making units (DMUs) and the results applied (DEA) show major inefficiency in aspects such as waste management (Angeles et al., 2017).

Data Resources and Methodology

A. Data Resources

This research was based on the published secondary data of the Egyptian Ministry of Agriculture and Lands Reclamation of the Economic Affairs Sector (Ministry of Agriculture bulletins, 2001-2018), and Central Agency for Public Mobilization and Statistics (CAPMAS, 2001-2018) and data of International Network, including the website (Faostat, 2001-2018) and previous studies related to the subject of the study.

B. Methodology

The research was based on method of descriptive and quantitative economic analysis using descriptive statistics, growth rate and index number (It measures relative changes in price, quantity and value during certain period of time) (CAPMAS, 2018). DEA is a linear programming and non-parametric technique used in to determine the efficiency scores of the enterprises (Ali and Seiford, 1993). There are two main models to compute the DEA, the Charnes-Cooper-Rhodes (CCR) which is a Constant Returns-to-Scale model (CRS) and the Banker-Charnes-Cooper (BCC) which is a Variable Returns-to-Scale model (VRS) (Cooper et al., 2007). DEA scale represents the appropriate method for performing analysis efficiency of DMUs, when there are multiple inputs and outputs measured in different units, and scores range between zero and one. The most efficient units take the estimation of one, while inefficient units take values lower than. Both created models produce a piecewise-linear envelopment surface and are simultaneously input-or-output oriented, only depending on if the objective is to maximize input contraction or yield expansion, where can be estimated efficiency according to the relationship of combination of inputs used in this field (Coelli and Perelman, 1996). DEA does not need a particular functional structure not a priory assignation of weights of each output and input, instead of being gotten variables weights for each input and output to vary being derived from the data instead of being fixed or pre-determined, which advances objectivity and reduce bias (Cooper et al., 2007).

DEA models are used to quantify the technical and economic efficiencies of DMUs throughout a specific period of time in a static manner, because of fixed inputs during a long-run period might not be allocated efficiently or acclimated to the ideal levels and the inter-relationship during consecutive periods to achieve the economic efficiency should be considered (Kao, 2013). Also, using DEA modals can be calculated Scale Efficiency (SE) score for every unit was obtained by dividing the constant returns to scale by the variable returns to scale.

Scale efficiency can be interpreted as follows:

-If SE = 1, then a unit is scale-efficient, its combination of inputs and outputs is efficient both under CRS and VRS (at optimal size).

– If SE < 1, then the combination of inputs and outputs is not scale-efficient.

This measure manages with the input excesses and the output shortfalls of the DMU to find the optimal solutions.

In agriculture, control input could be utilized rather than controlling output quantity. Therefore, this research used an input-oriented model, similarly to most other studies (Dogan et al., 2018; Umanath and David, 2013; Ismat et al., 2009; Shamsudeen et al., 2018) using DEAP 2.1. program, by studying the efficiency of time series (DMUs) of inputs and determine slacks from them to evaluate economic efficiency of inputs that used in producing maize crop in newly lands.

DEA assumes constant returns to scale (CRS)

Fig.1 shows efficiency estimation according to input oriented measure, where assumes that a set of units use two inputs (X1, X2) to produce an output (Y) under constant return to scale. Using Isoquant curve (SS`) and any combination of inputs that fall on it achieves efficiency, but (P) point a combination of inputs is inefficiency because it is located above the curve and the distance (QP) represents inefficiency technical, where it is amount of inputs that can be reduced without affecting the level of production.

Technological Efficiency (TE) could be estimated as follows (Coelli, 1996):

$$TE = OQ / OP$$

And with information of production and inputs prices could be derived Is-cost line (AA`), it reflects the costs of purchasing inputs, and estimate efficiency allocation (AE):

$$AE = OR / OQ$$

Whereas, the RQ distance expresses the amount of reduction in production costs can be achieved when the combination (Q), where Economic Efficiency (EE) could be estimated:

$$EE = OR / OP = TE * AE$$

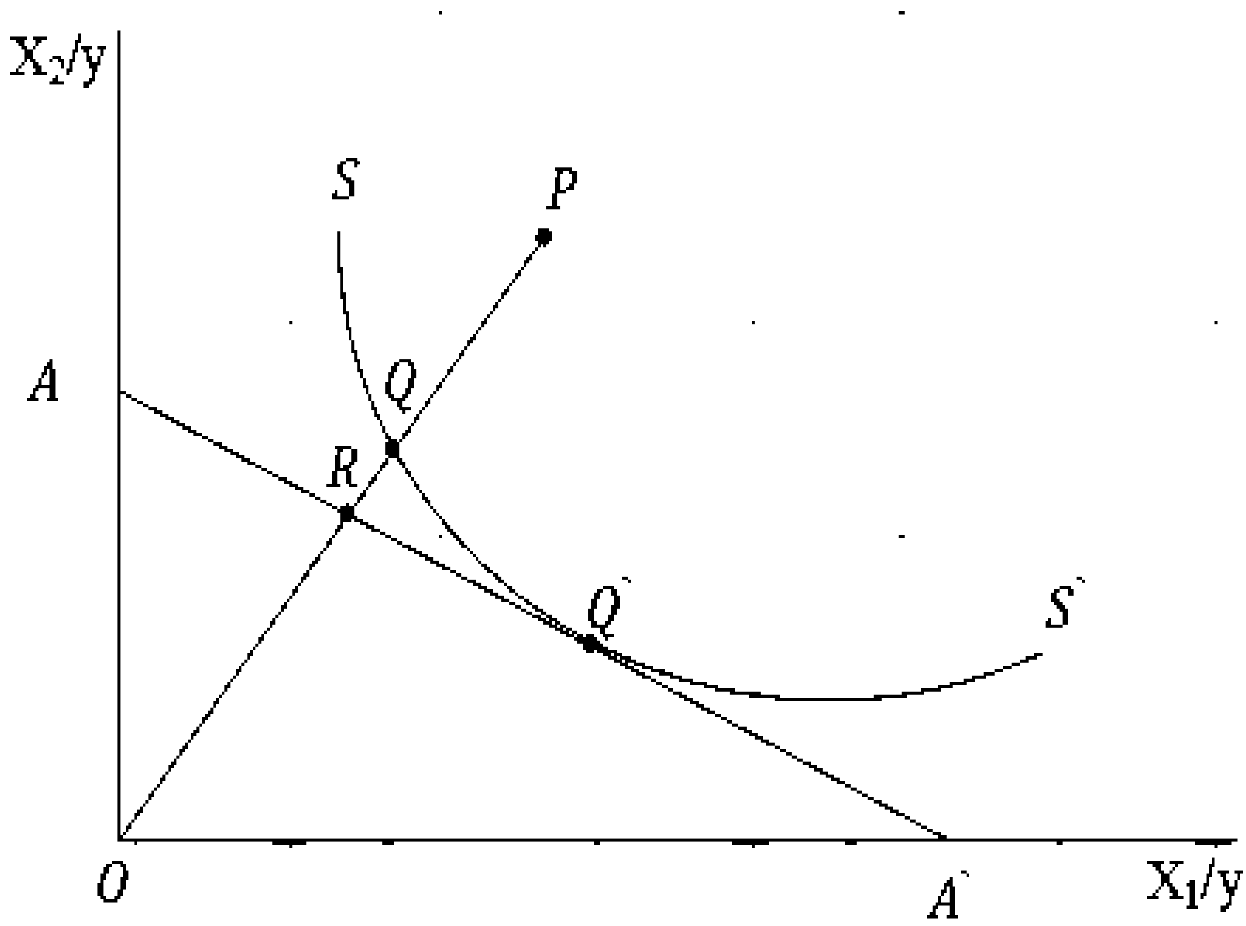

Figure 1. Efficiency according to Input Oriented Measure (Coelli, 1996)

Results and Discussion

Production inputs and yield

The production costs are the most important economic indicators that show the success of economic units, means the total costs of resources used in the production process. Yield is a value indicating the percentage of inputs that were used in production (Battal et al., 2017).

So, this research focused on costs with inputs used in producing maize in reclaimed lands, and their effects on yield.

Table1 Indicated to that mean of total cost of maize during the period (2001-2018) about LE 4.43 thousand pounds /fed with a significant annual growth rate of 5.5% both variable and fixed costs contribute about LE 3.6 and 0.80 thousand pounds respectively represents about 81.9%, 18.1% from total cost. This cost led to increase the value of maize about LE 1154 million pounds during this period, with a significant annual growth rate of 14.4 %. But, there is a high increase in costs, too, from a minimum of LE 2588 pounds in 2001 to a maximum of LE 6356 pounds in 2018, a result of continuing increase in using inputs as shown in, where mean of variable costs of maize about LE 3631 pounds distribution on production inputs, and should be achieved balance production and resource use efficiency goals are limited according to (Sara et al., 2020), where show proportion of the main inputs using in cultivation maize that contributed about LE 1008, 582, 546, 418, 358, 329 pounds represent about 27.8%, 16%, 15%, 11.5%, 9.6% and 9.1% respectively from variable costs for labor wages, machinery, fertilizers, manure, seeds and insecticides that represented in Table1.

All of that led to high cost of maize crop cultivation in reclaimed lands and negatively use effects on soil fertility and productivity, which led farms to refrain from cultivation. Also, this led to the production level is not matching domestic demand and trend to import it to fill the food gap from it, where decrease of yield by about 3.1 tons / feddan during this period matinees (CAPMAS, 2018), where that optimal yield of inputs involve an efficient utilization of inputs in the production process according to (Peter et al., 2013).

Table1: Descriptive statistics of the output and production inputs used for the DEA (n=18)

Inputs/Output (L.E./fed)	Mean	Standard Deviation	Minimum	Maximum	Sum	Growth Rate%	%
Maize Value* Y	1154	1132	309	3832	20773	14.4***	-
Labor Wages X1	1008	258	687	1463	18147	4.7***	27.8
Machinery X2	582	235	260	986	10481	7.9***	16
Seeds X3	358	118	150	536	6444	6.8***	9.6
Manure X4	418	92	287	549	7523	4.2***	11.5
Fertilizers X5	546	122	349	734	9826	4.3***	15.0
Insecticides X6	329	127	110	520	5915	8.2***	9.1
Other expenses	390	51	300	464	7026	2.5***	10.7
Variable costs	3631	994	2138	5252	65362	5.3***	81.9
Fixed costs	803	285	450	1299	14448	6.3***	18.1
Total cost	4434	1262	2588	6356	79810	5.5***	100

L.E.: Egyptian Currency. Fed: is abbreviation for feddan. * (Output) million pounds
(***) statistically significant difference at the 0.001.
(inputs have been measured by Egyptian pound per Feddan)
Source: Collected and calculated from Ministry of Agriculture and Land Reclamation, Economic Affairs Sector, databases, (2001-2018).

Economic Efficiency (EE) of maize

Economic efficiency is a unit of maize production to achieve minimal costs from inputs, which means that at value of 1 the input is using efficiently and there is no excess from it.

Table 2. According to Constant Returns-to-Scale model CRS and Variable Returns-to-Scale model VRS the input-oriented model to measure the economic efficiency during period (2001-2018) shows that value of the average economic efficiency was inefficiency by about 87% for VRS, with a standard deviation of 9.6%, and about 44% for CRS, with a standard deviation of 25%, because values of efficient were less than 1, this consist with (Abigail et al., 2019). It means using of inputs have not been efficient and costs should be reduced by 13% for VRS and 56% for CRS to reach the optimum size and could be infer by index number of CRS in table 2 that efficiency was raised by 102%, 202%, 250% and 262% in 2003, 2016, 2017 and 2018 respectively compared to base year in 2001, and there is no change in efficiency for VRS, this is consistent with (Nicola, 2018) and

the reason of inefficiency as a result of misuse of agricultural inputs and led to decrease in land productivity in reclaimed lands.

On the other hand, production of maize could be increased by about 56% and 13% for VRS and CRS with the same amount of inputs to achieve economic efficiency, this is consistent with (Moutinho et al., 2017) in deciding the technical eco-efficiency rankings utilizing DEA-VRS and DEA-CRS models.

Also, the economic efficiency of CRS varied from a minimum of 23.2% in 2007 to maximum of 100% in 2018, whereas the economic efficiency of VRS scale obtained was in 2001, 2003 and 2018 of 100% and the minimum of 72.5% in 2014. The increase return to scale (irs) on the variable return to scale in the DEA model has been assessed in all years accept the last year. This means that increase their production efficiency by modifying their input use. Therefore, using of input-oriented DEA can help decision makers in assessing resource use efficiency aim at minimizing inputs, this is consistent with (Pierluigi et al., 2017).

Scale Efficiency (SE)

Expresses whether a DUM is operating at its optimal size. This could determine the efficient and inefficient unit, using CRS and VRS DEA. Only 2018 had a SE score of 100%, meaning it was at the optimal size for their inputs, but the rest of years were less than 100% meaning scale inefficient.

Table2. represents that mean scale efficiency was about 50%, with a standard deviation of 25%, this means that using inputs is inefficient (SE < 1) according to (Umanath and David, 2013), and this is reason for decrease in yield of maize to about 3.1 tons/fed during the period study, but the scale could increase production by reducing amount of inefficient inputs by 50% without affecting their current output levels according to (Kirigia et al., 2013), until it becomes efficient to reach to 1 at the optimum production size according to (Silva et al., 2004) .

Table 2: Economic indicators for input-oriented model of Maize, (2001-2018)

DMU Years	Efficiency indicators			Type of return to scale	%index of CRS	%index of VRS
	CRS	VRS	Scale			
2001	0.381	1	0.381	irs	100	100
2002	0.287	0.995	0.288	irs	75.3	99.5
2003	0.390	1	0.390	irs	102	100
2004	0.280	0.918	0.305	irs	73.5	91.8
2005	0.323	0.916	0.352	irs	84.8	91.6
2006	0.356	0.903	0.394	irs	93.4	90.3
2007	0.232	0.816	0.284	irs	60.9	81.6
2008	0.243	0.806	0.302	irs	63.8	80.6
2009	0.249	0.781	0.319	irs	65.4	78.1
2010	0.300	0.790	0.380	irs	78.7	79.0
2011	0.284	0.763	0.372	irs	74.5	76.3
2012	0.330	0.761	0.433	irs	86.6	76.1
2013	0.381	0.765	0.498	irs	100	76.5
2014	0.420	0.725	0.579	irs	110	72.5
2015	0.720	0.867	0.830	irs	70.9	86.7
2016	0.770	0.899	0.856	irs	202	8.99
2017	0.951	0.983	0.967	irs	250	98.3
2018	1	1	1	-	262	100
Mean	0.439	0.872	0.496			
Standard Deviation	0.250	0.096	0.249			
Maximum	1.000	1.000	1.000			
Minimum	0.232	0.725	0.28			

Note: scale = scale efficiency = CRS / VRS. irs: stands for increasing return to scale
Result DEAP 2.1 program.

Inputs slacks from using excess inputs

The DMU is described as effective when the DEA score is equal to one and all slacks are equal to zero (Shamsudeen et al., 2018). So, there are no output slacks, but Table3 represents that input slacks determine the optimum amount without extravagance. There is an excess of inputs used in the production process where the greatest slacks were in insecticides, seeds, machinery, fertilizers, manure and labor wages by about 118, 121, 147, 106, 69 and 134 pounds/fadden showed about 35.9%, 33.8%, 25.3%, 19.4%, 16.5% and 13.3% represented from the actual use of inputs Fig.4. By providing this extravagance this be given the same amount of production, according to (Umanath et al., 2013), where the optimum values (target) could be determined from inputs by using DEA. Fig.5 shows the amount of excess in actual inputs that effects decrease yield of maize, and also amount of target inputs that achieve efficiency by about 874, 440, 435, 349, 237, and 211 pounds, respectively from labor wages, fertilizers, machinery, manure, seeds, and insecticides, according to (Nicola, 2018) and this helps to achieve the goal of sustainable development, by estimating optimum quantity of inputs for maize production in reclaimed lands.

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Table 3 : Inputs slacks from using excess inputs, (2001-2018)

Inputs	Actual	Target	slack	%
Labor Wages	1008	874	134	13.3
Machinery	582	435	147	25.3
Seeds	358	237	121	33.8
Manure	418	349	69	16.5
Fertilizers	546	440	106	19.4
Insecticides	329	211	118	35.9

Analysis of results using DEAP V.2.1

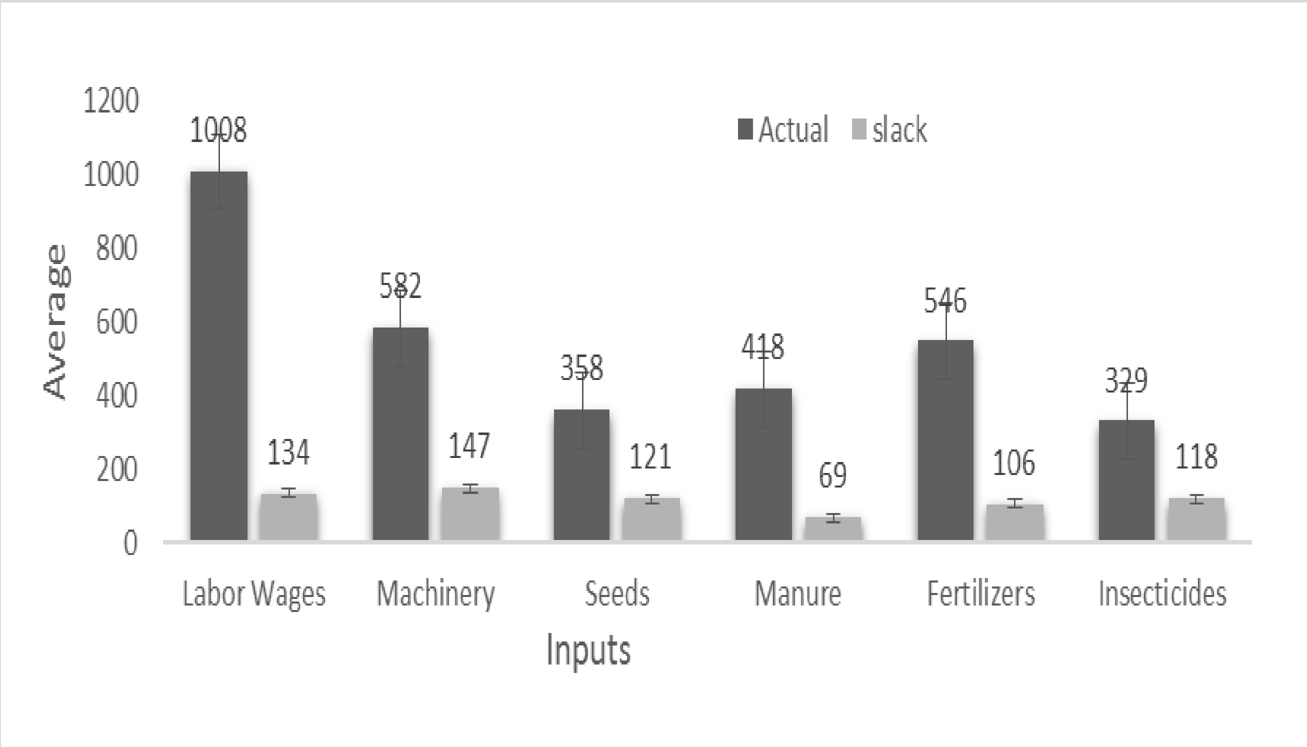

Figure2. The amount of inputs slacks, (2001-2018)

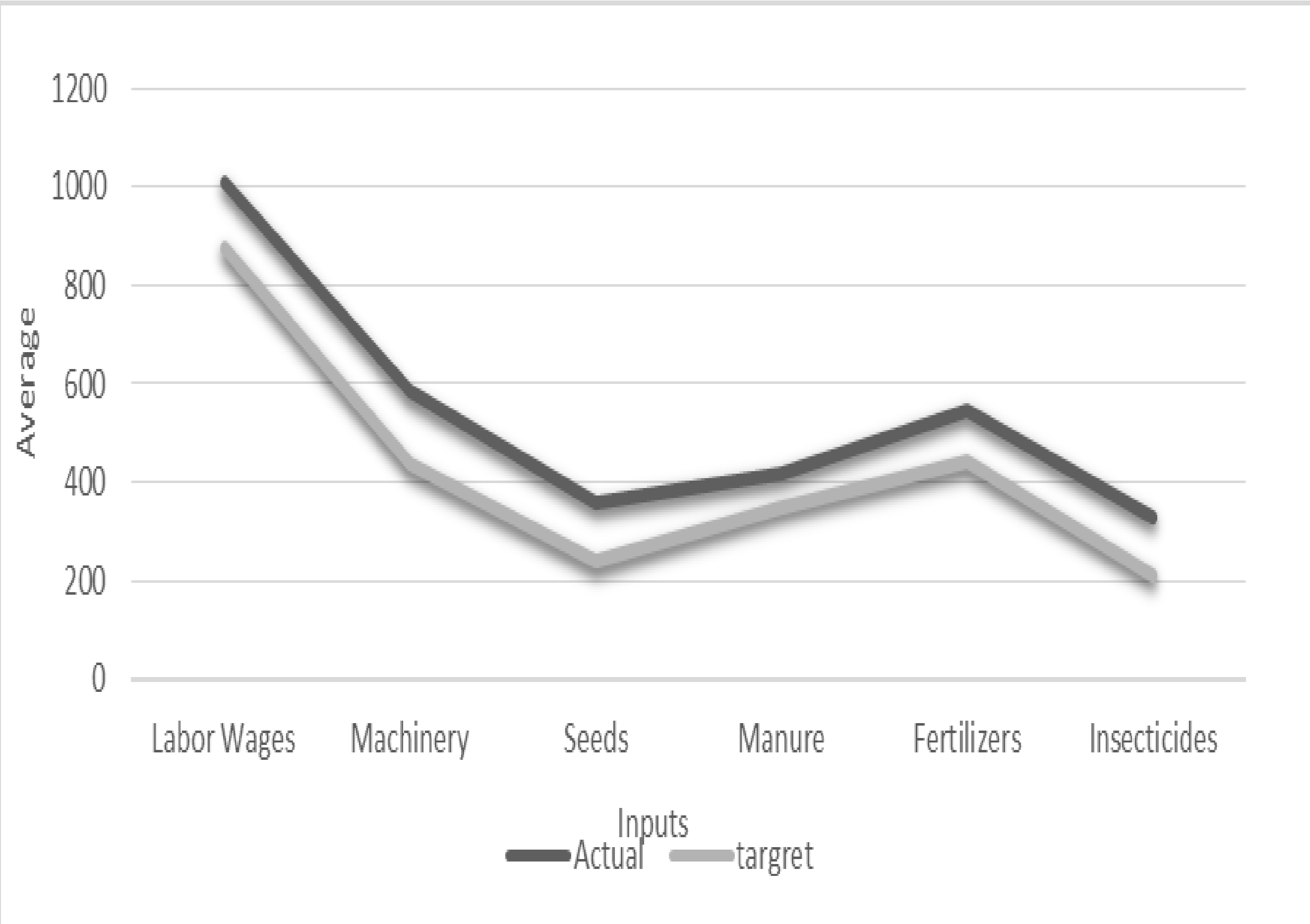

Figure 3. Actual and target inputs, (2001-2018)

Conclusion

DEA program - as a realize in economic efficiency by using inputs to reach the optimum size – is directed at this work to locate amount of input slacks used in cost reduction of maize cultivation in newly lands. Lots of benefits could be obtained from minimizing of maize production costs, maintain soil productivity and encourages farmers to continue cultivating maize. This leads to achieve optimal yield of inputs those involve an efficient utilization of inputs in the production process.

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