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Technical and Environmental Efficiency of Wheat Farms in Saline Irrigated Areas of Central Iraq

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Technical and Environmental Efficiency of Wheat Farms in Saline Irrigated Areas of Central Iraq

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Abstract

This study set out to investigate the impact of salinity on technical efficiency (TE) and environmental efficiency (EE) in wheat production in central Iraq, where 360 farmers have been interviewed and soil and water samples were collected and analyzed. This study aims to consider how farmers could re-allocate their resources in efficient and sustainable ways to produce viable agricultural production in the salt-affected areas of Iraq without introducing a new technology. Stochastic frontier analysis (SFA) approach was proposed to estimate both TE and EE in irrigated wheat production farms. The empirical findings showed that, on average, TE was 75% for low saline farms (EC less than 2.5 dSm^{-1}), 58% for moderate saline farms (EC ranging between 2.5 and 7.5 dSm^{-1}), and 32% in the severe saline farms (EC exceed 7.5dSm^{-1}). The mean level of EE was 76%, 64%, and 34% for low, moderate, and high saline farms, respectively. Two main sources of environmental degradation have been considered: Urea and DAP. The fertilizer (Urea) coefficient indicatedthat toimprove EE by 1%, wheat yield needs to be reduced by 6% through the farmer using recommended quantities of Urea fertilizer. Soil salinity level was associated negatively with the technical and environmental efficiency of farm.

Keywords: Environmental Efficiency,Iraq, Soil salinity, Technical Efficiency, Wheat.

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Introduction

By 2050, the world will host nine billion people and that is if population growth slows in much of the developing world. Currently, the great challenge is how can agriculture be intensified to feed a growing population while addressing environmental concerns. With the current agricultural production system and stable rate of population growth, the demand for food will outstrip supply by 2050. The world population will grow about 76.6% from its current population by 2050, when the demand for cereal and livestock products will grow by 70% and 17.5%, respectively (Alexandratos et al., 2006). During the past 60 years, food demand has been met through input-intensive, mechanized agricultural and irrigation in agricultural system in which agricultural area has grown only by 12% while production has grown around 2.7 times (Dubois, 2011).

In developing countries, despite the fact that irrigated agricultural land covers only 20% of all arable land, it accounts for 47% and 60% of all crop and cereal production respectively. In total, 11% of irrigated area is affected by salinity (Pakistan, China, United States, and India present more than 60% of this percentage). The removal of salts from the soil through leaching and drainage increases the salinity of drainage water, which then might be up to 50 times more concentrated than irrigation water, in which surface water supplies 62% of the irrigated area. Irrigated area disposal can raise the salinity of receiving water bodies to levels that make them no longer usable (Mateo-Sagasta and Burke, 2010).

Soil salinity has been affecting agricultural productivity in many countries worldwide, especially developing countries in arid and semiarid regions(Naifer et al., 2011). In recent years, various regions have lost significant agricultural production due to soil salinity. There are no reliable estimates as to the effect of water logging and salinity on agricultural production at farm level, regional level, and global scale, as a result of human-environment interactions in arid and semi-arid regions (Dregne and Chou, 1992). One of the important factors leading to low crop productivity in Iraq is salinity. This situation is particularly critical for the irrigated areas in Iraq, which produce an important share of crops for the country (Zowain et al., 2012). In Iraq, many studies have focused on the relationship between agricultural productivity and salinity of irrigation water, but from a publication standpoint, the relationship between agricultural productivity and soil salinity has been ignored.

Generally, there are two types of goods produced in each production system, tradable and non-tradable goods (Goldstein et al., 1980). From an economic perspective, firms, farms or any production establishment around the world focuses more on tradable commodities than non-tradable ones, due to cost benefit analysis. In recent years, environmental economists (Bennett and Blamey, 2001) have examined non-tradable outputs. Despite the fact that the agricultural sector is playing a crucial role in food production, it is also producing non-tradable goods (Keohane and Olmstead, 2016). Non-tradable agricultural production could be divided into two categories: positive externalities, which have a positive impact on the environment, and negative externalities, which have negative impacts on environment (Griffin and Bromely, 1982). Indeed, improving environmental efficiency (EE) leads to a reduction in these negative externalities with respect to a constant level of tradable production (Coelli et al., 2005).

Overall, in terms of food production processes, the interaction between human activities and natural resources generates environmental damages, measured, in this case, by estimating environmental efficiency. The DEA and SFA approaches used to estimate technical and environmental efficiency in agriculture by Picazo researches (Picazo-Tadeoet al., 2011; Picazo-Tadeoet al., 2012). On the other hand, Beltran assesses the differences in the technical and environmental efficiency in olive farms using meta-frontiers (Beltran-Esteveet al., 2014). The DEA approach has been used worldwide in many researches to estimate the environmental and technical efficiency for different crops under different agro-geographic systems (Ullah and Perret, 2014; Pang et al., 2016).

This study investigates the impact of soil salinity on technical efficiency (TE) and environmental efficiency (EE) in wheat production in central Iraq, where 360 farmers interviewed in winter season 2015-2016. The main objective of this study is to present soil salinity as factor, which has two side impacts. Parametric approaches are used to estimate TE and EE, as well as assess the fact that wheat farmers reach different levels of TE and EE. The hypothesis to be tested is whether soil salinity reduces both TE and EE of wheat farmers in the study area.

Data Collection and Sampling Procedure

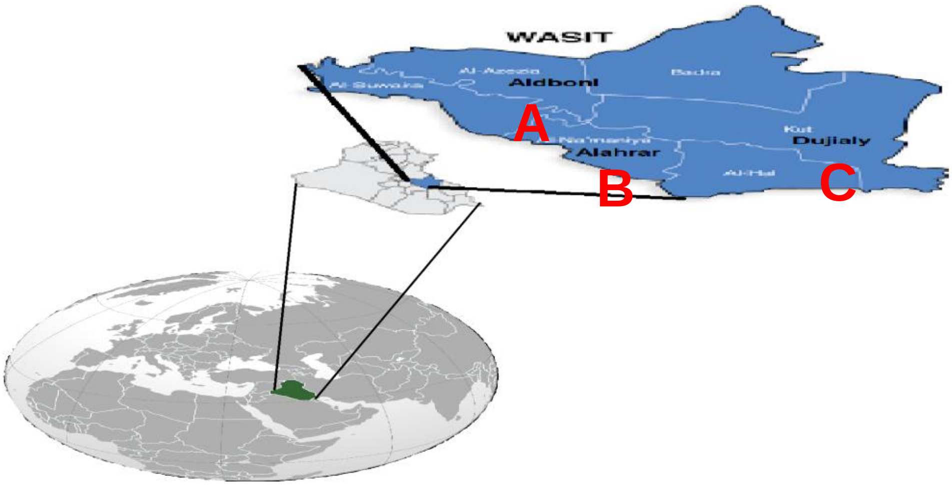
The stratified random sampling technique is used. A household survey on wheat farmers for the 2015/2016 production season has been implemented in three districts (Aldboni, Alahrar, and Dujialy). A multi-stage sampling technique and Stevin Thomson Law[1]is used to calculate the sample size, which was 360 households. Working with wheat farmers at Aldboni, Alahrar, and Dujialy districts, 360 households have been interviewed and soil samples were collected and analyzed.

The researcher conducted the face-to-face interviews. Based on secondary data assessment on the impact of salinity on wheat production and the share of wheat production, three districts were selected in the first stage, one district from each level of cultivatable land affected by salinity. In addition, the selected districts have a large share of wheat production, and geographical location was considered into account based on the district's position with respect to the Tigris River. Aldboni district (A) is located upstream, while Dujialy district (D) is downstream, and Alahrar district (C) is in the middle, as shown in Figure 1. In the second stage, we classified each district based on

1 $= \frac{N\times P(1-P)}{[[(N-1)\times(d^2\div z^2)]+P(1-P)]}$.

agricultural land types (1: Un-reclaimed land, 2: Un-reclaimed land located on the main river, 3: Semi-reclaimed land and 4: Reclaimed land). Only the villages totally inside each type have been included in the survey sample. In the third stage, a random sample of wheat farmers in each selected village was chosen proportionally to the sample size of each district. Figure 1 shows the position of the study area in relation to the world and Iraq.

Figure 1. *Study Area*



Based on soil sample lab analysis, Figure 2 shows the total sample classification based on soil EC, in which farms were divided into three sub groups according to the soil salinity level[2] - low salinity (S1), medium salinity (S2), and high salinity (S3). It shows that 47% of farms were located in S1 level, while the other farms divided between S2 and S3 by 24% and 29% respectively.

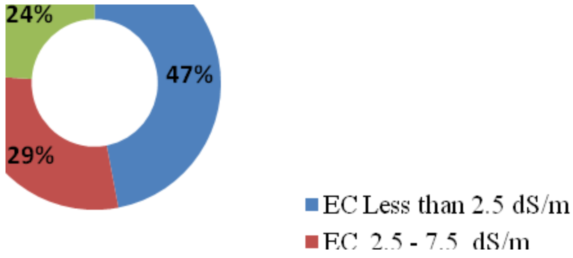
[2] Based on EC (Electric Conductivity) of the soil in the root zone, Irrigation water classification could be classified into three main classes:

a- S_1 is refer to LS (Low Salinity) less than 2.5 dS m^{-1}

b- S_2 is refer to MS (Medium Salinity) 2.5 – 7.5 dS m^{-1}

c- S_3 is refer to HS (High Salinity) higher than 7.5 dS m^{-1}

Figure 2. *EC Levels and Sample Classification*



Methodological Framework

As well as different concepts about the production function, there are two main methods to calculate parameter values for frontier models: parametric and non-parametric. Parametric approaches comprise econometric models (Stochastic Frontier Analysis or SFA), and non-parametric models (Data Envelopment Analysis or DEA) are different from the parametric models in that they do not need to specify a functional form.

Technical Efficiency Measurement

One technique of estimating a farm's relative position to the frontier used in this empirical study was the SFA approach. This method is used to estimate the technical efficiency level of wheat producers and the sources of inefficiency. The theoretical model of a SFA is defined as follows:

$$y_i = f(x_i;\ \beta_i)\exp\,(v_i\ - \qquad (1)$$

Where:

- = output of the ith farm;
- is an appropriate function is vector of input used by the ith farm;
- is a vector of the unknown parameter to be estimated;
- = 1,………………….. (Number of farm);
- is a random error, which accounts for random variations in output because of factors out of the farmers' control such as weather, measurement error, etc; and is a non-negative random variable representing inefficiency in output relative to the stochastic frontier.

The error component is assumed to be independently and identically distributed as $N(0,$. We were particularly concerned about the case of where is derived from a distribution $N(0,$ truncated at zero (i.e. an exponential or half normal distribution)(Aiger and Cain, 1977),while Meeusen and Van den Broeck (1977) considered only the case of Ui which has an exponential distribution (Meeusen and van Den Broeck, 1977).Estimating the TE of an individual farmer is defined in terms of the ratio of observed output to the corresponding frontier output with constant technology.

$$\mathrm{TE} = \qquad (2)$$

$$\mathrm{TE} = \frac{f(x_i;\beta_i)\exp(v}{f(x_i;\beta_i)\exp} \qquad (3)$$

$$\mathrm{TE} = \exp(\qquad (4)$$

The process of estimating TE is a two-stage process. The first step involves measuring the efficiency/inefficiency value using a normal production function. Using a suitable model to determine the socio-economic factors that affected the efficiency value comprises the second stage. The following Cobb-Douglas functions estimate the wheat crop in the study area (Wasit province).

$$\ln Y_i = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_6 \ln X_6 + \beta_7 \ln X_7 + v_i - u_i \qquad (5)$$

The dependent variable, , is a production of wheat, measured in kilograms (Kg), and is a number of Irrigation (NOI) during the cultivation season measure in number; is an agricultural chemical, which is the quantity of chemical pesticide (CH) measured in liters (lit); is a fertilizer (FER-Urea) used in wheat production measured in kilograms (kg); is a fertilizer (FER-DAP) used in wheat production measure kilograms (kg); is the quantity of seed (SQ) used and measured in kilograms (kg); is thequantity of labor (L) employed during the season of wheat production, and measured in man-days per hectare (man-days); and finally, is the mechanization (M) in wheat production measured in machine-hours (Mach-hours).

The maximum likelihood method estimated the impact of these socio-economic factors on technical efficiency of the farmers, The Maximum Likelihood Estimations (MLEs) model is specified as:

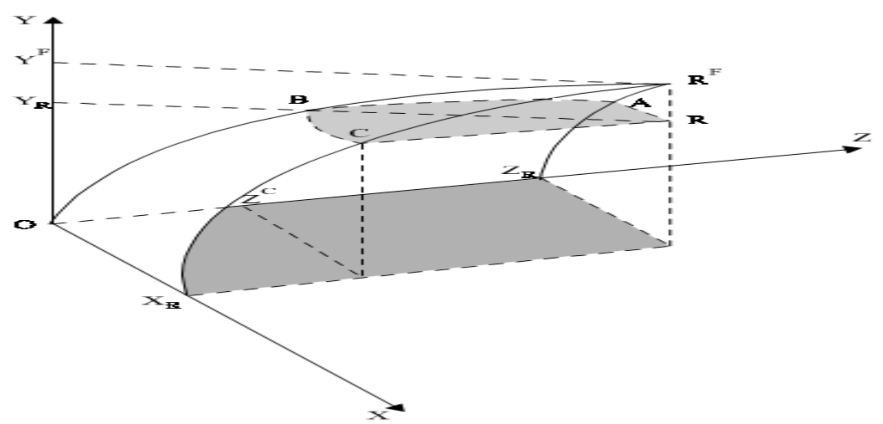
$$ui = \sigma_0 + \sigma_1 z_1 + \sigma_2 z_2 + \sigma_3 z_3 + \sigma_4 z_4 + \sigma_5 z_5 + \sigma_6 z_6 + \sigma_7 z_7$$

$\sigma_1, \sigma_2, \sigma_3, \dots\dots\dots\dots$ Unknown parameters to be estimated

Environmental Efficiency Measurement

The methodological framework used in this research to estimate the environmental efficiency is the parametric approach, which is one technique of estimating the farm's relative position to the frontier (Figure 3).

Figure 3. *Environmental Efficiency Measurement*



Source: (Coelli, 2005).

Figure 3 presents a basic idea of the environmental variable. It shows that farm R used two inputs (x: environmentally safe or conventional input, and z: environmentally detrimental input) to produce Y within the best practice production frontier F(•), and Y ≤ F(X,Z). The frontier is the increasing, quasi-concave surface 0XRRFZR. YR is the observed output, produced using XR of the conventional input and ZR of the environmentally detrimental input. ABCR is the surface with identical output quantity, YR, as farm R.

Estimating the EE for an individual farmer is defined in terms of the ratio of observed output to the corresponding frontier output with constant technology. So that the environmental efficiency of farm R is:

$$En.E_R = \min\{\theta: F(X_R, \theta Z_R) \geq Y_R\} = |OZ^F|/|(\qquad (6)$$

Where ZF is the minimum feasible environmentally detrimental input use, given F(•)and the observed values of the conventional input XR and output YR.

In Figure 3 the observed output YR is technically inefficient, since (YR, XR, ZR) lies beneath the best practice production frontier F(•). It is possible to measure technical efficiency using an input-conserving orientation, as the ratio of minimum feasible input to observe the input used, conditional on technology and observed output production. SFA approach used to estimate EE level of wheat producers and the sources of inefficiency. The theoretical model of a SFA is defined by:

$$y_i = f(x_i; z_i;\ \beta_i)\exp\,(v_i\ - \qquad (7)$$

Where = output of the ith far, is an appropriate function is vector of input used by the ith farm, is environmental input, and is a vector of the unknown parameter to be estimated. = 1,….. (Number of farms), is a random error thataccounts for random variations in output because of factors out of the farmers’ control such as weather, measurement error, etc. and is a non-negative random variable representing inefficiency in output relative to the stochastic frontier.

The error component is assumed to be independently and identically distributed as $N{\sim}(0,$ were particularly concerned about the case of where it is derived from a distribution $N{\sim}(0,$ truncated at zero (i.e. an exponential or half normal distribution),while Meeusen and Van den Broeck (1977) considered only the case of Uithathas an exponential distribution. Equation 3 is used to estimate EE in the study area:

$$\ln Y_i = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln Z_3 + \beta_4 \ln Z_4 + \beta_5 \ln X_5 + \beta_6 \ln X_6 + \beta_7 \ln X_7 + v_i - u_i \quad (8)$$

The dependent variable, is the yield of wheat, measured in kilograms per hectare (kg/ha), and is the amount of irrigation used (NOI) during the cultivation season measured in number. is an agricultural chemical, which is quantity of chemical pesticide (CHP) measured in liters per hectare (lit/ha); is the actual quantities of Urea fertilizer used by farmers in wheat production and measured in kilograms per hectare (kg/ha); is the actual quantities of DAP fertilizer used by farmers in wheat production measured in kilograms per hectare (kg/ha). is the quantity of seed (SQ) used measured in kilograms per hectare (kg/ha); is the labor quantity (L) employed during the season of wheat production, and measured in man-days per hectare (man-days/ha); is the mechanization (M) in wheat production measured in machine-hours per hectare (Mach-hours/ha).

The maximum likelihood method was used to estimate the impact of these socio-economic factors on environmental efficiency of the farmers. The Maximum Likelihood Estimation (MLE) method used to estimate the inefficiency model below:

$$ui = \sigma_0 + \sigma_1 z_1 + \sigma_2 z_2 + \sigma_3 z_3 + \sigma_4 z_4 + \sigma_5 z_5 + \sigma_6 z_6 + \sigma_7 z_7$$

$\sigma_1, \sigma_2, \sigma_3, \dots\dots\dots\dots$ Unknown parameters to be estimated.

$$\ln Y_i = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln Z_3^F + \beta_4 \ln Z_4^F + \beta_5 \ln X_5 + \beta_6 \ln X_6 + \beta_7 \ln X_7 + v_i \quad (9)$$

In which and are minimum feasible inputs Urea and DAP fertilizers respectively.

The yield in both equations is identical, so by rearranging equation 3 with 4 we gain:

$$0 = \ln(Z_3^F/Z_3) + \ln(Z_4^F/Z_4) \quad (10)$$

So that:

$$\ln En.E = \ln(Z_3^F/Z_3) + \ln(Z_4^F \quad (11)$$

$$\ln \text{En.E} = \ln Z_3^{En} + \ln Z_4^{En}$$

Results and Discussion

This section is divided into three parts: socioeconomic characteristics of the interviewed farmers, technical efficiency results and environmental efficiency results.

The socioeconomic characteristics of wheat farmers, who were interviewed in the research, are presented in Table 1. It shows that there were three types of families in the study area, as follows. About 45% of wheat farmers have a nuclear family structure, while 34 % and 21% have extended and polygamous family structures, respectively. The descriptive analysis shows that about 46% of those adults are women.

Table 1. *Socioeconomic Characteristics of Wheat Farmers*

Character	Frequency	%	Character	Frequency	%
Family Structure			Land tenure		
Nuclear [3]	162	45	Won	18	5
Extended [4]	122	34	Rent from Government	306	85
Polygamous [5]	76	21	Rent from Private	36	10
Household gender			Agricultural Experience		
Man	165	46	< 30	177	49
Woman	194	54	$30 - 50$	165	46
Woman own land	27	7.5	> 50	18	5

Source: Own elaboration based on field survey data (2016).

With this large proportion of females in total household members, only 7.5% of them have their own farm. They were included in the rent from government category under land tenure classification categories, in which 85% of wheat farmers are situated. Additionally, only 10% of wheat producers rent their farm from other farmers. The age of interviewed wheat farmers ranged from 24 to 85 years old, with about 62% of farmers within the age group 40-60 years, and 19% of farmers over 60 years old. The impact of theage of wheat farmers on agricultural experience is clear in Table 1 in which 51% of farmers have over 30 years of agricultural experience.

Table 2 presents descriptive statistics of quantities of inputs and outputs. The mean value of wheat yield in the study area was around 2,826 kg/ha. From the input side, the amount of irrigation during the wheat-growing season was recorded at a maximum as 7 times in some farms, while the mean value was 4 times. The mean value of agricultural chemicals was 1.19 L/ha applied in the study area. Fertilizer Urea, DAP, and seed use had mean values of 295 kg/ha,

[3] The nuclear family is usually consists of two generations of family, parents and their own children resident in the same household.

[4] The extended family is the three-generation family consisting of grandparents, their children and their grandchildren resident in the same household.

[5] The polygamous family in this study is the husband or his son has more than one wife at same time resident in the same household.

230 kg/ha, and 253 kg/ha, respectively. In fact, Table 2 shows the mean value of labour work per season as 6.03 man-days/ha. Moreover, the one hectare of wheat required an average of mechanization working for 7.47 hours during the production season. Soil testing laboratory provided the research with soil EC results, which are included in Table 2. In total samples, the EC analysis indicates an average EC around 4.77 dS m^{-1}.

Table 2.*Descriptive Statistic of Quantities of Inputs and Outputs*

Variable (Unit)	Mean
Yield (Kg/ha)	2826
No. of Irrigation; NOI (number)	4.17
Agricultural Chemicals; CH(L/ha)	1.19
Fertilizer Urea; Fer-U(Kg/ha)	295
Fertilizer DAP; Fer-D(Kg/ha)	230
Seed; SQ(Kg/ha)	253
Labour; L (Man-Days/ha)	25
Mechanization; M (Mach -hours/ha)	7.32
Electric Conductivity; EC (dS m-1)	4.77

Source: Own elaboration based on field survey data (2016).

Based on soil salinity levels, the impacts on resource use and productivity are presented in Table 3. Table 3 presents the descriptive statistics with respect to average value of recourse used and productivity. Table 3 findings provide a basic idea about the soil salinity effects on inputs used in wheat production. The mean value of yield reduced remarkably by 40% when the level of soil salinity changed from S1 to S3. Meanwhile, in the inputs side, the scenario is opposite in some cases. For instance, in Table 3, the average quantities of Urea fertilizer and seed used by farmers in S3 were more than those quantities used by farmers in S1 by 5% and 9.6% respectively.

Table 3. *Impact of Salinity on Resource Use and Productivity*

Salinity level	No. of farms	Mean[6]								
		Yield	NOI	CH	FER-U	FER-D	SQ	L	M	EC
S1	172	3574	4.27	1.11	289	238	247	24	7.25	1.27
S2	103	2743	4.1	1.18	300	227	258	23	7.43	4.56
S3	85	1416	4.07	1.37	303	217	257	31	7.32	12.09

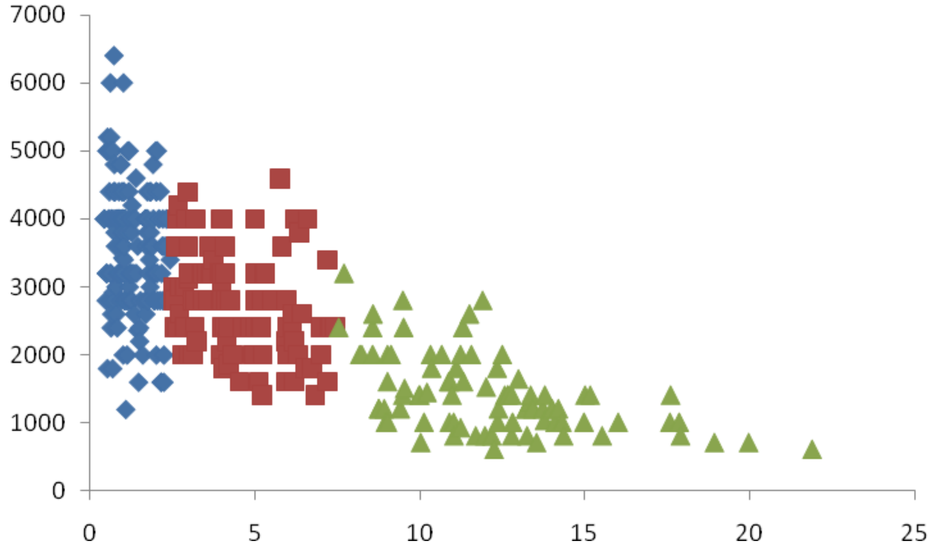
Source: Own elaboration based on field survey data (2016).

Figure 4 shows the relationship between soil salinity and yield for each farm. The figure shows that only farms belonging to the S1 category produced

[6] Acronyms and units are the same in Table 2.

yield more than 4000 kg/ha, and farms in S3 category could not produce yield more than 3000 kg/ha.

Figure 4. *Causality between Wheat Yield and Soil Salinity Levels (EC)*



Source: Own elaboration based on field survey data (2016).

The remarkable changes in resource use efficiency and productivity connected to the soil salinity level from an econometric perspective are presented in Table 4. It shows the results of stochastic frontier Cobb-Douglas production functions analysis for wheat farmers.

The analysis from the stochastic frontier production function for wheat farmers estimated that the amount of irrigation has a significant positive effect on production. Likewise, Urea fertilizer, labour, and mechanization have significant positive effects on production. Holding other factors constant, farmers in the study area can increase production by increasing each one of these variables. For instant, holding other factors constant, if Urea fertilizer is increased by 1 % this leads to increase wheat production by 0.12%.

There were five main sources of inefficiency, as follows. The first was the EC of soil. If the EC of soil is reduced, this leads to a reduction in the technical inefficiency. The second source was the location of the farm. For example, if the farm is closer to the main river, it will be more technically efficient. The third source was the location of the farm in terms of reclaimed land, on which they will be more technically efficient.

The fourth source was the agricultural experience of the farmer, which was associated positively with technical efficiency. Finally, the wheat variety has a significant impact on technical inefficiency. The farmers who used IPA variety aremore technically efficient than non-IPA users.

Table 4.*Estimate of Stochastic Frontier Production Function Parameters*

Variable	Coefficient	Std.err.
Constant *	5.01***	0.37
ln (Number of Irrigation)	0.21***	0.08
l (Agricultural Chemicals)	0.005	0.03
ln U (Fertilizer Urea)	0.12***	0.05
ln D (Fertilizer DAP)	0.001	0.005
l (Seed Quantity)	0.12	0.10
(Labour)	0.12**	0.06
(Mechanization)	0.67***	0.10
Inefficiency Variables		
EC (dSm^{-1})	0.09***	0.005
Location, Dummy (1: Main River, 0: Otherwise)	-0.10*	0.08
Position , Dummy (1: Reclamation Project, 0: Otherwise)	-0.21***	0.06
Level of Education, Dummy (1: Read &Write, 0: Otherwise)	-0.02	0.05
Agricultural Experiences,(Years)	-0.004**	0.002
Wheat Variety, Dummy (1: IPA, 0: Otherwise)	-0.06*	0.04
Wheat share, Ration	0.04	0.08
σ^2	0.10***	0.01
γ	0.77***	0.10

Source: Own elaboration based on field survey data (2016) and Frontier 4.1 outputs.
The asterisks indicate levels of significant: *** is significant at 1% level; ** is significant at 5% level; * is significant at 10% level

TE results are presented and discussed in the following section: Results in Table 5 shows the mean value of TE, which was classified with respect to salinity zones. In general, it shows that the mean value of technical efficiency of farms was around 60%. The technical efficiency level on average was declining as the salinity level was increasing. The results show that farms located in the S1 zone are more technically efficient in comparison to those located in the S3 zone by about 43%.This implies that farmers in the S3 zone could increase their efficiency by 43% if soil salinity reduced within or less than 2.5 dSm^{-1}.

Table 5. *Frequency Distribution of TE Estimates and Soil EC Classifications*

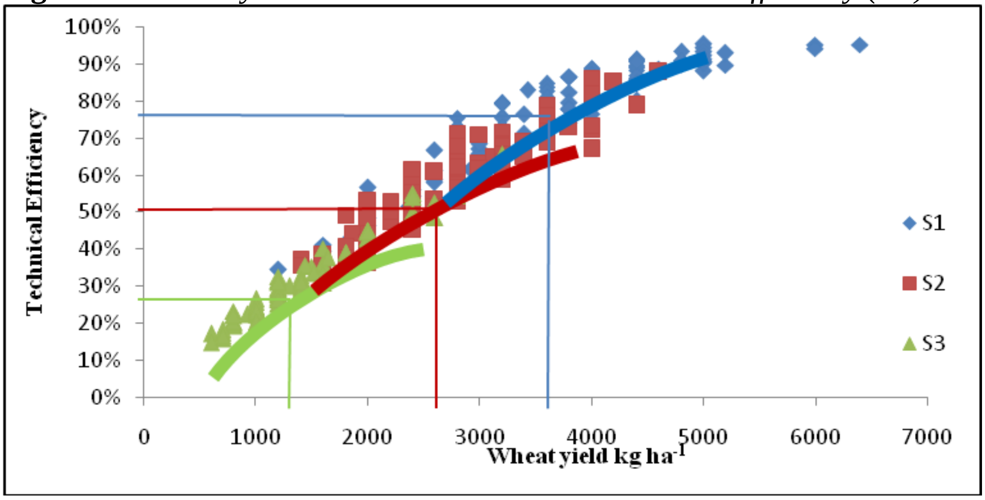
TE Value	S_1	S_2	S_3	Total Sample/ average
# Farmers	172	103	85	360
Mean	74.79	57.82	31.54	59.72
Maximum	95.53	87.92	65.90	95.53
Minimum	34.53	35.72	14.77	14.77

Source: Own elaboration from model results.

Based on the SFA approach and Cobb-Douglas production function, Figure 5 presents the relationship between TE and wheat yield with the value of soil salinity. Yield varies across farms in the sample and their range of TE. The more efficient farmers gain more yield than those farmers who are technically less efficient. Despite this, some farmers who achieve high levels of TE in high salinity levels gain low yield compared to those who have the same or lower level of TE in low salinity farms.

This result clearly indicates that reducing soil salinity at the farm level will contribute to an increase in yield level for the same level of input use or less. Thus, one way to remove the inefficiency in wheat production and increase productivity in Iraq is to improve the efficiency of resources used in wheat production through reducing soil salinity at the farm level. This threat could be managed through investing in reclaimed land.

Figure 5. *Causality between Wheat Yield and Technical Efficiency (TE)*



Source: Own elaboration from model results.

Table 6 presents the empirical results from the econometric estimation of the SFA-CD production function. It shows the results of the stochastic frontier Cobb-Douglas production function analysis for wheat farmers in central Iraq.

Table 6.*Estimate of Environmental Efficiency Parameters*

Variable	Coefficient	Std. Err.
Constant *	8.64***	0.57
ln (Number of Irrigation)	0.25***	0.09
l (Agricultural Chemicals)	-0.06	0.05
$\ln(Z_3^F$ (Environnemental Input Fer U)	-0.07**	0.03
$\ln(Z_4^F$ (Environnemental Input Fer DAP)	-0.01	0.01
l (Seed Quantity)	-0.02	0.09
(Labour)	-0.10	0.06
(Mechanization)	-0.11	0.13
Inefficiency Variables		

EC (dSm-1)	0.57***	0.06
Location, Dummy (1: Main River, 0: Otherwise)	-0.03	0.10
Position, Dummy (1: Reclamation Project, 0: Otherwise)	-0.35***	0.09
Level of Education, Dummy (1: Read &Write, 0: Otherwise)	-0.0002	0.08
Agricultural Experiences, (Years)	0.03	0.05
Wheat Variety, Dummy (1: IPA, 0: Otherwise)	-0.02	0.03
Wheat share	0.07	0.08
σ^2	0.14***	0.02
γ	0.83***	0.05

Source: Own elaboration based on field survey data (2016) and Frontier 4.1 outputs.
The asterisks indicate levels of significant: *** is significant at 1% level; ** is significant at 5% level.

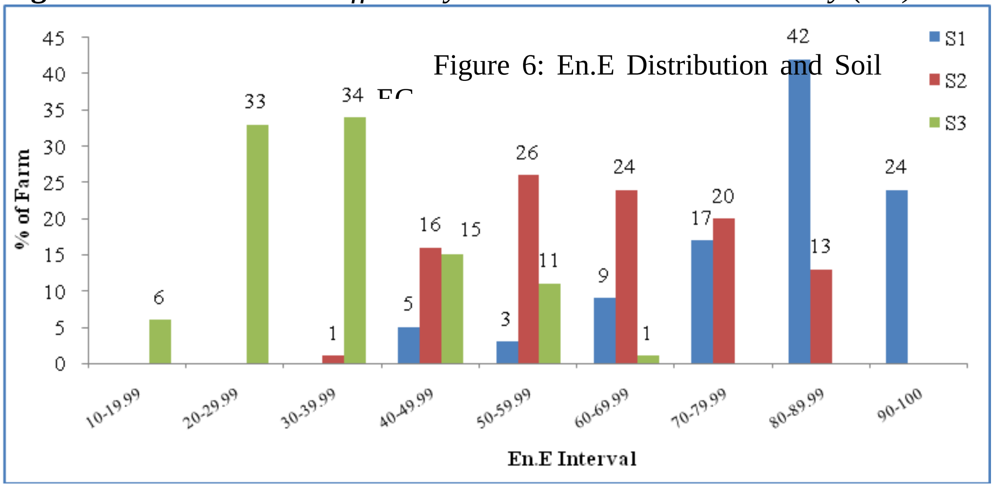
The findings from the estimation of stochastic frontier production function for environmental efficiency estimations of wheat farmers showsthat for a 1% increase of EE in the study area a farmer needs to use Urea fertilizers with adequate and feasible quantities, which will lead to yield reduction of0.07%. Results also show that DAP fertilizers do not affect the environment significantly.

There were two main sources of environmental inefficiency and both relate to soil salinity; the first was the EC of soil. Farms with low levels of soil salinity are more environmentally efficient. The second source was the farm's position on reclaimed land.If a farmer cultivated their wheat in reclaimed land, they were more environmentally efficient than farmers who cultivated their land in semi-reclaimed orun-reclaimed land.

The average EE for the total sample was 0.65 indicating that, on average, they could obtain the same production level while reducing the pressures of their productive activity exertion on the environment by 35%. In other words, the economic-ecological management of farms analyzed is markedly inefficient. The EE results are presented and discussed in the following section. Table 3shows the mean value of EE, which was classified with respect to the different salinity zones.

The EE level on average was declining as the salinity level was increasing. The results showthat farms located in the S1 zone are 42% more environmentally efficient than thosein the S3 zone are. That is, farmers in the S3 zone could increase their efficiency by 42% if soil salinity was reduced within or less than 7.5 dSm^{-1}. In general, the mean value of EE of farms was 65%, while Figure 6 shows that about 83% of S1 farmers have EE more than 70%, and only about 5% of the S1 farmers have EE between 40-50%, which is the lowest EE at this salinity level.

Figure 6. *Environmental Efficiency Distribution and Soil Salinity (EC)*



Source: Own elaboration based on field survey data (2016) and Frontier 4.1 outputs.

The fact that S1 farms record higher EE could simply be due to the low level of soil EC. The farms in this salinity level have the potential to reduce their environmental impacts by 24%, while farms in the S2 and S3 zones have the potential to reduce their environmental impacts by 36% and 66% respectively. In addition, only farms in S1 reach higher than 90% EE. Consequently, reducing soil salinity levels entails a reduction in the environmental impacts of overuse of fertilizers in high salinity farms, while using feasible quantities of fertilizer in these farms to reduce environmental impacts entails a loss of value added per hectare through revenue reduction as the result of production loss.

Concluding Remarks and Implications

This research gives an analytical understanding ofsoil salinity's effects on technical and environmental efficiency in irrigated wheat production systems in the Waist province, central Iraq. Soil salinity has multi-sided impacts. The first impact is on the inputs side, in which farmers in salt-induced soil use higherquantities of inputs compared tothe farmers in the low salinity soil. Soil salinity causes different impacts on each input. Some of these impacts lead to a reduction in productivity of that input. The second impact is on the production side, in which farming in high salinity land tends to reduce wheat production by 50% in irrigated wheat systems. Such results are affecting farmers' revenues, and consequently their livelihoods.The last impact is unaccounted ones, in which salinity has negative externalities on the environment such as downstream water pollution fromthe quantities of fertilizer and agricultural chemicals, given their massive use by farmers to mitigate the high level of salinity.

The comprehensive analysis of SFA shows the soil salinity impacts on technical and environmental efficiency in the study area of Iraq. There were five main sources of technical inefficiency; the first was EC of soil. If EC of soil is reduced, this leads to a reduction in technical inefficiency. The second source was the positionof the farm in relation to the mainriver. If it is closer, it will be more technically efficient. The third source was the positionof the farm in relation to reclaimed land. If a farmer cultivated their wheat in reclaimed land, they were more technically efficient.The fourth source was the agricultural experience of the farmer, which was associated positively with technical efficiency. Finally, wheat variety has a significant impact on technical inefficiency.A farmer who used the IPA variety is more technically efficient than non-IPA users.

Compared to these many sources of technical inefficiency, there were only two main sources of environmental inefficiency.Both relate to soil salinity levels.The first source was the EC of the soil. That is, if EC of the soil is reduced by less than 7.5dSm-1, this leads to a reduction in the EE. The second source was the location of the farm in relation to reclaimed land.If farmers cultivated their wheat onreclaimed land, they were more environmentally efficient.

Average levels of technical and environmental efficiency, estimated using SFA, were 60% and 72% respectively. Soil salinity has a clear impact on technical and environmental efficiency levels. This was shown by the fact that some farmers in high salinity areas who reached their maximum TE, stillcould not reach the yields gained by less efficient farmers in low salinity areas.

There is a space for recommendations that could improve TE and EE in the study area, such as: (i) raising awareness on the use of adequate fertilizer quantities through farmer training and workshops, as well asextension; (ii) enhancement of wheat farming management; (iii) reductions ofsoil salinity in the course of reclamation of land; (iv) reduce subsidies level of fertilizers, and increase subsidies level for other inputs (i.e. organic fertilizers).

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