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-allocative 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}).

While, 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 indicated that for improving EE by 1%, wheat yield need to be reduce by 6% through using recommended quantities of Urea fertilizer by farmer. Soil salinity level associated negatively with technical and environmental efficiency of farm.

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

1. Introduction

The dilemma is increasing both population and agricultural production, combined with climate change have led to negative impacts on environment. With current agricultural production system and stable rate of population growth, the demand for food is outstripping supply in by 2050. The world population will grow about 76.6% from 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 approached through input-intensive, mechanized agricultural and irrigation in agricultural system in which agricultural area has grown only by 12% while the agricultural production has grown around 2.7 times (Dubois, 2011).

In developing counties, despite the fact that, irrigated agricultural cover only 20% of all arable land, its account for 47 and 60 % of all crop and cereal production respectively. 11% of irrigated area are affected by some level of salinity (Pakistan, China, United Stat, and India present more than 60% of this percentage). 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 supply 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 that lead to low crops productivity in Iraq is salinity. This situation is particularly critical for the irrigated areas in Iraq, which produces an important share of crops for the country(Zowain *et al*., 2012). In Iraq, many studies have been focused on the relationship between agricultural productivity and salinity of irrigation water, but, from publication stand point, the relationship between agricultural productivity and soil salinity have been ignored.

Generally, there are two types of goods produced in each and every production system, tradable and non-tradable goods (Goldstein *et al*., 1980). From economic perspective, firms, farms or any production establishment around the world, is more focusing on tradable commodities rather than non-tradable ones, due to cost benefit analysis. However, developing countries as a part of the world is follow suit (Edwards, 1989). In recent years, non-tradable outputs have been examined by Environmental Economists (Bennett and Blamey, 2001). Despite of the fact that, agricultural sector is plying a crucial role in food production, it's also producing non-tradable ones (Keohane and Olmstead, 2016). The non-tradable agricultural production could be divided into two categories, first is positive externalities which have a positive impact on environment. While, the second ones is negative externalities which has negative impacts on environment (Griffin and Bromely, 1982).

Indeed, improving environmental efficiency (En.E) lead to reduce these negative externalities with respect to constant level of tradable production (Coelli *et al*., 2005). This study investigates the impact of soil salinity on technical efficiency (TE) and En.E 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 sides' impacts. Parametric approaches employed to estimate TE and En.E. The fact that wheat farmers reach different levels of TE and En.E. The hypothesis to be tested is whether soil salinity reduce both TE and En.E of wheat farmers in the study area.

2. Data collection and sampling procedure

The stratified random sampling technique is used. Household survey on wheat farmers for 2015/2016 production season was conducted in three districts (Aldboni, Alahrar, and Dujialy). Multi-stage sampling technique and Stevin Thomson Law[1]were used to calculate the sample size

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

which was 360 households. Working with wheat farmers at Aldboni, Alahrar, and Dujialy districts, where 360 households were interviewed and soil samples were collected and analyzed.

The face-to-face interviews were conducted by the researcher. Based on secondary data assessment on the impact of salinity on wheat production and the share of wheat production, three districts have been selected in first stage, one district from each level of cultivable land affected by salinity. In addition, the selected districts have large share of wheat production as well, and geographical location was taken into the count based on the district position with respect to the Tigris River. Aldboni district (A) is located in the upstream, while Dujialy district (D) is on the downstream, and Alahrar district (C) in the middle, as they is showed in Figure 1. In the second stage, we classify each district based on 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 in each selected village was used to choose randomly farmers of wheat proportional to the sample size of each district. Figure 1 shows the position of study area regarding to the world and Iraq.

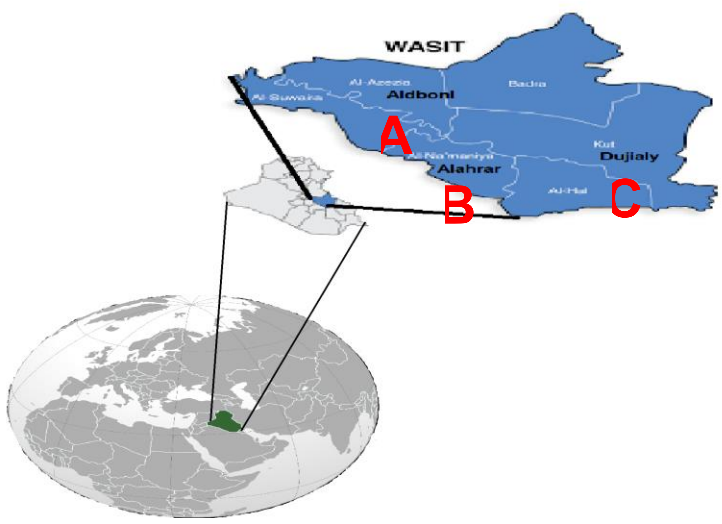


Figure 1. Study area

Based on soil sample lap analysis, Figure 2 shows 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). Its show that 47% of farm were located in S1 level, while the other farms divided between S2 and S3 by 24 and 29 % respectively.

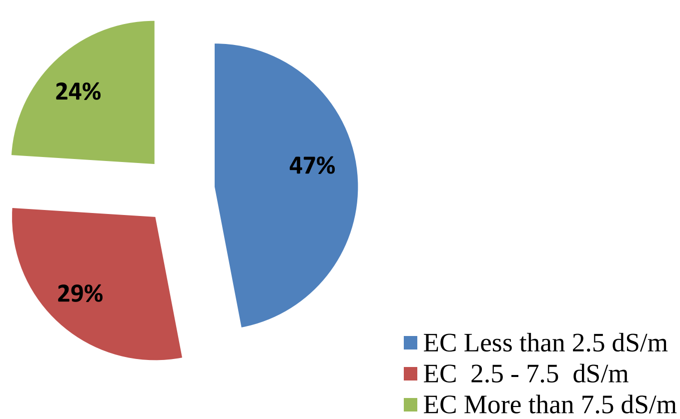


Figure 2. EC levels and sample classification

[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}

3. 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 that 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. Generally, the methodological framework used in this research is the DEA approach Parametric approaches that comprise econometric models (the Stochastic Frontier Analysis – SFA) :

Technical Efficiency Measurement

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

$$y_i = f(x_i;\ \beta_i)\exp(v_i - u_i)\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..(1)$$

Where:

y_i= output of the ith farm

$f(.)$is an appropriate function x_i is vector of input used by the ith farm

$\beta_i$is a vector of the unknown parameter to be estimated

i=1.2.3,…………………..n (Number of farm)

$v_i$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.

$u_i$is a non-negative random variable representing inefficiency in output relative to the stochastic frontier.

The error component v_i is assumed to be independently and identically distributed as $N(0, \sigma_{v^2})$. were particularly concerned about the case of u_i where is derived from a distribution $N(0, \sigma_{u^2})$ 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.

$$TE = \frac{Y_i}{Y_{i^*}}\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(2)$$

$$TE = \frac{f(x_i;\ \beta_i)\exp(v_i - u_i)}{f(x_i;\ \beta_i)\exp(v_i)}\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(3)$$

$$TE = \exp(-u_i)\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

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 is second stage. The following Cobb-Douglas functions is estimated for the wheat crop in the study area (Wasit province).

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

The dependent variable,Y_i is a Production of wheat, measure in kilogram (Kg), and $X_1$is a number of Irrigation (NOI) during the cultivation season measure in number;X_2 is agricultural chemical which is quantity of chemical pesticide (CH) measure in liters (lit); X_3 is a fertilizer (FER-Urea) used in wheat production measure kilograms (kg) ;X_4 is a fertilizer (FER-DAP) used in wheat production measure kilograms (kg), X_5 is quantity of seed (SQ) used measure in kilograms (kg); X_6 is Labors quantity (L) employed during the season of wheat production, measure in man-days per hectare (man-days); X_7 is mechanization (M) in wheat production measure in machine-hours (Mach-hours).

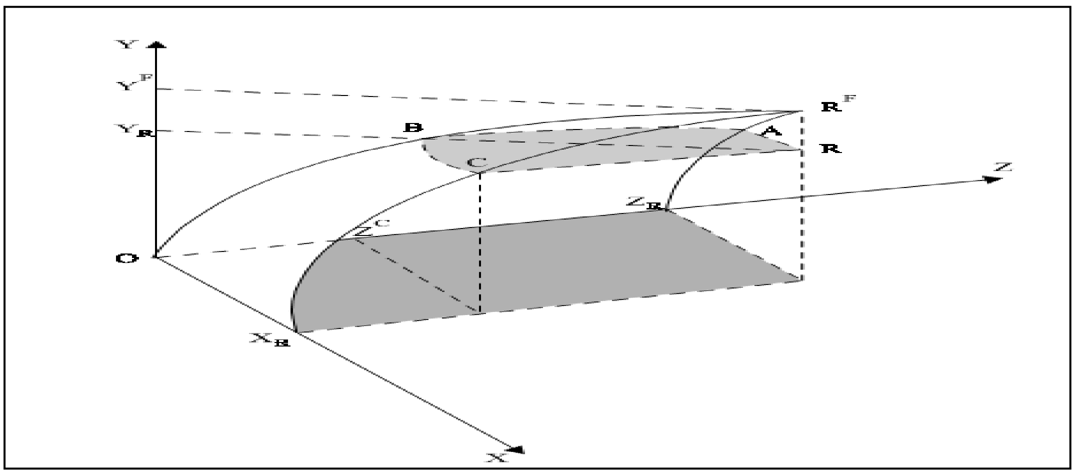
The maximum likelihood method was used to estimate the impact of these socio-economic factors on technical efficiency of the farmers, The Maximum Likelihood Estimations (MLEs) model is specified as:

$$ui = \sigma_0 + \sigma_1 z_1 + \sigma_2 z_2 + \sigma_3 z_3 + \sigma_4 z_4 + \sigma_5 z_5 + \sigma_6 z_6 + \sigma_7 z_7$$ [3]

$\sigma_1, \sigma_2, \sigma_3, \ldots\ldots\ldots\ldots\ldots \sigma_7$ 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).



Source: (Coelli, 2005).

Figure 3. Environmental efficiency measurement

Figure 3 presents a basic idea of environmental variable. It shows, farm R used two inputs (x: environmentally safe or conventional input, and z: environmentally detrimental input) to produce Y within 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 En.E 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:

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

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 En.E level of wheat producers and the sources of inefficiency. The theoretical model of a SFA is defined by:

$$y_i = f(x_i; z_i; \beta_i)\exp(v_i - u_i) \ldots\ldots\ldots (7)$$

Where y_i= output of the ith far,f(.)is an appropriate function x_i is vector of input used by the ith farm, z_i is environmental input, and β_i is a vector of the unknown parameter to be estimated. i = 1.2.3,….. n (Number of farms), v_i is a random error which accounts for random variations in output because of factors out of the farmers' control such as weather, measurement

[3]Z1= EC of soil dS m^{-1}
Z2= Farm location (dummy: 1 for main river, 0 sub-river).
Z3= Position of farm (LF) (dummy: 1 in irrigation project and 0 for not)
Z4= Educational level dummy: 0 for primary school or less, 1 for secondary school or more
Z5= Experience (years).
Z6= Wheat share (wheat cultivated land /total cultivated land) %.
Z7 = Seed variety (Dummy: 0 IPA99, 1others)

error, etc. and $u_i$is a non-negative random variable representing inefficiency in output relative to the stochastic frontier.

The error component v_i is assumed to be independently and identically distributed as $N\sim(0,\sigma_{v^2})$ were particularly concerned about the case of u_i where is derived from a distribution $N\sim(0,\sigma_{u^2})$ truncated at zero (i.e. an exponential or half normal distribution) ,while Meeusen and Van den Broeck (1977) considered only the case of Ui which has an exponential distribution. Equation 3 is used to estimate En.E in the study area:

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

The dependent variable,Y_i is the yield of wheat, measured in kilogram per hectare (kg/ha), and $X_1$is a number of irrigation (NOI) during the cultivation season measure in number;X_2 is agricultural chemical which is quantity of chemical pesticide (CHP) measure in liters per hectare (lit/ha); Z_3 is the actual quantities used by farmers of Urea fertilizer used in wheat production measured in kilograms per hectare (kg/ha);Z_4 is the actual quantities used by farmers of DAP fertilizer used in wheat production measured in kilograms per hectare (kg/ha);X_5 is quantity of seed (SQ) used measure in kilograms per hectare (kg/ha); X_6 is Labors quantity (L) employed during the season of wheat production, measured in man-days per hectare (man-days/ha);X_7 is 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:

$$ui = \sigma_0 + \sigma_1 z_1 + \sigma_2 z_2 + \sigma_3 z_3 + \sigma_4 z_4 + \sigma_5 z_5 + \sigma_6 z_6 + \sigma_7 z_7$$ [4]

$\sigma_1, \sigma_2, \sigma_3, \ldots\ldots\ldots\ldots \sigma_7$Unknown parameters to be estimated.

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

In which $Z_3^F$and $Z_4^F$are minimum feasible inputs Urea and DAP fertilizers respectively.

The yield in both equations are identical, so be rearrange equation 3 with 4 we gain:

$$0 = \ln(Z_3^F/Z_3) + \ln(Z_4^F/Z_4) - u_i \ldots\ldots (10)$$

So that:

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

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

4. Results and discussion

This section is divided into three parts, socio-economic characteristics of the interviewed farmers is presented in part one, while technical and environmental efficiency results are presented in part two and three, respectively.

The socio-economic characteristics of wheat farmers, who interviewed in the research, have been presented in table 1. Its show that there were three types of family in the study area, 45% of wheat farmers have a nuclear family structure, while 34 % and 21% have extended, and polygamous family structure, respectively. The descriptive analysis shows that about 46% of those adults are women.

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[4]Z1= EC of soil (Dummy: 1= less than 7.5 dS m^{-1}, 0= for equal or more than 7.5dS m^{-1})
Z2= Farm location (dummy: 1 for main river, 0 sub-river).
Z3= Experience (years).
Z4= Educational level dummy: 0 for primary school or less, 1 for secondary school or more
Z5= Position of farm (LF) (dummy: 1 in irrigation project and 0 for not)
Z6= Wheat share (wheat cultivated land /total cultivated land) %.
Z7 = Seed variety (Dummy: 0 IPA99, 1others)

Table 1: Socio-economic characteristics of wheat farmers					
Character	Freque ncy	%	Character	Freque ncy	%
Family Structure			Land tenure		
Nuclear [5]	162	45	Won	18	5
Extended [6]	122	34	Rent from Government	306	85
Polygamous [7]	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 female in household members, only 7.5% of them have their own farm, and they included in rent from government category under land tenure classification subject, in which 85% of wheat farmer situated. Additionally, only 10% of wheat producers rent their farm from other farmer. The age of interviewed wheat farmers ranged from 24 to 85 years old, about 62% of farmers within the age group of 40 – 60 years, and 19 % of farmers classified in aged category with age over 60 years old. Reflecting age 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 statistic of quantities of inputs and output. The mean value of yield on wheat in study area was around 2826 kg/ha. From the input side, the number of irrigation during wheat growing season was record as maximum irrigation as 7 times in some farms, while the mean value of number of irrigation was 4 times. The mean value of agricultural chemicals was 1.19 L/ha, applied in study area. Fertilizer Urea and DAP, and seed used with mean value of 295 kg/ha, 230 kg/ha, and 253 kg/ha, respectively. In fact, table 2 shows mean value of labour work per season 6.03 man-days/ha. Moreover, the one hectare of wheat was requiring an average of mechanization working for 7.47 hours during production season of wheat. 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 of EC around 4.77 dS m^{-1}.

Table 2 Descriptive statistic of quantities of inputs and output	
Variable (Unit)	Mean
Yield (Kg/ha)	2826
No. of Irrigation; NOI (number)	4.17
Agricultural Chemicals; 8CH(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 level, salinity 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 provides a basic idea about the soil salinity effects on inputs used in wheat production. The mean value of yield reduced remarkable by 40% when the level of soil salinity change from S1 to S3. While in the inputs side the scenario is opposite in some cases, for instance, in table 3 average quantity 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.

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

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

[7] 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.

[8]Agricultural chemicals are also known as pesticides and include herbicides and fungicides (King, 2013)

Table 3 Impact of salinity on resource use and productivity										
Salinity level	No. of farms	Mean[9]								
		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 said figure shows that only farms belongs to S1 category produced yield more than 4000 kg/ha, and farms in S3 category could not produce yield more than 3000 kg/ha.

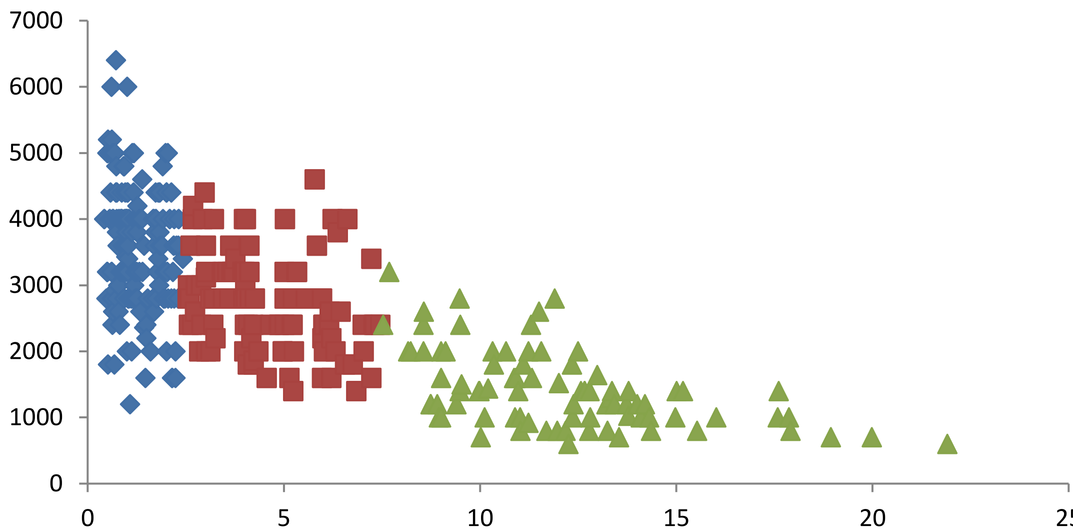

Figure 4. Causality between wheat yield and soil salinity levels (EC)

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

The remarkable changes in resource use efficiency and productivity connecting to the soil salinity level, from econometric perspective are presented in table 4. Its show the results of stochastic frontier Cobb-Douglas production functions analysis for wheat farmers.

Table 4 Estimate of Stochastic Frontier Production Function Parameters		
Variable	Coefficient	Std.err.
Constant *	5.01***	0.37
ln NOI (Number of Irrigation)	0.21***	0.08
ln CH (Agricultural Chemicals)	0.005	0.03
ln FER U (Fertilizer Urea)	0.12***	0.05
ln FER D (Fertilizer DAP)	0.001	0.005
ln SQ (Seed Quantity)	0.12	0.10
ln L (Labour)	0.12**	0.06
ln M (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

[9] Acronyms and units are the same in table 2

γ	0.77***	0.10
Source: Own elaboration based on field survey data (2016) and Frontier 4.1 outputs.		
*The asterisks indicates levels of significant: *** is significant at 1% level; ** is significant at 5% level; * is significant at 10% level*		

The stochastic frontier production function analysis for wheat farmers estimated that, number of irrigation has significant positive effects on production. Likewise, Urea fertilizer, labour, and mechanization have a significant positive effect on production. Holding other factors constant, farmers in study area can increase production through increases 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, the first was EC of soil. If EC of soil is reduced, this leads to reduce the technical inefficiency. The second source was the localization of the farm in which if farm based on main river, it will be more technically efficient. The third source was the localization of the farm in which if farmer cultivated their wheat in reclaimed land, they will be more technically efficient.

The forth source was the agricultural experiences of the farmer which was associated positively with technically efficient. Finally, wheat variety has significant impact on technical inefficiency in which farmer who had use IPA variety is more technically efficient than once who didn't.

TE results are presented and discussed in the following section. 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 increasing. Results present that farm located in S1 zone is more technically efficient than once in S3 zone by 43% this imply that, farmer in 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 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, it can be clearly seen that some farmers who achieve high level of TE in high salinity levels gain low yield from those who has the same or less level of TE in low salinity farms.

This result clearly indicates that reducing soil salinity at farm level will contribute to increase 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 improve efficiency of resources used in wheat production through reducing soil salinity at farm level. This can be done through investing in reclaimed land.

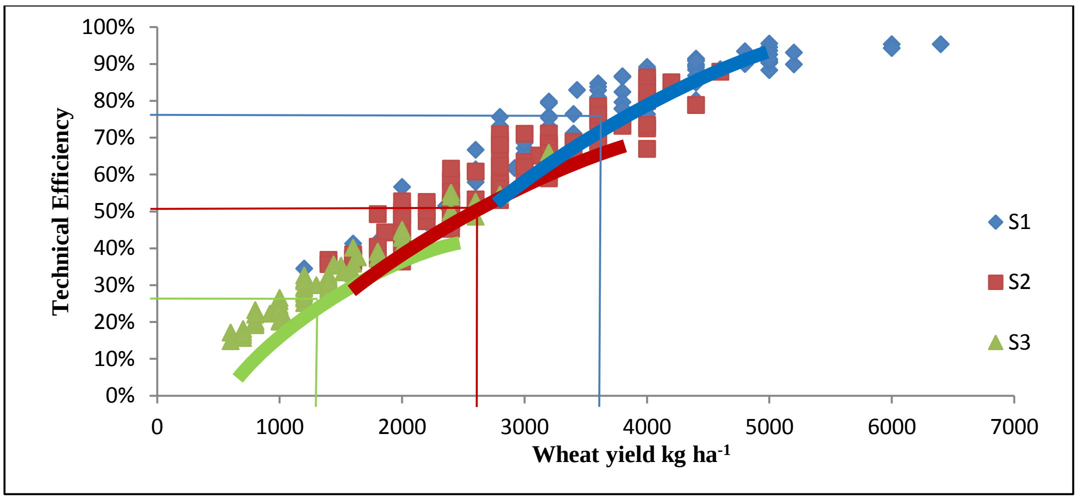

Figure 4. Causality between wheat yield and technical efficiency (TE)

Source: Own elaboration from model results.

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

Table 6: Estimate of Environmental Efficiency Parameters

Variable	Coefficient	Std.Err.
Constant *	8.64***	0.57
ln NOI (Number of Irrigation)	0.25***	0.09
ln CH (Agricultural Chemicals)	-0.06	0.05
$\ln(Z_3^F/Z_3)$ (Environnemental Input Fer U)	-0.07**	0.03
$\ln(Z_4^F/Z_4)$ (Environnemental Input Fer DAP)	-0.01	0.01
ln SQ (Seed Quantity)	-0.02	0.09
ln L (Labour)	-0.10	0.06
ln M (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 indicates levels of significant: *** is significant at 1% level; ** is significant at 5% level.*

The stochastic frontier production function analysis for environmental efficiency estimation of wheat farmers presents that, for an increase of En.E in study area by 1%, farmer needs to use Urea fertilizers with adequate and feasible quantities which will lead to yield reduction by 0.07%. Results also show that DAP fertilizers does not affect the environment significantly.

There were two main sources of environmental inefficiency and both are related to soil salinity, the first was EC of soil. Farms with low level of soil salinity are more environmentally efficient. The second source was the location of the farm in which if farmer cultivated their wheat in reclaimed land, they will be more environmentally efficient than farmers who cultivated their land in semi-reclaimed and un-reclaimed land.

The average En.E for total sample was 0.65 indicating that, on average, they could obtain the same production level while at the same time 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 En.E results are presented and discussed in the following section. Table 3shows the mean value of En.E, which was classified with respect to the different salinity zones.

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

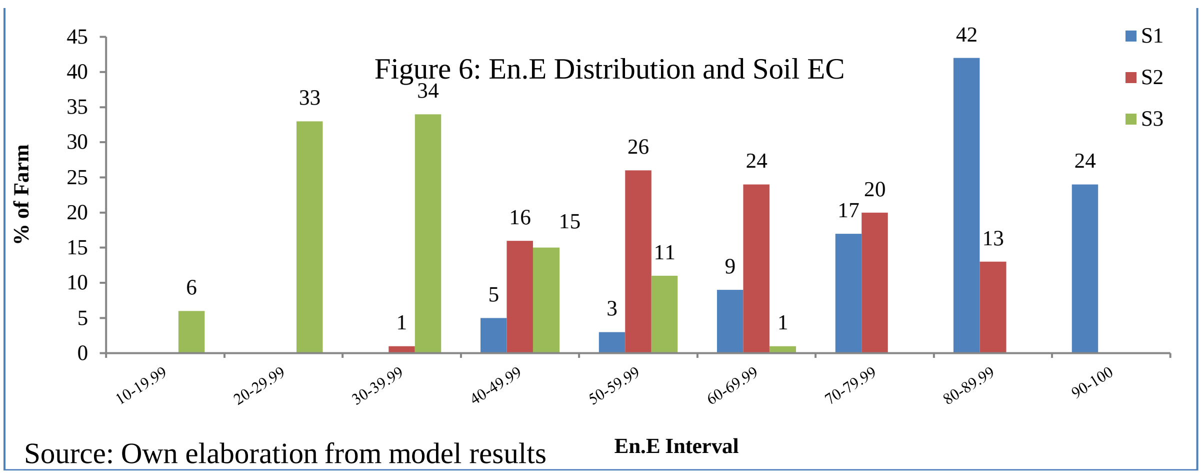

Figure 6. Environmental efficiency distribution and soil salinity (EC).

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

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

5. Concluding remarks and implications

This research gives an analytical understanding on the salinity effects on Technical and environmental efficiency in irrigated wheat production system in Waist province, central of Iraq. Soil salinity has multi-sided impacts: The first impact is on the inputs side, in which farmers in salt-induced soil use more quantities of inputs compared with the farmers in the low salinity soil. Soil salinity causes different impacts on each input. Some of these impacts lead to reduce the 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 system. Such results are affecting clearly farmers' revenue, and consequently their livelihoods. .The last impact is unaccounted ones, in which salinity has negative externalities on the environment such as downstream water pollution by the 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 reduce the technical inefficiency. The second source was the localization of the farm in which if farm based on main-river, it will be more technically efficient. The third source was the localization of the farm in which if farmer cultivated their wheat in reclaimed land, they will be more technically efficient.

The forth source was the agricultural experiences of the farmer which was associated positively with technically efficient. Finally, wheat variety has significant impact on technical inefficiency in which farmer who used IPA variety is more technically efficient than once who didn't. That was the sources of technical inefficiency, while there were two main sources of environmental inefficiency and both are related to soil salinity, the first was the EC of soil. That is if EC of soil is reduced by less than 7.5dSm-1 leads to reduce the En.E. The second source was the location of the farm in which if farmers cultivated their wheat in reclaimed land, they will be more environmentally efficient.
An average level of technical and environmental efficiency estimated through using SFA, were 60 and 72% respectively. Soil salinity has a clear impact on technical and environmental efficiency levels, in which even some farmers in high salinity area reach their maximum TE, they could not reach yield gained by less efficient farmers in low salinity area.

There is a space for recommendations that could be assist to improve TE and En.E in the study area, such as, rising awareness on the use of adequate quantities of fertilizers through farmer training and workshops, and extension, enhancing wheat farming managements, reducing soil salinity in the course of reclamation of land, reduce subsides level of fertilizers, and increase subsides level for other inputs in environmental farms.

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